Loviisa Nuclear Power Plant

Environmental impact assessment report

September 2021

fortum

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.

Simon-Erik Ollus
Executive Vice President, Generation

Contact Details

Project owner:	**Fortum Power and Heat Oy**
Postal address	P.O. Box 100, FI-00048 FORTUM, Finland
Telephone	+358 10 4511
Contact persons	Mira Salmi, Satu Ojala
Email	firstname.lastname@fortum.com
Coordinating authority:	**The Ministry of Economic Affairs and Employment**
Postal address	P.O. Box 32, FI-00023 Government, Finland
Telephone	+358 295 048274, +358 295 060125
Contact persons	Jaakko Louvanto, Linda Kumpula
Email	firstname.lastname@tem.fi
International hearing:	**Ministry of the Environment**
Postal address	P.O. Box 35, FI-00023 Government, Finland
Telephone	+358 295 250 246
Contact person	Seija Rantakallio
Email	firstname.lastname@ym.fi
EIA consultant:	**Ramboll Finland Oy**
Postal address	PL 25 FI-02601 Espoo, Finland
Telephone	+358 20 755 611
Contact person	Antti Lepola
Email	firstname.lastname@ramboll.fi

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Työ- ja elinkeinoministeriö
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.

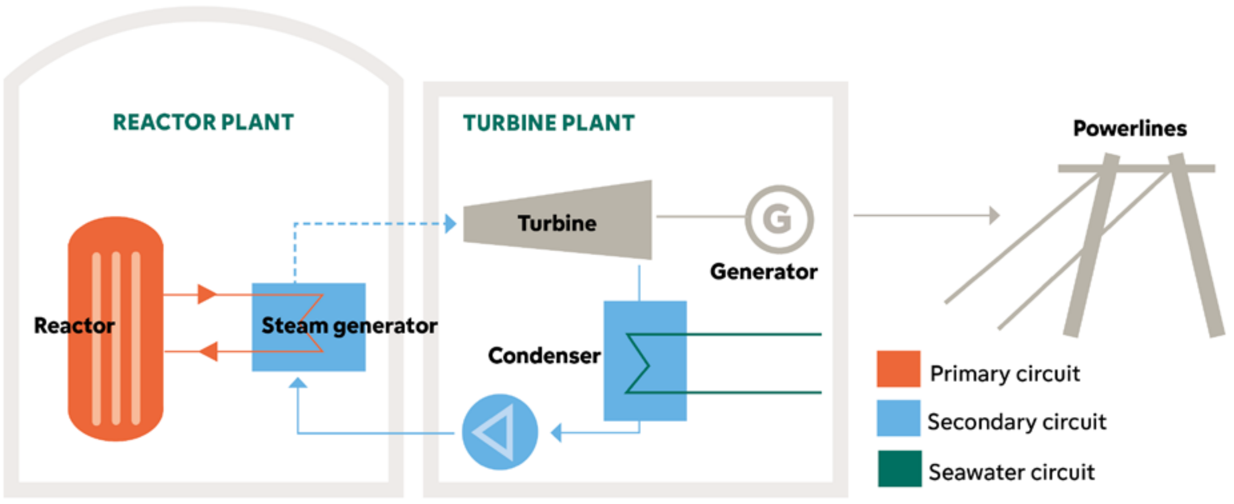

Figure 1-1. Operating principle of a pressurised water plant.

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.

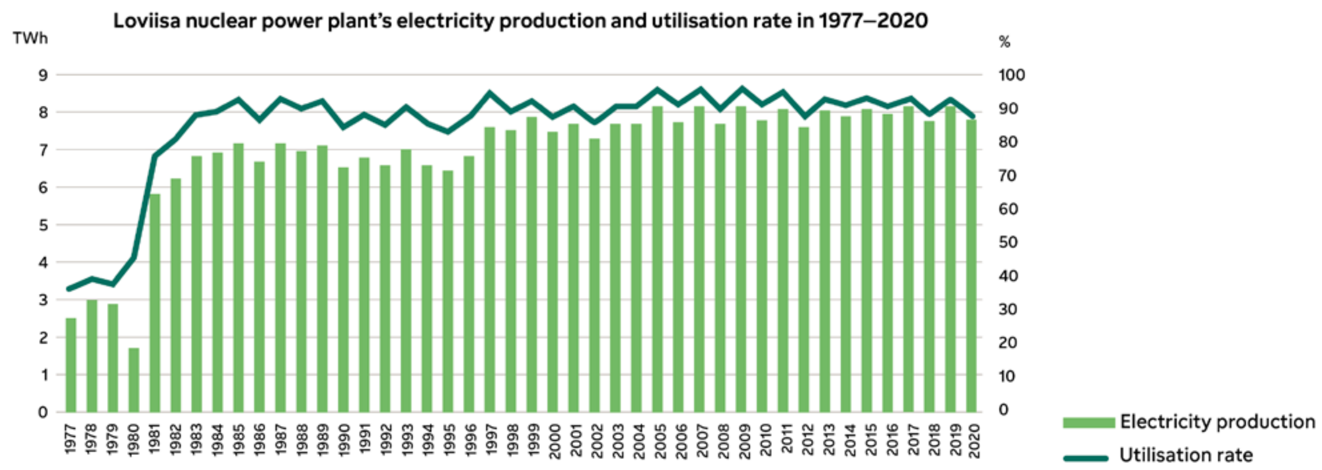

Figure 1-2. The electricity production and load factor of Loviisa power plant during the plant's operating history.

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.

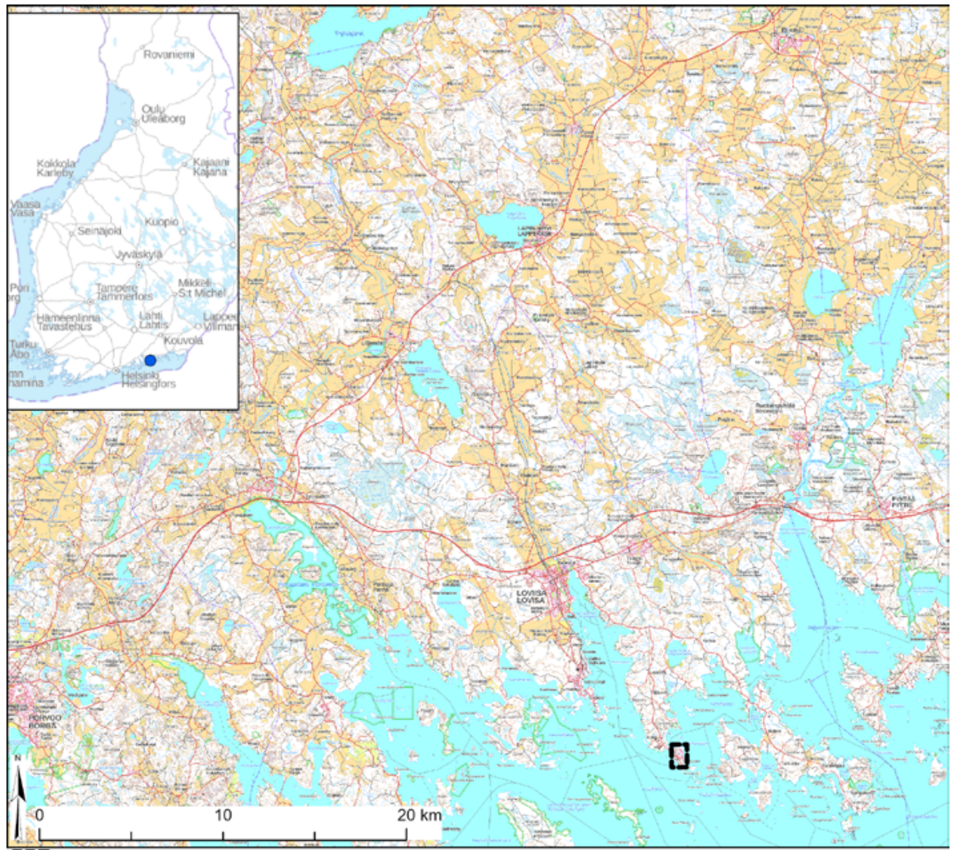

Figure 1-3. Location of Loviisa power plant.

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.

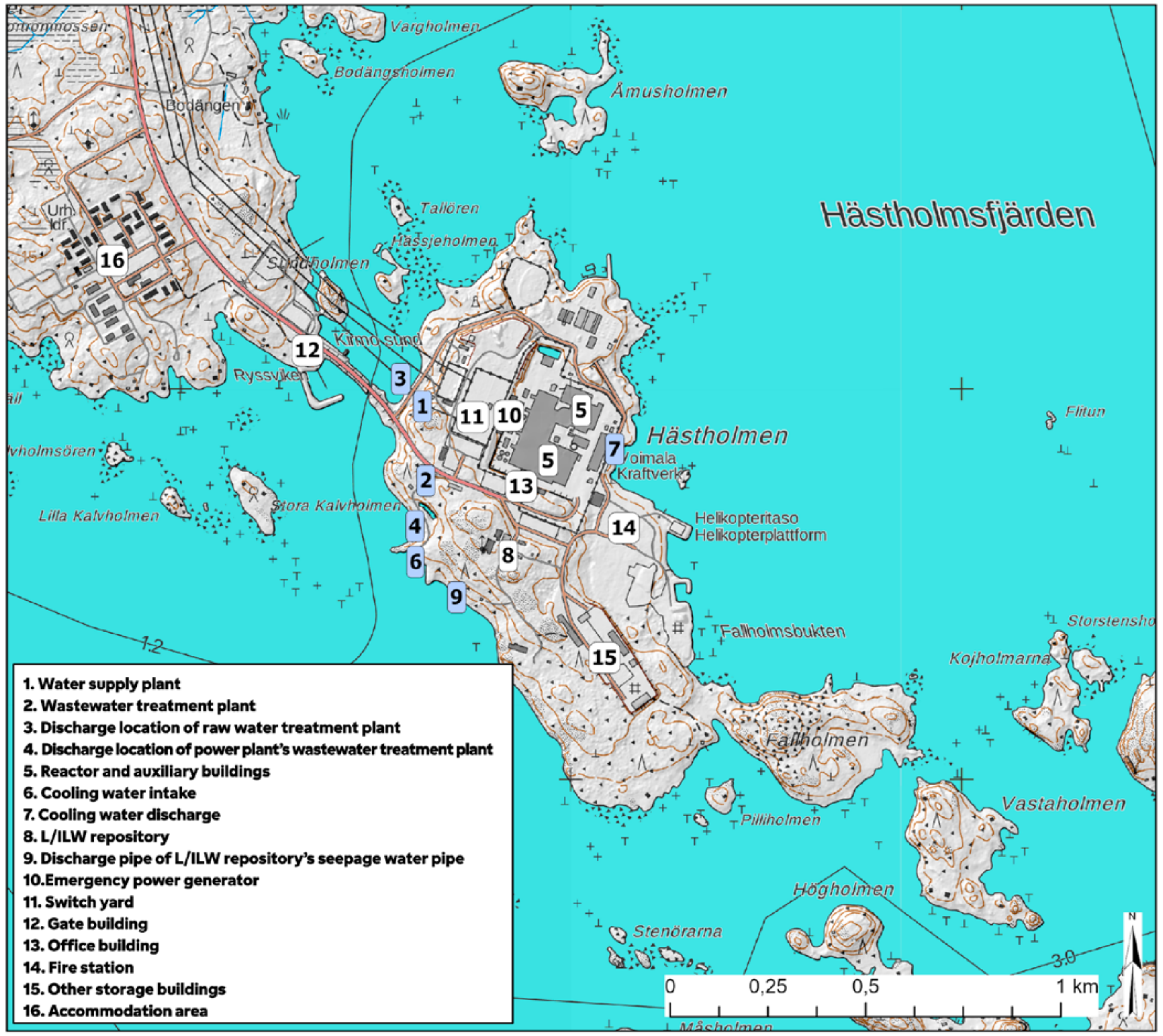

Figure 1-5. The most central buildings and functions in Loviisa power plant area.

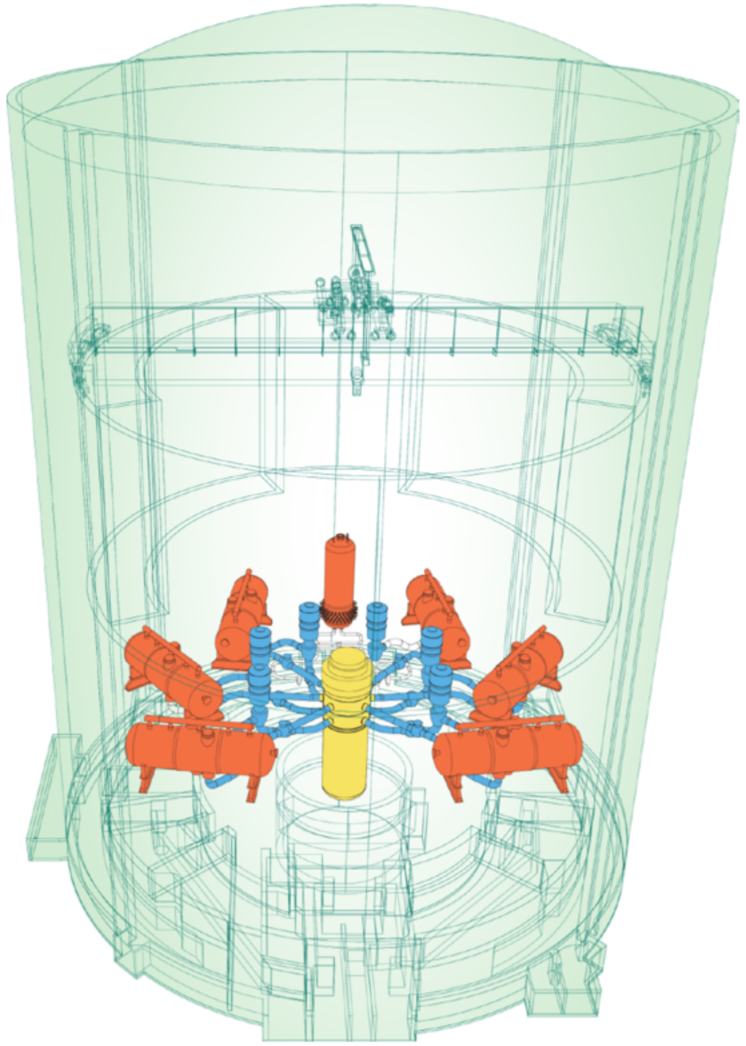

Figure 1-6. Illustration of reactor building and the location of the primary system's main components. The reactor pressure vessel is shown in yellow, the six steam generators and the pressuriser in red, and the main coolant loops of the reactor's cooling system in blue.

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.

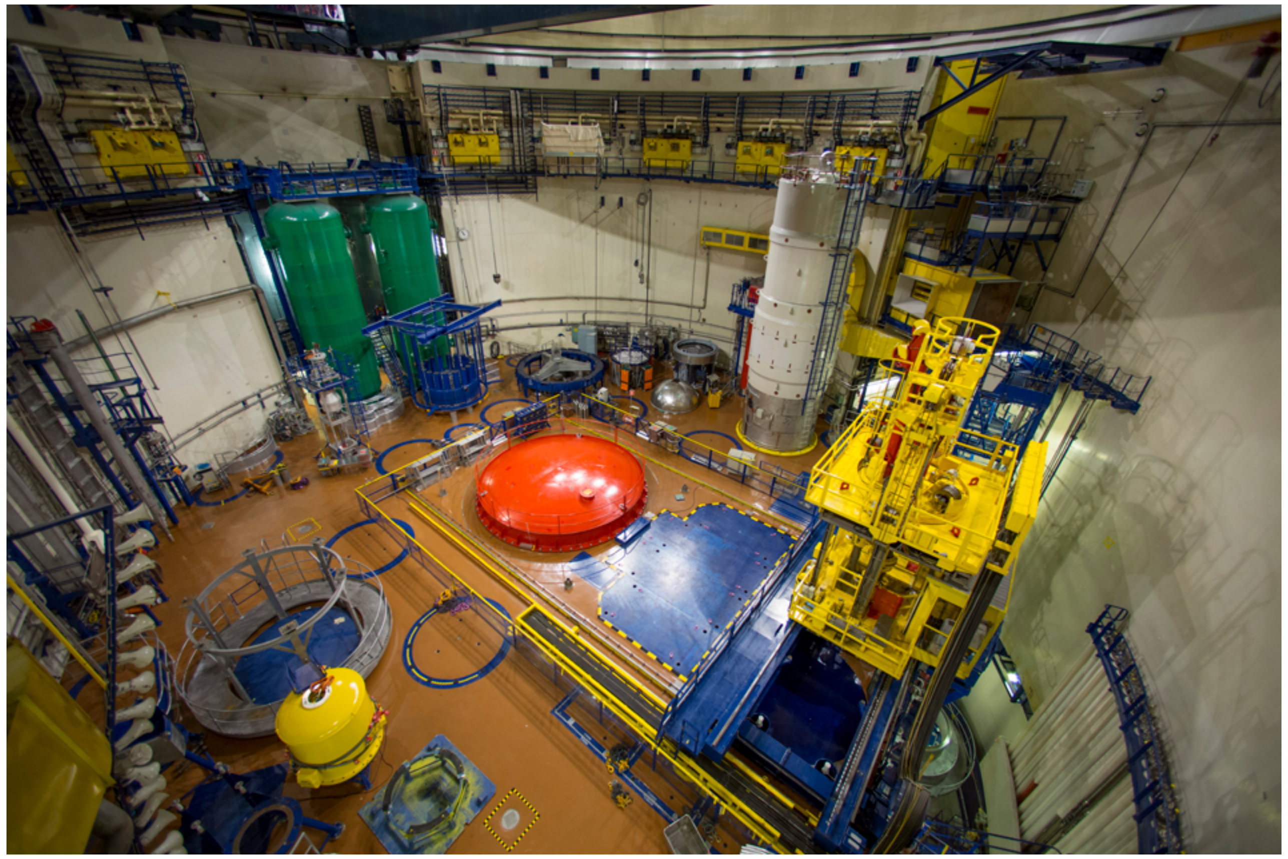

Figure 1-7. The interior of the containment building. The green hydro accumulators can be seen on the left. The reactor's red cover can be seen in the middle and adjacent to it the refuelling pool, covered with blue plates. The yellow refuelling machine can be seen on the right-hand side of the picture.

1.3.4.2 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

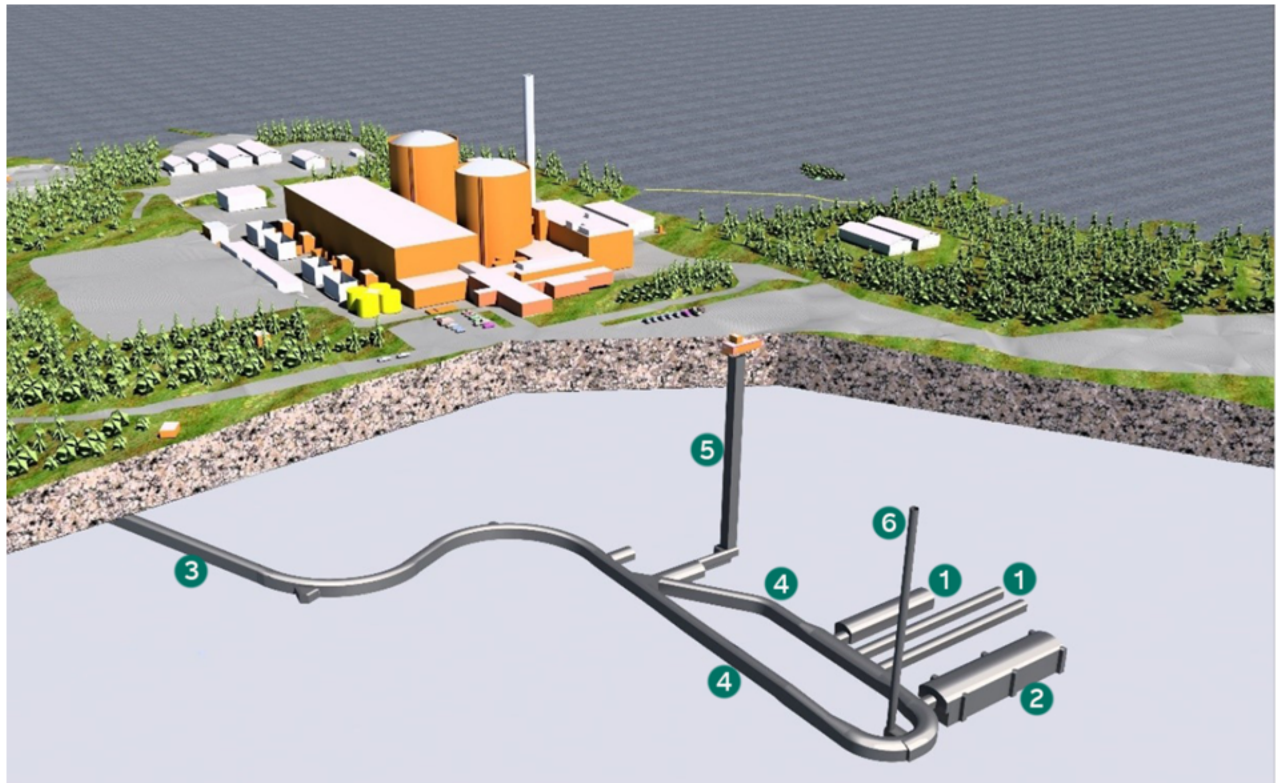

Figure 1-8. Loviisa power plant's final disposal facility for low- and intermediate-level waste (L/ILW repository) in its current size. Layout: Timo Kirkkomäki, Fortum.

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 feedwater 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.

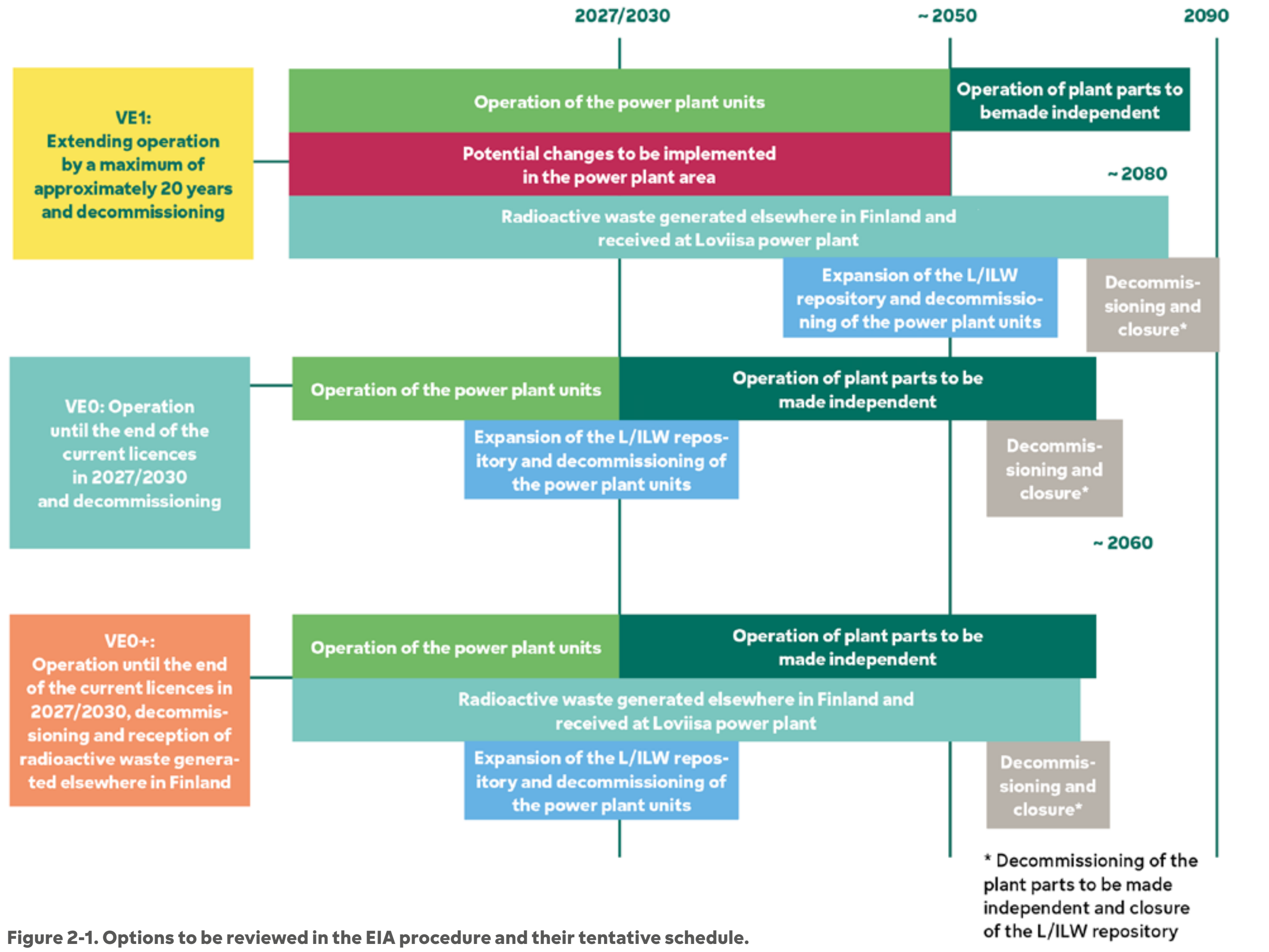

Figure 2-1. Options to be reviewed in the EIA procedure and their tentative schedule.

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

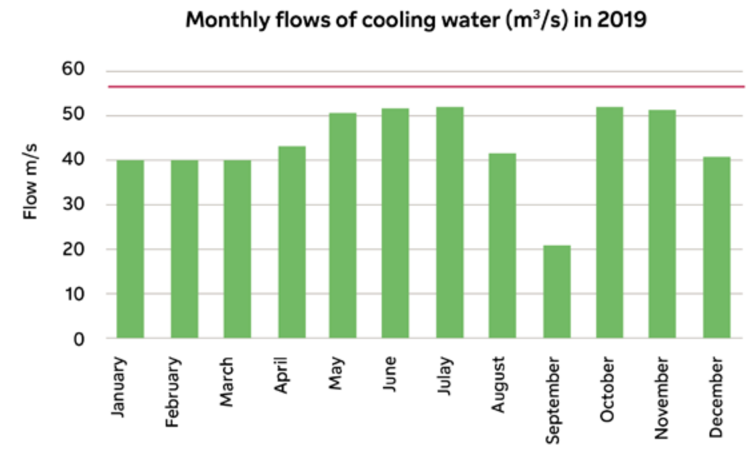

Figure 4-1. Monthly flows of cooling water in 2019 The environmental permit's limit value (56 m^3/s) is indicated with a red line.

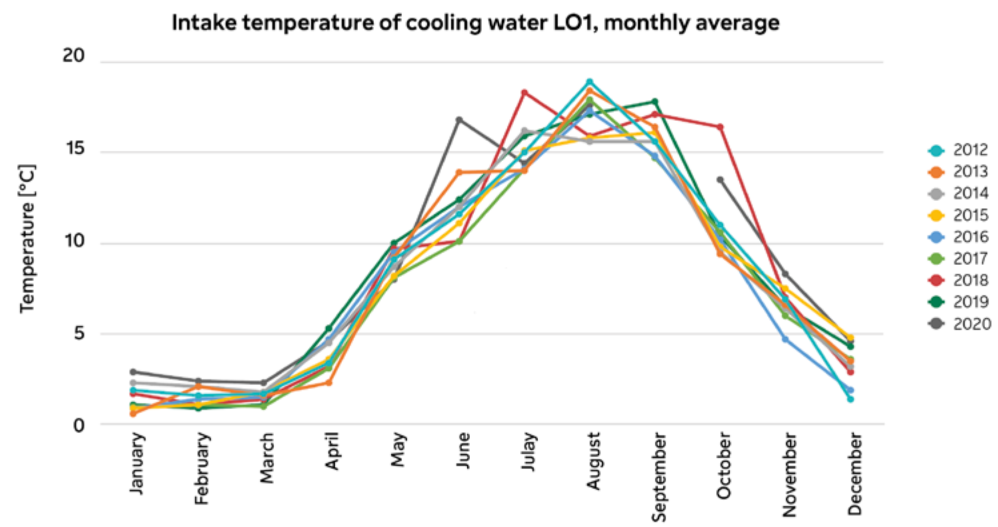

Figure 4-2. The average monthly temperatures of the cooling water taken for power plant unit Loviisa 1 in 2012-2020.

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

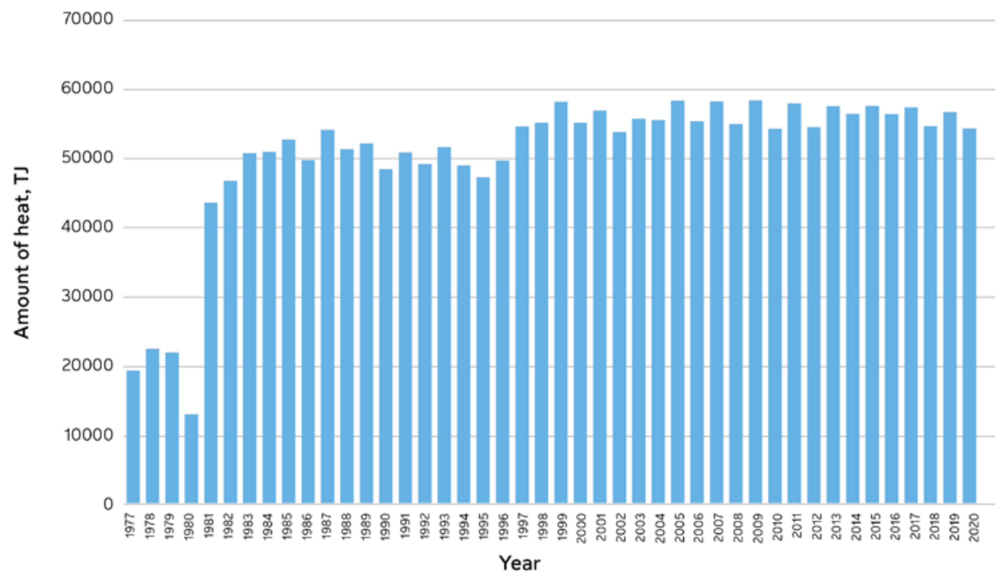

Figure 4-4. Loviisa power plant's thermal load (TJ) into the sea in 1977–2020.

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.

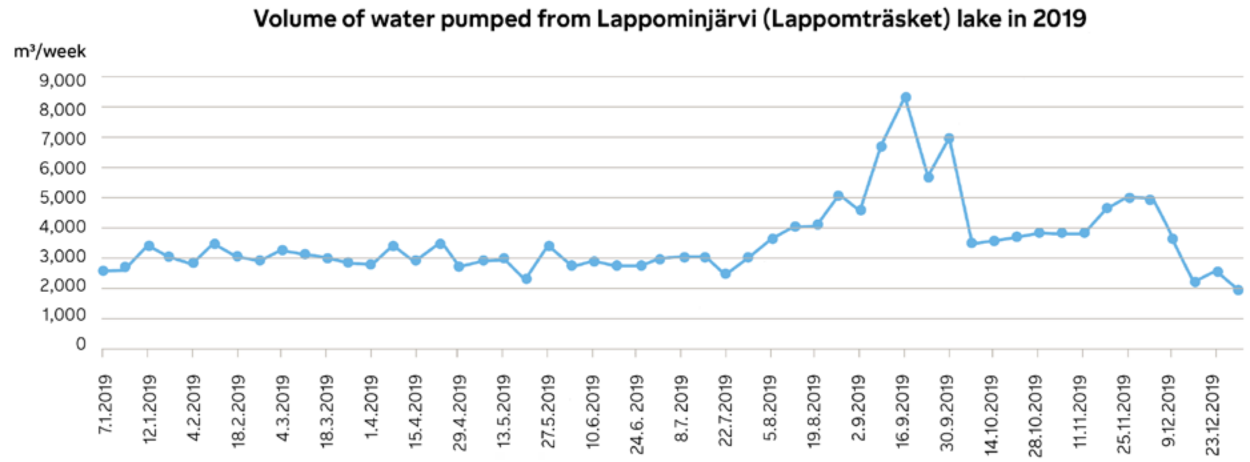

Figure 4-5. Volume of raw water taken by the power plant from Lappomträsket lake in 2019.

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.

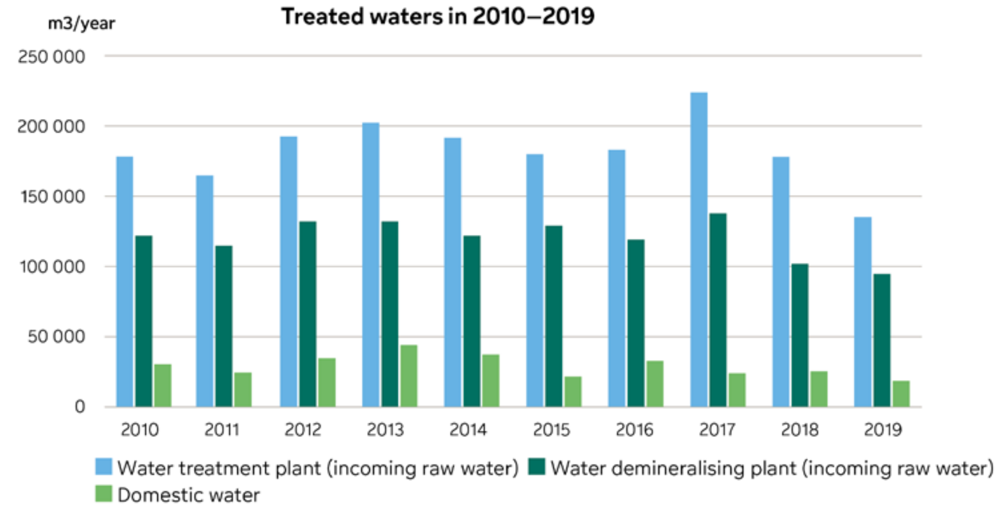

Figure 4-6. The volume of waters treated at the water supply plant, water demineralising plant and the wastewater treatment plant in 2010–2019.

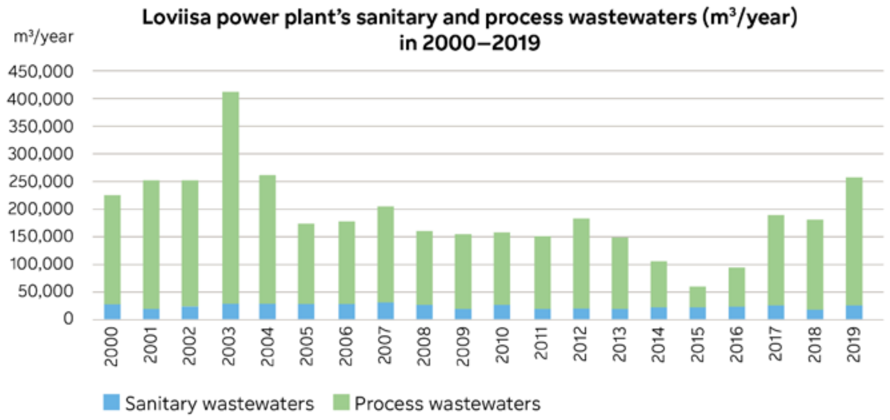

Figure 4-7. Volumes of Loviisa power plant's sanitary and process wastewaters (m³/year) in 2000–2019.

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 m³ 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 m³/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 m³/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 m³/year On average 60 m³/day (max. 120 m³/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 m³/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 (m³/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 m³ 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 Hästholmsfjärden;
- the L/ILW repository's seepage waters (approximately 20,000–40,000 m^3/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

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.

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

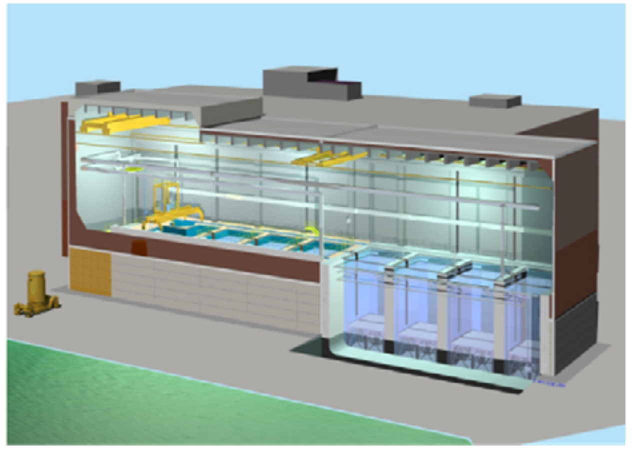

Figure 4-9. Loviisa power plant's storage 2 for spent fuel.

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.

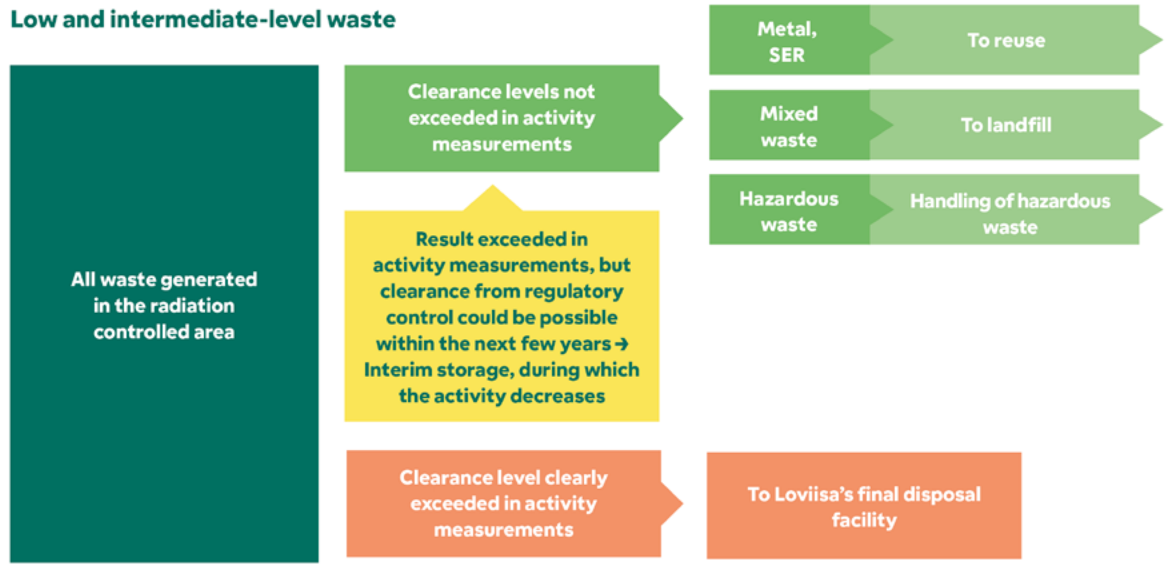

Figure 4-10. Breakdown of maintenance waste into waste to be cleared from regulatory control and waste to be deposited for final disposal.

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

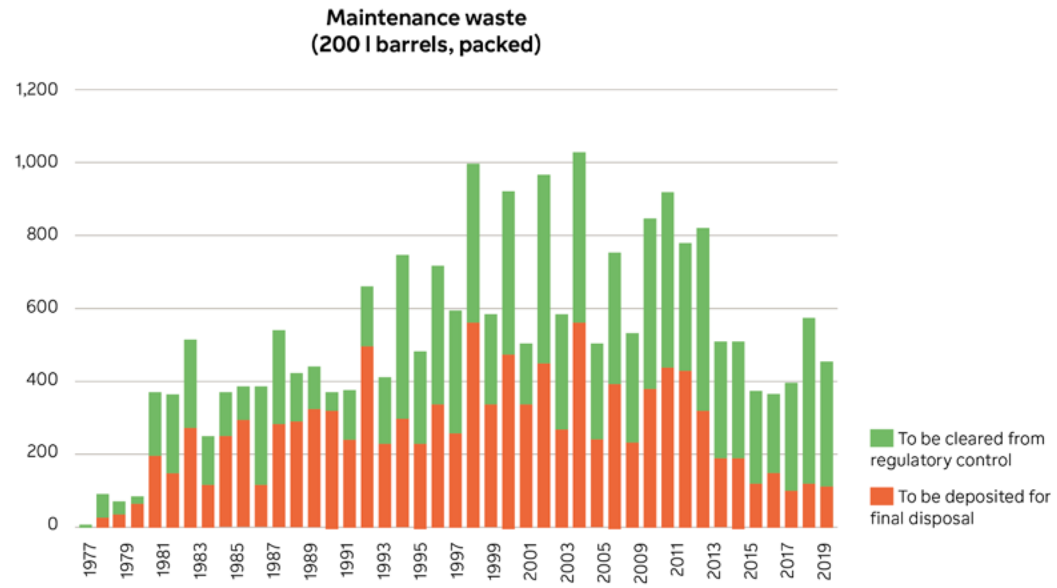

Figure 4-11. The number of waste barrels generated at Loviisa power plant divided by the barrels cleared from regulatory control and deposited for final disposal in 1977–2019.

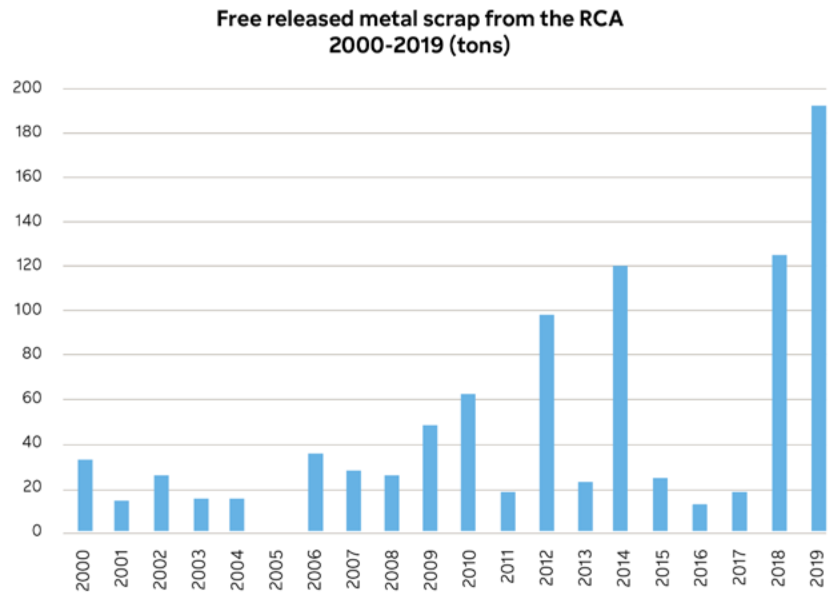

Figure 4-12. Amount of scrap metal cleared from regulatory control in 2000–2019.

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.

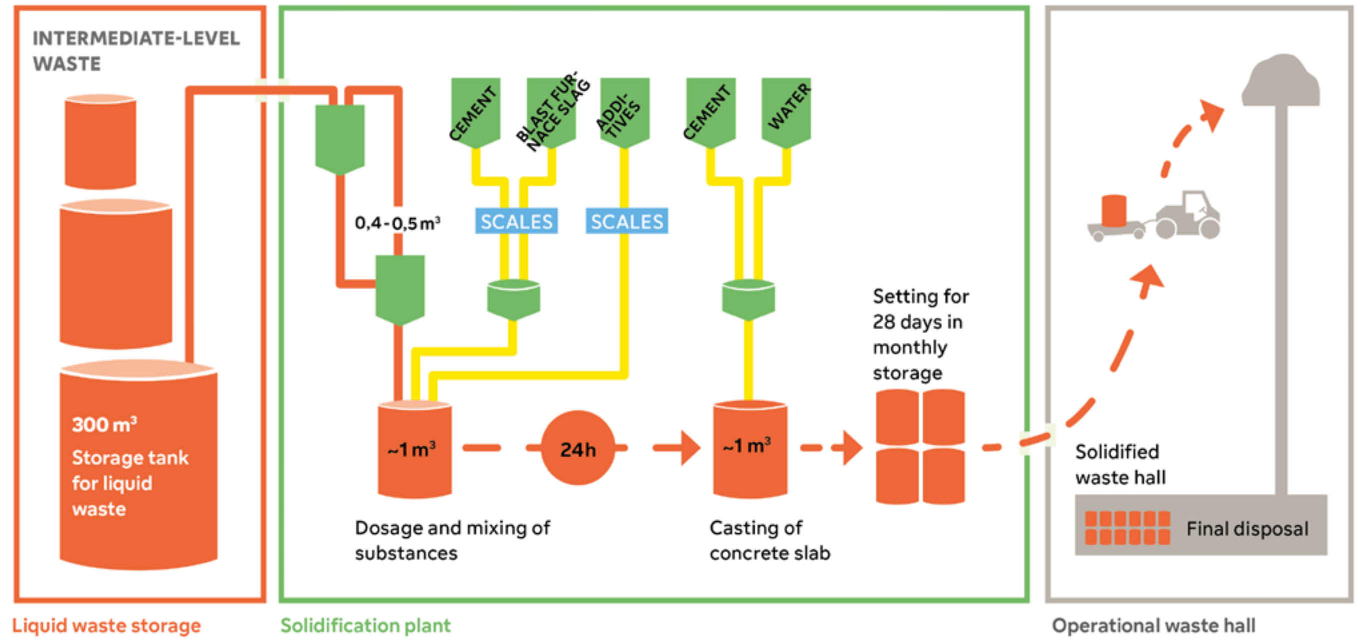

Figure 4-13. Handling of liquid waste.

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.

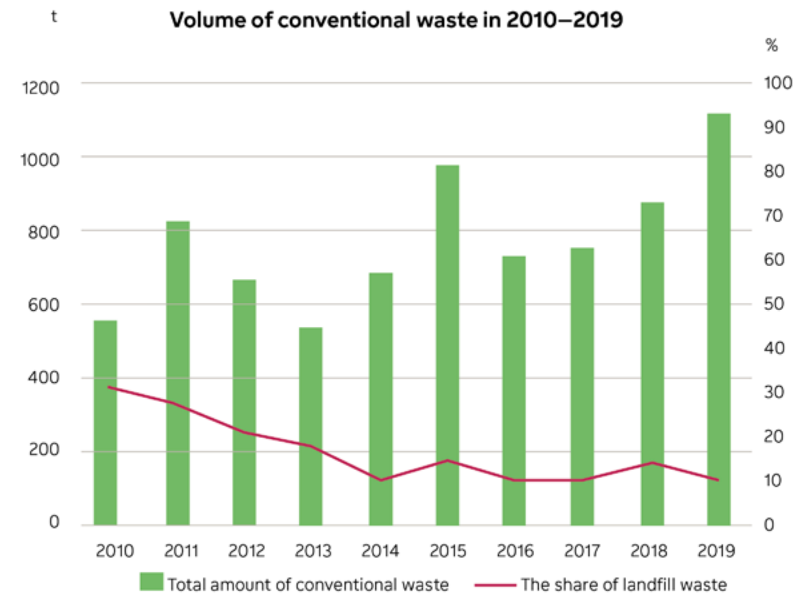

Figure 4-16. Total volume of Loviisa power plant's conventional waste and share of landfill waste in 2010–2019.

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.

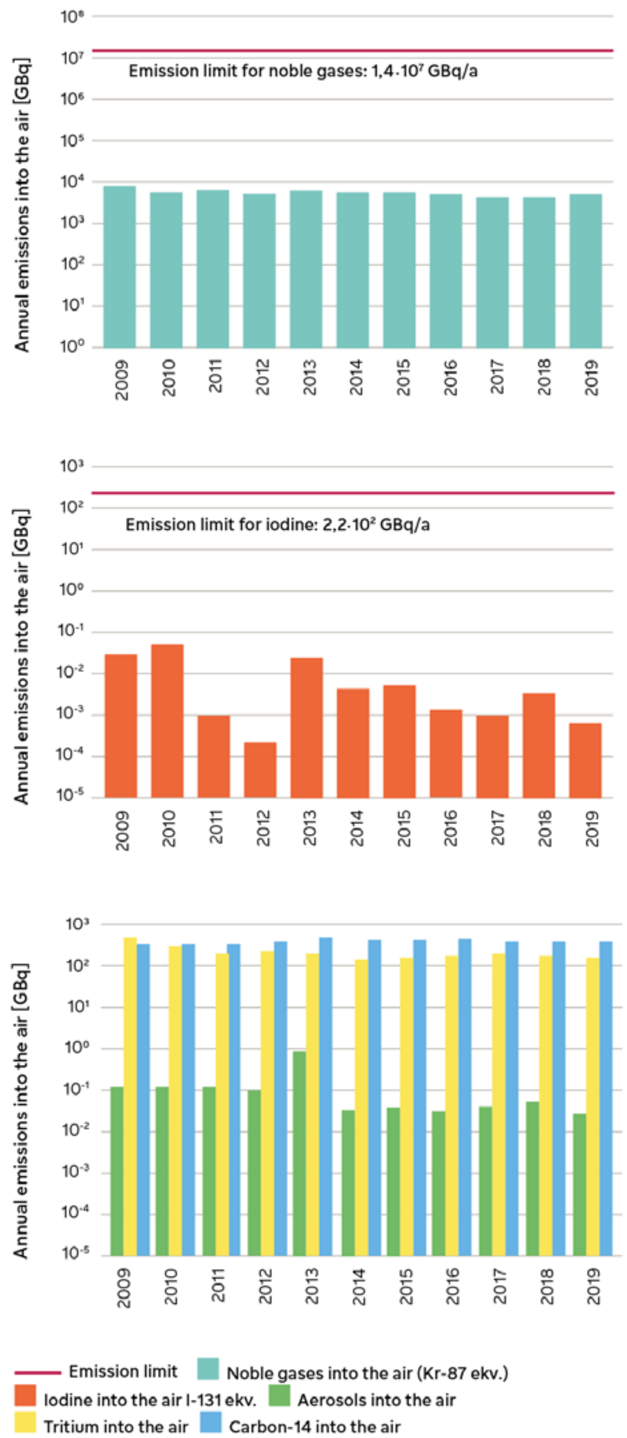

Figure 4-17. Loviisa power plant's radioactive emissions into the air in 2009–2019, and the emission limits for noble gases and iodine.

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

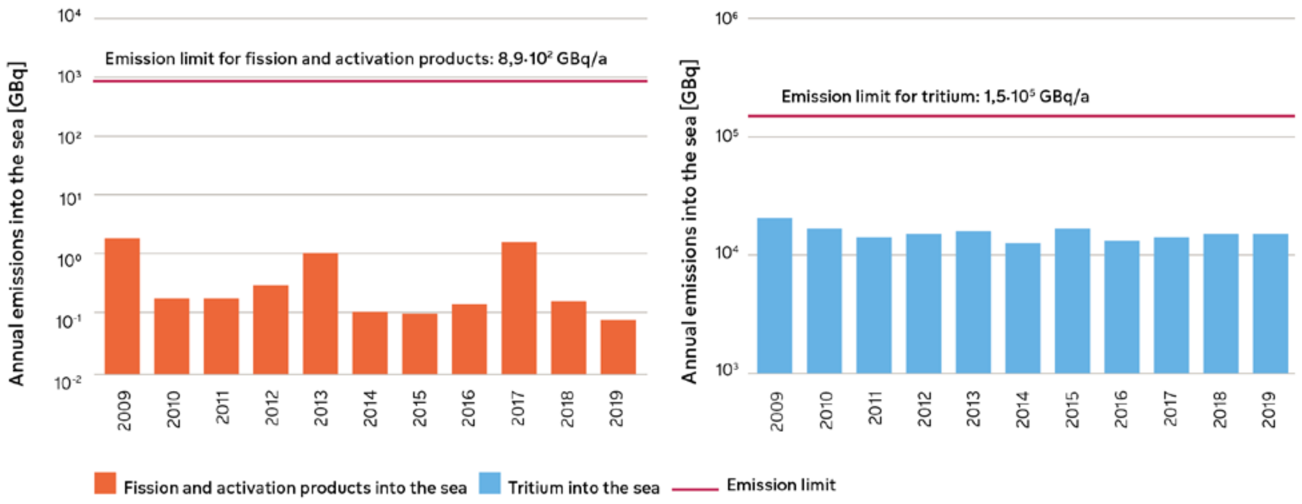

Figure 4-18. Loviisa power plant's radioactive discharges into the sea in 2009–2019 and the emission limits for tritium as well as for fission and activation products.

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	No major changes.
	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%.	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

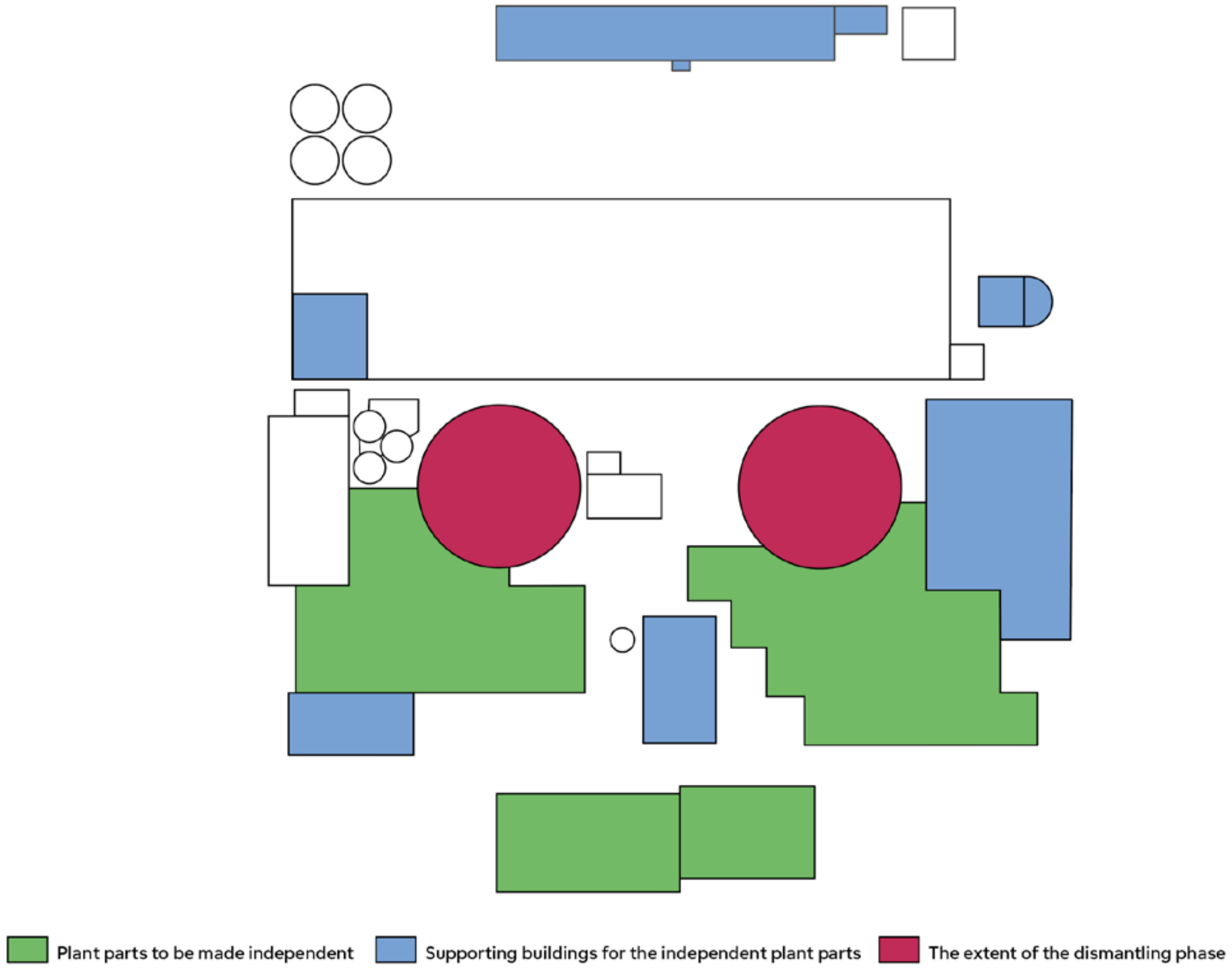

Figure 5-1. The activated and contaminated parts of the reactor buildings, marked in red, will be dismantled during dismantling phase 1, while the plant parts marked in green will be made independent. Their operation during independent operation will be supported by the buildings marked in blue.

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

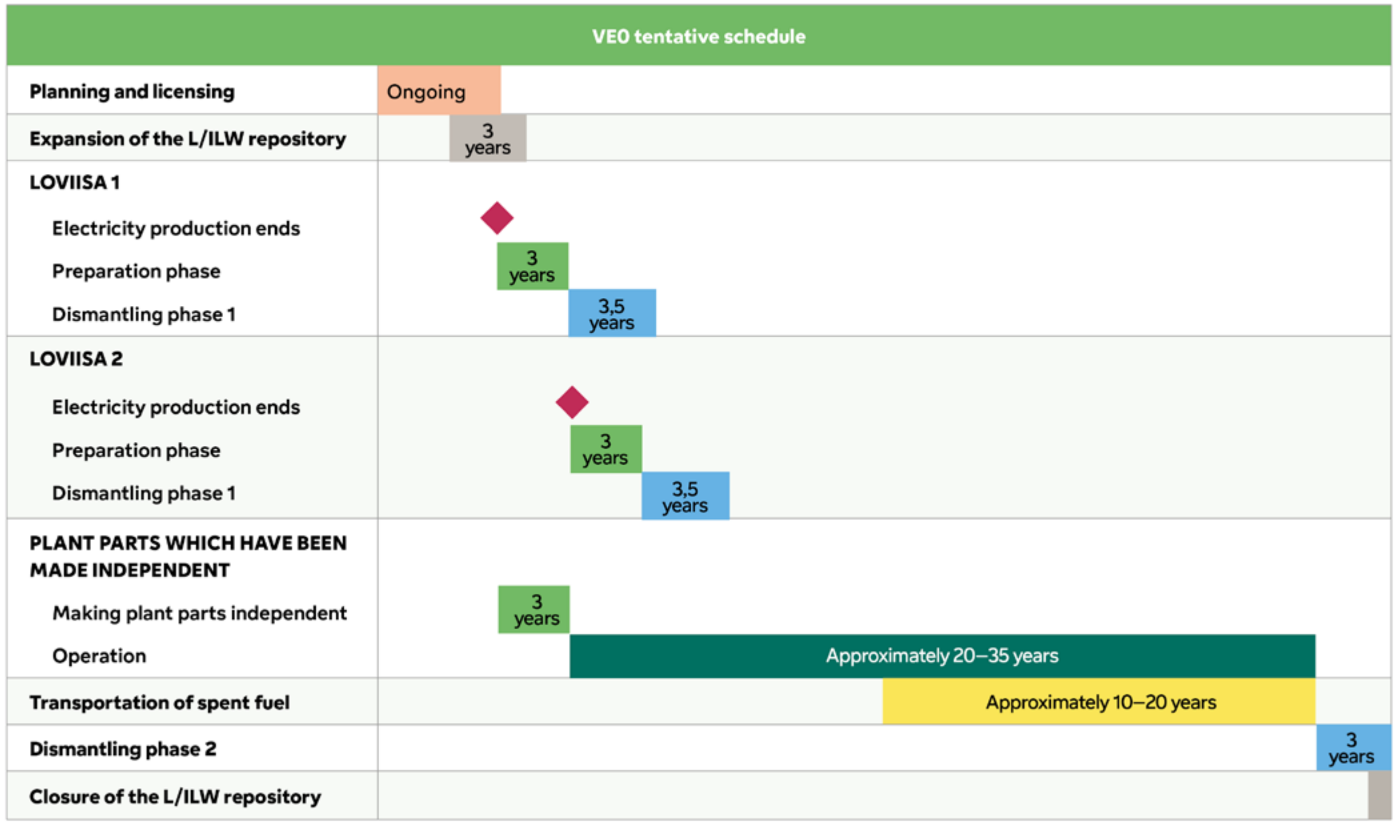

Figure 5-2. depicts a tentative schedule for the dismantling phases in accordance with VE0.

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

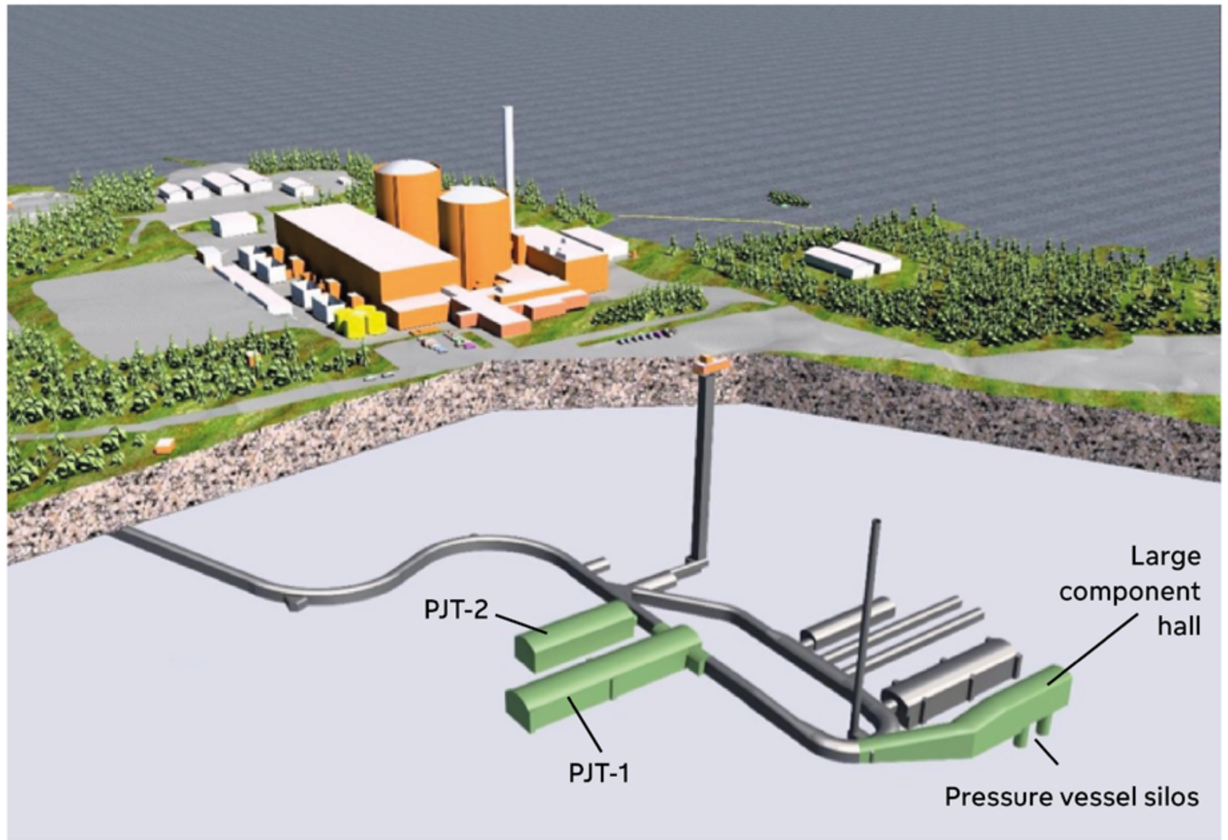

Figure 5-3. An illustration of the final disposal facility of Loviisa power plant for low and intermediate-level waste. In addition to the existing halls, the illustration shows the planned final disposal halls for decommissioning waste in green. In the illustration, PJT-1 and PJT-2 refer to halls 1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

volume combined with the other spaces to be quarried would be 71,000 m³. 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 m³ of rock (rapakivi granite), the volume of which as quarry material is approximately 100,000 m³. After the expansion, the L/ILW repository's total volume will be around 188,000 m³.

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.

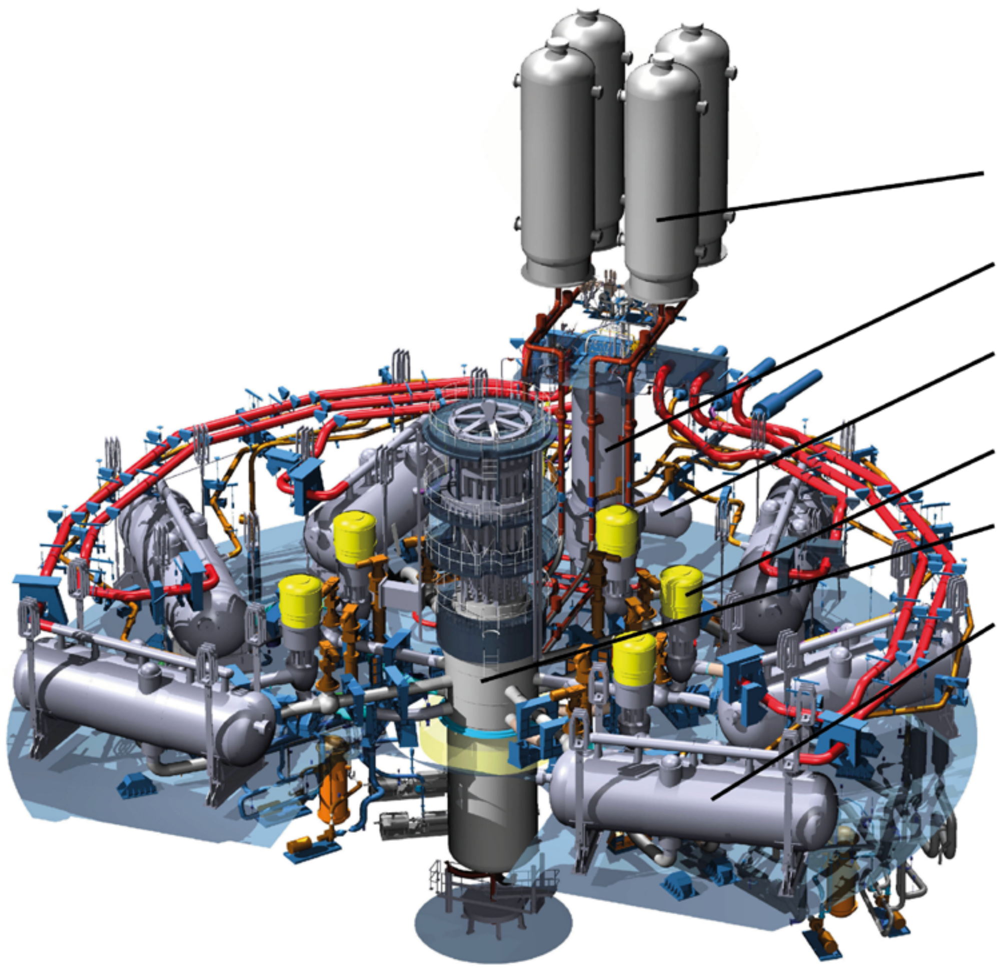

Figure 5-4. An illustration of the primary system of Loviisa power plant unit. The illustration indicates the large components which, according to current plans, are to be deposited for final disposal in one piece.

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

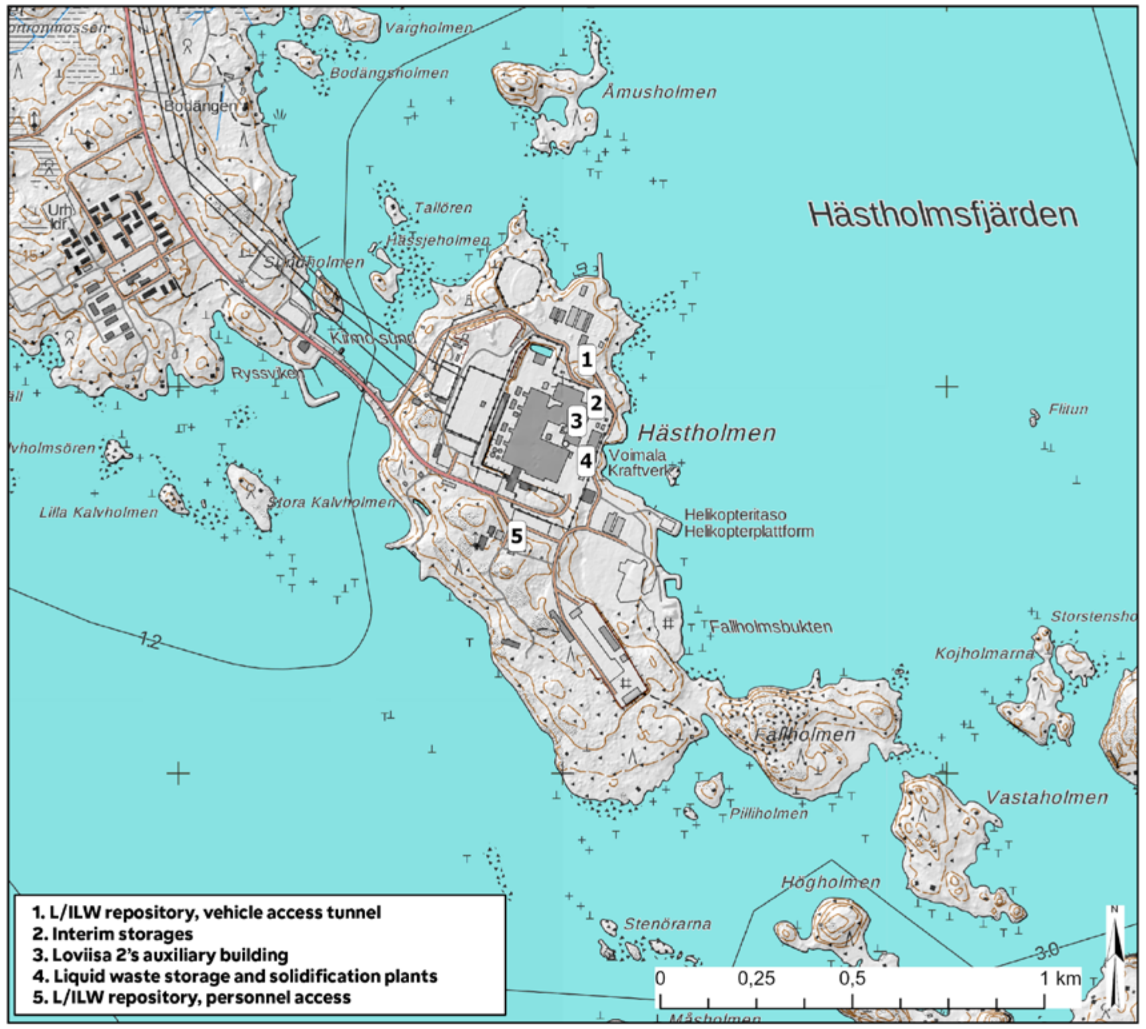

Figure 5-5. Plant parts to be made independent at Loviisa power plant.

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 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.

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**

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.

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.

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.

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 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.	
Service water requirement and supply	The quarrying work will require approximately 15,000–150,000 m³ 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 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.
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 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 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.
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 m³ • Maintenance waste: 20 m³.
Decommissioning waste		• Activated waste: 3,300 m³ • Contaminated waste: 19,000 m³ • Maintenance waste: 700 m³ • Solidified liquid waste: 2,260 m³ • Concrete with a very low level of activity: less than 50,000 m³.	

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.
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 m³) 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 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 [m^3]	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 m^3, 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 m^3 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 (m^3)	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 m^3.

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.

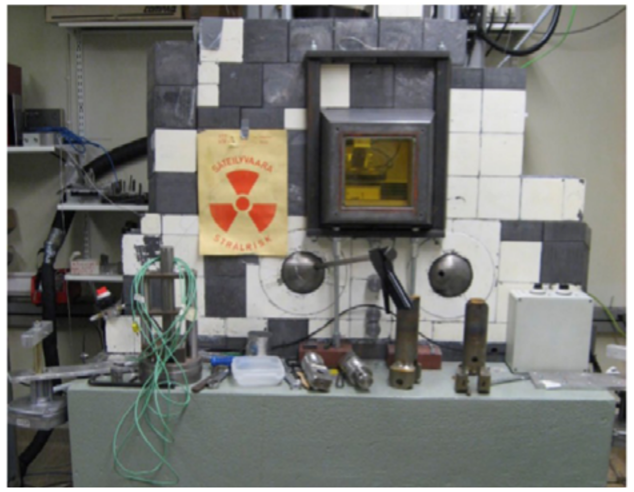

Figure 6-2. Contaminated facilities in VTT's Otakaari 3 research laboratory (MEAE 2019).

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.

7. Radiation safety

The risks in the use of nuclear energy are derived from the radioactive substances at nuclear facilities, which may be detrimental to health. The industry is therefore heavily regulated and controlled. The principal objective is to limit and prevent exposure to radiation caused by radioactive substances during both the facility's normal operation and during incidents and accidents. The nuclear energy industry falls within the remit of the Ministry of Economic Affairs and Employment (MEAE). The Radiation and Nuclear Safety Authority (STUK), which operates under the Ministry of Social Affairs and Health, functions as the regulatory control authority for the use of nuclear energy in Finland.

Radiation safety refers to all measures by which the adverse effects of ionising radiation on the environment, people and property are prevented, combatted and reduced. At Loviisa nuclear power plant, radiation safety is considered in daily operation, facility improvements and emergency preparedness operations, as well as in the planning of the final disposal of nuclear waste and the power plant's decommissioning, and their eventual implementation.

Nuclear safety refers to all the technical and structural solutions of a nuclear power plant as well as the organisation and its operations and measures which aim to prevent, control and mitigate any radioactive emissions caused by the power plant, and the consequences of such emissions. Security arrangements are an important part of nuclear safety – they safeguard the facility's normal, undisrupted operation and systems as well as the people working at the facility against the threat of unlawful activities. The role of emergency preparedness operations in terms of nuclear safety is to prepare for accidents in advance and to mitigate the consequences of a possible accident. Radiation protection aims to protect the facility's personnel against radiation.

This Chapter discusses the radiation safety of Loviisa nuclear power plant from the perspective of nuclear safety, security arrangements, emergency preparedness operations and radiation protection within the framework of the activities taking place within the Loviisa power plant area. Finnish legislation distinguishes between radiation safety and nuclear safety but internationally, nuclear safety is considered part of radiation safety.

The radioactive emissions into the air and the sea originating from the normal operation of Loviisa power plant and the means and measures by which to limit and reduce them are presented in Chapter 4. The decommissioning of Loviisa power plant is described in Chapter 5. The impact that the radioactive emissions of normal operation, accidents and decommissioning have on people is reviewed in Chapter 9.

7.1 REQUIREMENTS AND REGULATORY CONTROL CONCERNING NUCLEAR FACILITIES

According to the Nuclear Energy Act (990/1987), a nuclear facility must be safe, and it may not cause harm to people, or damage to the environment or property. In Finland, the radiation and nuclear safety requirements imposed on nuclear facilities are based on the provisions of the Radiation Act (859/2018), the Nuclear Energy Act and the Nuclear Energy Decree (161/1988), the requirement levels of which are complemented with regulations issued by STUK (STUK Regulations), and in the detailed requirements presented in the regulatory guides on nuclear safety and security (YVL Guides), and the regulatory guides on emergency preparedness (VAL Guides). Finnish legislation accounts for international requirements and treaties. Figure 7-1 shows the hierarchy of requirements pertaining to nuclear facilities.

The STUK Regulations most relevant for the use of nuclear energy have been issued pursuant to the Nuclear Energy Act (in the Y Series) and concern the safety of nuclear power plants (Y/1/2018), the emergency arrangements of nuclear power plants (Y/2/2020), safety and security arrangements (Y/3/2020), and the final disposal of nuclear waste (Y/4/2020). Numerous regulations have also been issued by

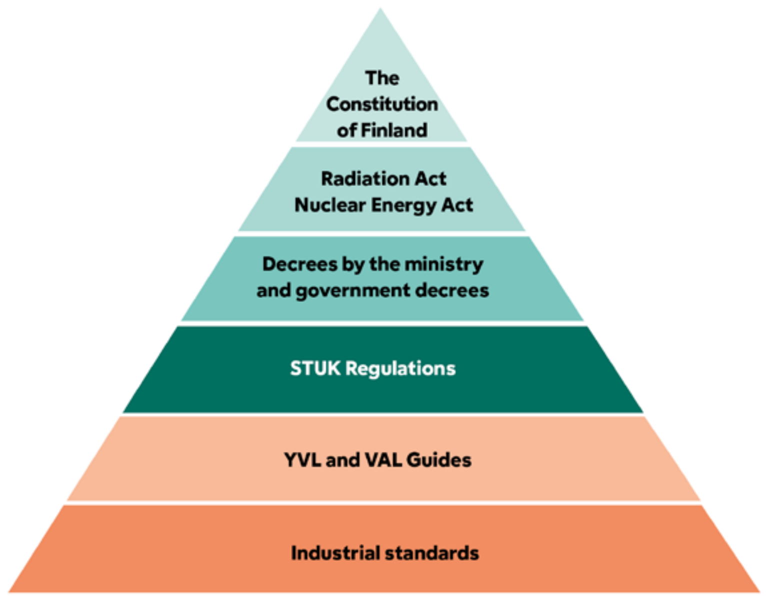

Figure 7-1. Hierarchy of requirements pertaining to nuclear facilities.

virtue of the Radiation Act in relation to radiation protection (the S Series), and a regulation on the exemption levels of radioactive substances and the clearance levels of radioactive materials has been issued by virtue of the Nuclear Energy Act and the Radiation Act.

The YVL Guides are divided into five different groups:

- Group A: Safety management of a nuclear facility
- Group B: Plant and system design
- Group C: Radiation safety of a nuclear facility and the environment
- Group D: Nuclear materials and waste
- Group E: Structures and equipment of a nuclear facility

The requirement level has changed during the service life of Loviisa power plant, and changes are also to be expected in the future. For example, the largely revised YVL Guides published, for the most part, in 2013 were amended in 2019 and 2020.

STUK supervises the use of and changes to a nuclear power plant with the help of:

- document inspections;
- the licence holder's reports;
- supervisory visits to the facility;
- inspections related to the operational inspection programme (KTO inspections);
- annual outage supervision;
- supervision carried out by local inspectors;
- operational experiences measures carried out on the basis of the results of safety inspections.

The Nuclear Energy Decree and the Government Decree on Ionising Radiation (1034/2018) set the limit values for radiation doses during the normal operation, incidents and accidents, and the decommissioning of nuclear facilities. The classification of incidents and accidents at nuclear facilities is presented in Chapter 7.4. The dose limits for radiation workers as well as members of the public and comparable workers, the limits for the annual dose of a member of the public in relation to the normal operation and decommissioning of various nuclear facilities, and the annual dose limits related to incidents and accidents are shown in Table 7-1.

The limit value for the emission of a severe reactor accident is specified in the Nuclear Energy Decree (section 22 d) in such a way that the emission may not result in a need for large-scale protection of members of the public, or extensive long-term restrictions on the use of land and water areas. To limit long-term effects, the limit value for a caesium-137 emission into the ambient air is 100 terabecquerels (TBq).

7.2 RADIATION

Radiation can be divided into non-ionising radiation (such as radio waves) and ionising radiation (such as gamma radiation and corpuscular radiation). However, electromagnetic radiation can fall within the scope of either non-ionising or ionising radiation, depending on its wavelength. Figure 7-2 clarifies the distribution of the most typical types of radiation.

The radioactive radiation present in nuclear power plants is ionising radiation. Ionising radiation is radiation with sufficient energy to detach electrons from the atoms of the substance exposed to the radiation or to ionise the substance's molecules. A radiation dose is a quantity describing the detrimental effects radiation has on a person, and its unit is the sievert (Sv) or a derivative thereof, like the millisievert (mSv), which is 0.001 Sv. The overall detrimental effect that radiation has on health is described by the effective dose. The collective dose refers to the calculated total dose of a particular group of the population, and its unit is the man-sievert (manSv).

In a nuclear power plant, radioactive substances emitting radiation are primarily generated as fission products when the atomic nuclei of the fuel split, through neutron activation in the reactor or its vicinity, and as the products of the radioactive decay chains of the aforementioned substances. The most important radiation sources during the operation of Loviisa nuclear power plant are the nuclear fuel and activation products in the primary system's water, due to which the vicinities of the primary system are inaccessible.

The radiation control of Loviisa power plant's environment is based on continuous dose rate measurements, air and fallout samples, seawater samples, and samples taken from the food chain. The power plant's radioactive emissions are monitored by emission measurements, both within the power plant area and its environment, and the emissions' dispersion into the environment is monitored in accordance with the environmental radiation control programme approved by STUK. Loviisa power plant's radioactive emissions are reported to STUK every three months. STUK's independent monitoring complements the power plant's own monitoring.

7.2.1 The health effects of radiation

The detrimental effects of ionising radiation may be the result of either an internal dose caused by radioactive substances within the body or an external dose, and they can be divided further into two categories. Direct, or deterministic, effects are definite detrimental effects resulting from extensive cell death. Random, or stochastic, effects are statistical detrimental effects caused by a random genetic mutation in one or more cells. Random detrimental effects can be considered long-term effects.

7.2.1.1 Direct effects of radiation

Direct effects involve sudden and very large single doses of radiation, with the effects usually manifesting themselves within a short period of time. While small radiation doses

Table 7-1. Limits for the annual radiation dose to which a member of the public and a worker is exposed (sections 22 b and 22 d of the Nuclear Energy Decree and sections 13 and 14 of the Government Decree on Ionising Radiation).

Radiation dose	Description
0.01 mSv	Nuclear waste cleared from regulatory control
0.01 mSv	Decommissioning of a nuclear facility according to plan
0.01 mSv	Normal operation of a nuclear waste facility
0.1 mSv	Final disposal facility for nuclear waste after its closure
0.1 mSv	Normal operation of a nuclear power plant (DBC 1) and operational occurrence of a nuclear facility (DBC 2)
1 mSv	Effective annual dose limit for members of the public and a comparable worker
1 mSv	Class 1 postulated accident (DBC 3)
5 mSv	Class 2 postulated accident (DBC 4)
20 mSv	Design extension condition of a postulated accident (DEC)
20 mSv	A radiation worker's effective annual dose limit

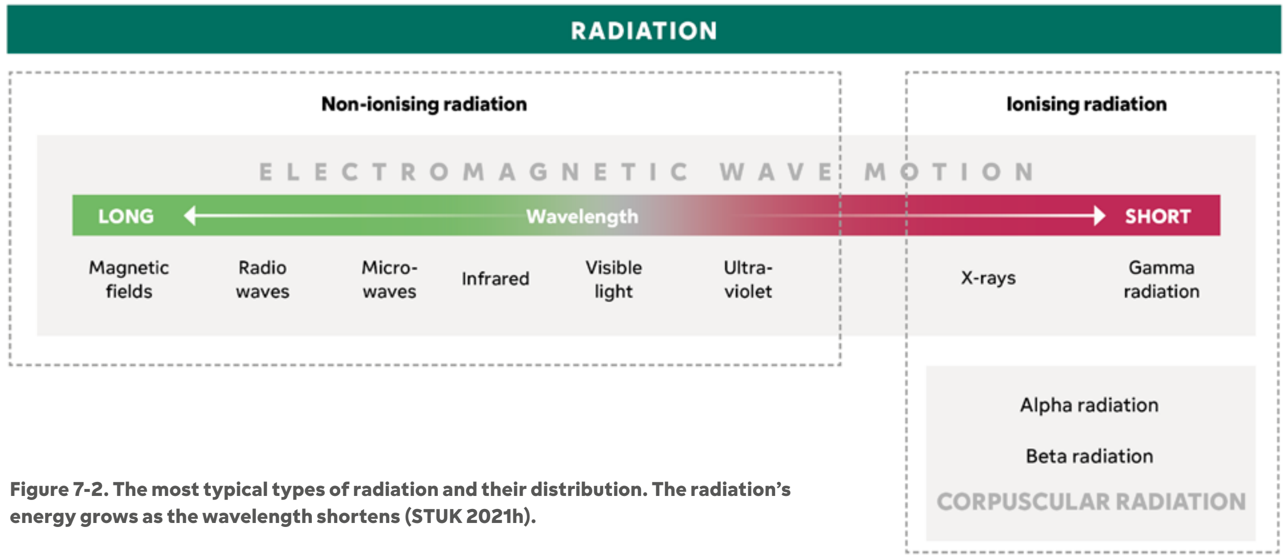

Figure 7-2. The most typical types of radiation and their distribution. The radiation's energy grows as the wavelength shortens (STUK 2021h).

Table 7-2. Threshold values for the radiation doses of direct effects. Radiation doses that fall below the value shown do not cause detrimental effects (STUK 2009, STUK 2019b).

Whole-body dose	
0.5 Sv	A change in complete blood counts within a few days
1.0 Sv	Nausea within a few hours
4.0 Sv	Lethal dose; the person may be saved with good treatment
10.0 Sv	Death; the person can no longer be saved
Local skin dose	
6.0 Sv	Redness within a few hours
15.0 Sv	Blisters → ulcers after a couple of weeks
20.0 Sv	Gangrene
Foetal dose	
0.1 Sv	Some impact on brain activity, mild intellectual impairment, microcephaly
0.5 Sv	Severe intellectual disability
1.0 Sv	Other intellectual disability

do not result in detrimental effects, such effects are certain when a specific level is exceeded (Table 7-2). The severity of the effects increases in line with the growth of the radiation dose, and the effects can typically be linked to a particular exposure. (STUK 2009)

The direct detrimental effects of radiation include radiation sickness, radiation burns, cataracts and foetal damage. The consequences of radiation exposure depend on several things. For example, consequences resulting from whole-body radiation exposure differ from those resulting from the exposure of an individual organ. In a whole-body exposure, the threshold value for direct detrimental effects is in the region of 0.5 Sv, whereas in the case of skin, for example, the threshold value may be one order of magnitude greater. (STUK 2009)

Radiation sickness is a life-threatening condition caused by sudden whole-body exposure to a large amount of ionising radiation. Such cases have not occurred in Finland, but in the Chernobyl nuclear power plant accident, for example, some of the people working in the power plant area suffered from radiation sickness. (STUK 2009)

7.2.1.2 Random effects of radiation

In principle, random long-term effects can arise from even a minor exposure to radiation. There is therefore no threshold value for random effects. Nor does the severity of the detrimental effect increase in line with the dose, as is the case in direct exposure to radiation. It is typical for random effects to manifest themselves only years after the exposure, and for the detrimental effect to be extremely difficult or impossible to be linked to any particular exposure. The dose rate also has a much smaller impact on the risk of detrimental effects attributable to random radiation than it does in the case of direct effects. (STUK 2009)

The random detrimental effects of radiation include various types of cancer and genetic mutation. An increase in the risk of cancer caused by radiation is usually difficult to detect at the level of individuals. Indeed, it is therefore assessed with the aid of the radiation dose of members of the public (collective radiation dose), although an increase in illness would be invisible in various statistics. The most important material for assessing random effects is based on the survivors of the atomic bombing of Hiroshima and Nagasaki. Material has also been obtained from people exposed to medical radiation, people who have been exposed to radiation in their occupation, and people exposed to higher-than-normal doses of environmental radiation. (STUK 2002, UNSCEAR 2000)

It is typical of random effects that the likelihood of cancer increases as the radiation dose grows. However, when the radiation doses are small, an individual's risk of developing cancer due to the exposure is small. (STUK 2002, STUK 2021h). The time it takes for the cancer to develop may be very long, and a cancer may not necessarily be the result of a possible radiation exposure; rather, it may also be the result of other errors in cell division, which become more common as the body ages. Cancer is a common cause of death among old people.

Nevertheless, the risks and detrimental effects stemming from radiation differ in children and adults. In the years following the Chernobyl disaster, for example, the incidence rate of thyroid cancer among children in the nearby areas grew significantly. (STUK 2009) According to the International Commission on Radiological Protection (ICRP), a 1 Sv radiation dose increases the risk of developing cancer by an average of approximately 5.5%, but for adults, the risk is around 4.1%. In terms of genetic effects, the entire population's risk of illness with a 1 Sv radiation dose increases by 0.2% and by 0.1% in adults. (Reference: ICRP 103, Table 1)

7.2.2 Reference data on radiation sources and radiation doses in Finland

The average annual radiation dose of people living in Finland is approximately 5.9 mSv, of which roughly 4 mSv is attributable to indoor radon and some 1.1 mSv to other natural background radiation. The radiation dose resulting from medical examinations is approximately 0.76 mSv.

Table 7-3 shows examples of the annual radiation doses of people residing in Finland and of doses attributable to medical imaging, compared to the annual radiation dose caused by the normal operation of Loviisa power plant for a resident of the nearby area.

7.3 RADIATION PROTECTION

At a nuclear power plant, radiation protection refers primarily to protecting the facility's personnel from radiation. At Loviisa power plant, radiation protection is based on:

- the sound planning of operations;
- appropriate working methods and work practices;
- modern radiation protection methods;
- equipment and protective equipment;
- taking advantage of the international experience accumulated over the decades;
- taking advantage international experience;
- the management of human factors.

Table 7-3. Examples of radiation doses (STUK 2020b, STUK 2021i, STUK 2021j).

Radiation dose	Description
0.00023 mSv	The annual effective radiation dose to which an individual in the environs of Loviisa power plant is exposed due to the power plant's operation.
0.01 mSv	The average effective dose to which a patient is exposed due to a dental X-ray.
0.01 mSv	The average effective dose of a person living in Finland resulting from the fallout of Chernobyl and nuclear weapons tests. The impact of the Fukushima accident in Finland is negligible.
0.1 mSv	The average effective dose to which a patient is exposed due to a chest X-ray.
0.3 mSv	The average annual internal radiation dose of a person living in Finland resulting from naturally occurring radionuclides.
0.45 mSv	The average effective dose in a year of a person living in Finland resulting from external (soil and construction materials) background radiation (values range from 0.17 to 1.00 mSv from one locality to the another).
0.76 mSv	The average annual effective dose of a person living in Finland resulting from the medical use of radiation (X-ray examinations generate an average dose of roughly 0.72 mSv, and gamma-ray examinations an average dose of roughly 0.04 mSv).
0.8 mSv	The average effective dose to which a patient is exposed due to a lumbar spine X-ray.
1.1 mSv	The average effective dose of a person living in Finland resulting from natural background radiation (excluding the dose caused by radon).
2.0 mSv	The average annual effective dose of a person working in an aircraft resulting from cosmic radiation.
4.0 mSv	The average annual effective dose of a person living in Finland resulting from the radon in dwellings (ranges from 2 to 100 mSv, depending on the place of residence and type of housing).
5.9 mSv	The average annual effective dose of a person living in Finland.
7.0 mSv	The average effective dose caused by a CAT scan of the abdomen.
20.0 mSv	The average effective dose resulting from coronary artery angioplasty.

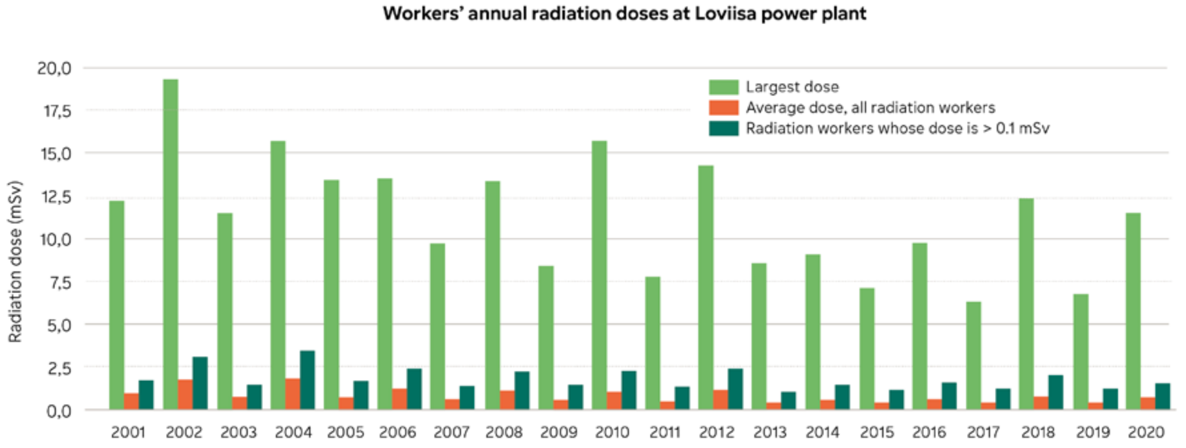

Figure 7-3. The annual radiation doses of Loviisa power plant's workers in 2001–2020.

Seamless cooperation between the different organisations of the power plant and accounting for the results of various international peer reviews in the plant's operations are also of fundamental importance. Radiation protection is important throughout the power plant's life cycle, including the maintenance and disposal of radioactive waste.

At Loviisa power plant, radiation protection is based on the principles of justification, optimisation and limitation, pursuant to the Radiation Act (859/2018). These principles help ensure that the overall benefits achieved from the radiation practice exceed the detriment it causes (the principle of justification), that the exposure to ionising radiation is kept as low as is reasonably achievable (the ALARA principle; the principle of optimisation), and that workers' radiation dose does not exceed the dose limit set for the operation (the principle of limitation). The principal means by which people are protected from radiation in radiation protection are time, shielding and distance. The radiation dose can be reduced by limiting the duration of the exposure, and by adding shielding between a person and the radiation source. Increasing distance to the radiation source reduces the radiation's dose rate.

At Loviisa power plant, systems containing radioactive substances are located in a radiation controlled area subject to special safety instructions which allow for protection against radiation. Continuous radiation dose monitoring has been arranged for personnel working within the radiation controlled area, and the persons and items exiting the area are subject to radiation measuring. Loviisa power plant has a separate organisation for protecting employees against radiation.

The radiation doses of Loviisa power plant's personnel fall significantly below the dose limits for workers. During the facility's operation, the doses are mainly derived from the inspection work carried out in the space of the primary coolant pumps. Most of the workers' radiation doses are accumulated in the steam generator space during outages and in work carried out on the reactor's lid unit. Figure 7-3 shows the radiation doses of Loviisa power plant's radiation workers in 2001–2020.

The success in turning the long-term trend of the workers' radiation doses downward in terms of the highest radiation doses and average radiation doses was achieved, among other things, by making use of operational experiences, plant modifications and above all, the planning of annual outage work. The larger annual variations seen in the figure are partly explained by the more extensive annual outages conducted at regular intervals, during which more work is carried out in the vicinity of radiating components.

The work to be carried out in an area defined as a radiation controlled area during decommissioning will still be radiation work, subject to the same safety and radiation protection principles as are complied with during the power plant's operation.

7.4 CLASSIFICATION OF INCIDENTS AND ACCIDENTS, AND THE REQUIREMENTS CONCERNING THEM

7.4.1 Classification according to the Nuclear Energy Decree

According to the Nuclear Energy Decree (161/1988), nuclear facility incidents and accidents are classified as anticipated operational occurrences, postulated accidents, design extension conditions and severe accidents. Incidents and accidents have been accounted for in the nuclear facility's design, the systems and structures carrying out safety functions, and in the facility's procedures and the organisation's operations.

Chapter 7.1 presents the approval criteria for event class-specific radiation doses and the emission limit for a severe reactor accident. Other approval criteria – including the criteria on the failure assumptions that must be used in designs to prepare for an event and on which safety class the systems must be designed for – are provided in STUK's YVL Guides, which also impose limits on physical parameters such as pressure and temperature. The fulfilment of the approval criteria must be shown with analyses.

The incident and accident classification was originally developed for nuclear facilities equipped with a nuclear reactor, but it was subsequently expanded for application to other nuclear facilities as well. The classification and descriptions therefore exhibit a strong focus on nuclear reactors.

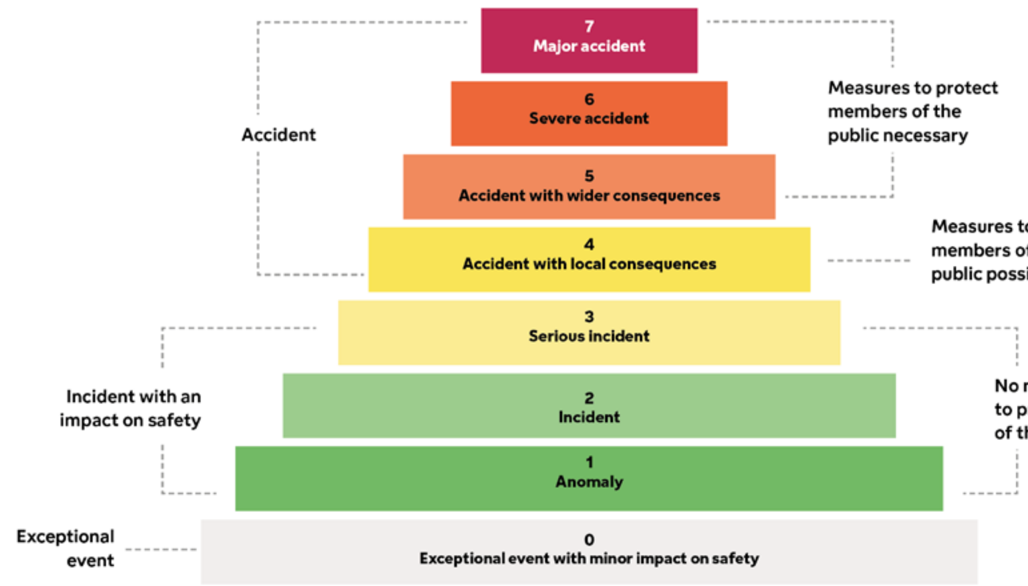

Figure 7-4. The International Nuclear and Radiological Event Scale (INES) and the rating of events.

Anticipated operational occurrence

Anticipated operational occurrences are events that can be expected to occur once or several times during any period of a hundred years of operation.

Postulated accident

Postulated accidents are events used in the design and dimensioning of the principal safety systems. In these events, the safety systems must halt the heat-generating chain reaction occurring in nuclear fuel, prevent nuclear fuel failure, and limit the amount of radioactivity emitted into the environment. Class 1 postulated accidents can be assumed to occur less frequently than once over a span of one hundred operating years. Class 2 postulated accidents can be assumed to occur less frequently than once over a span of one thousand operating years.

Design extension condition

Design extension conditions cover situations in which the initiating event of an operational occurrence or accident involves a common cause failure in a system required to execute a safety function (Class A), or in which a complex combination of failures occurs during the event (Class B), or in which the initiating event is a rare external event (Class C). The power plant is required to withstand such a situation without sustaining severe fuel failure.

Severe accident

In a severe accident, a considerable part of the fuel in a reactor or of the spent fuel in storage loses its original structure. As a result, a significant portion of the radioactive substances in the fuel is released into the containment building or the storage building for spent fuel.

7.4.2 International Nuclear and Radiological Event Scale (INES)

The International Nuclear and Radiological Event Scale (INES) is a scale used for the classification of various events. It describes the severity of an emission of radioactive material and radiation exposure. The scale is also used for events with no emission or radiation exposure consequences, but in which the relevant measures have not functioned as intended.

INES was developed to illustrate the safety significance of nuclear facility events and to function as support in communicating such events. According to the publication of the International Atomic Energy Agency (IAEA) (IAEA 2008) , INES levels/scales are determined on the basis of the impairment of safety or the radiation impacts on the environment, power plant area or personnel. All consequences of an event or accident are reviewed separately when determining the level. If the INES level can be determined on the basis of more than one consequence, the most severe consequence determines the ultimate INES level. In an incident or accident, the licence holder submits a proposal on the INES level to STUK for approval.

The nuclear facility events with relevance for nuclear or radiation safety are rated in eight levels on the event scale, as shown in Figure 7-4. Events without safety significance are rated as Level 0 events. Events that impair safety, but which do not warrant measures to protect members of the public, are rated as Levels 1–3. Accidents which involve emergency preparedness operations and measures to protect members of the public are rated as Levels 4–7.

Events pursuant to the event classification applied in Finland are divided into INES levels in such a way that anticipated operational occurrences fall under Levels 0–3, postulated accidents and design extension conditions under Level 3 or

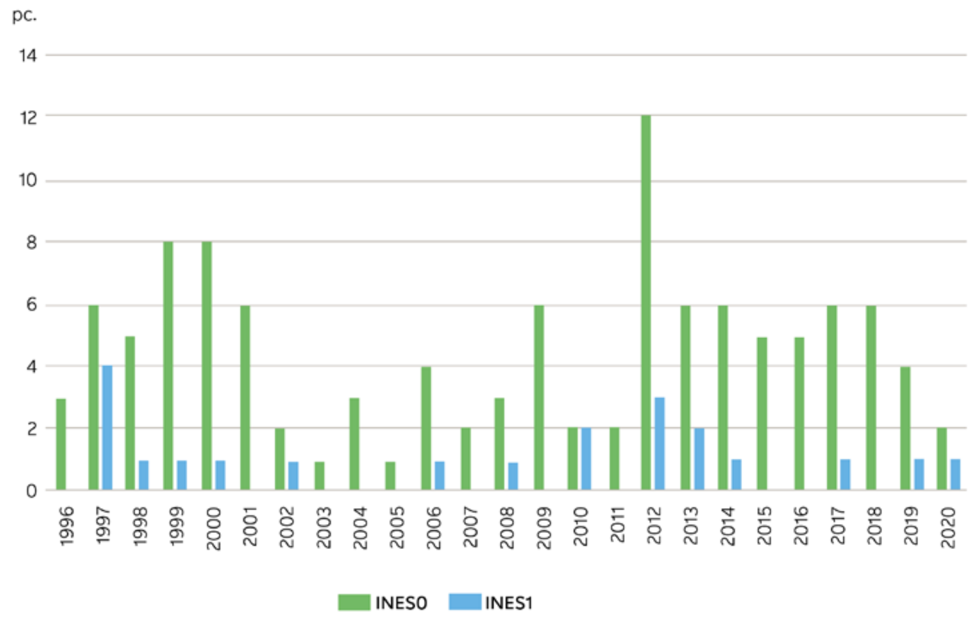

Figure 7-5. The number of INES events falling under INES levels 0 and 1 at Loviisa power plant in 1996–2020.

4, and severe accidents under Levels 5–7. The events that have taken place in Finland's nuclear power plants have been rated as INES levels 0, 1 and 2. (STUK 2021k) The number of INES events at Loviisa power plant as of 1996 are shown in Figure 7-5. The definitions and reporting of events in terms of incidents were changed in 2012. This is visible as an increased number of events, particularly at INES Level 0.

The consequences of radioactive emissions and the radiation doses to which people are exposed as a result of accidents rated as INES Level 4 and INES Level 6 accidents are assessed and presented in Chapter 9 as part of the environmental impact assessment procedure. Under the Nuclear Energy Decree, such situations are classified as design extension conditions and severe accidents.

A description of the INES levels and examples of the relevant events are presented below. Events that have occurred prior to 2004 are described in detail in Chapter 6 of the book series Säteily- ja ydinturvallisuus (STUK 2004).

INES 0 – An anomaly whose safety significance is so minor that it cannot be rated on the scale

Events whose safety significance is so minor that they cannot be rated on the scale fall under INES Level 0. The level covers the emergency shutdown of a reactor (reactor trip), for example. All systems in events of this level function as intended.

At Loviisa power plant, events of INES Level 0 have included various human errors and individual equipment failures. Examples include periodic delays in testing, periodic inspections and preventive maintenance, deviations from the permitted time limits for repairs, deviations from the required condition of systems, and operational errors.

INES 1 – Anomaly

Events rated as INES Level 1 events do not compromise safety, but the facility's situation or operations differ from normal to a material degree. The reasons for the deviation may include equipment failure, operational errors or deficient procedures.

At Loviisa power plant, INES Level 1 events have been related to some equipment not being available on demand, the management of fire loads and delays in periodic inspections.

INES 2 – Incident

Events rated as INES Level 2 involve a significant shortcoming in factors impacting safety, but safety is still ensured, despite a possible additional failure. The level also includes events in which a worker's dose limit is exceeded, or in which a significant unintended amount of radioactivity enters areas of the power plant. Loviisa power plant has had four events rated as INES Level 2, described below. A more detailed description of these events can be found in Chapter 6.6 of the book series Säteily- ja ydinturvallisuus (STUK 2004).

An erroneously tripped thermal relay stopped one of the primary coolant pumps of Loviisa power plant unit 2 in 1981. Due to additional failures, this caused the primary system's safety injection system to start up.

When Loviisa power plant unit 2 was being started up in 1987 following a refuelling outage, a turbine's generator switch opened when the reactor power was at 54%, and when only one of the two turbines was in operation. During the event's management, some of the valves were mistakenly in a closed-off position, and combined with the operators' actions, the situation ultimately led to the primary system's safety injection system starting up. This feed was erroneously connected to the tank of boron-free water. The mistake was quickly noticed, after which the feed was connected to a tank including boron.

In connection with the start-up of Loviisa power plant unit 1 after the annual outage in 1988, air was removed from the hydro accumulator's surface measurement pipes. According to instructions, the blowing should have been carried out with boron water, but it was carried out with boron-free water. The boron-free water caused the tank's boron concentration to drop below its normal level.

A secondary side feedwater pipe burst at Loviisa power plant unit 1 in 1990 and at Loviisa power plant unit 2 in 1993. Due to the recurrence, the latter event was rated as an INES Level 2 event.

INES 3 – Serious incident

In events rated as INES Level 3, emissions of radioactive substances exceed the emission limits approved by the authorities for normal operation and cause a radiation dose of less than one mSv for the most exposed individual living in the vicinity of the power plant. Protection measures outside the power plant are unnecessary. A worker's dose significantly exceeding the dose limit, resulting in health effects, can also constitute a Level 3 event, as can a serious dispersion of radioactivity within the plant. This level also includes events in which an individual additional failure of the safety system could lead to an accident, or in which a required safety system would be inoperative and therefore unable to prevent an accident resulting from an incident. Examples of INES Level 3 events are given below.

A fire broke out at Vandellòs Nuclear Power Plant in Spain in 1998. Several systems ensuring safety were damaged in the fire, due to which the event is rated as a Level 3 event.

Fuel bundles were being cleaned in a separate cleaning system designed for the purpose at the bottom of a deep pool of water during an annual outage at Paks nuclear power plant in Hungary. Due to a design error, the system's cooling circuit was disrupted, and the batch of 30 fuel bundles set to be cleaned overheated and was damaged. Due to the failure, radioactive noble gases and a very small amount of iodine were released into the reactor hall. However, emissions into the environment and the personnel's radiation doses remained minor.

INES 4 – Accident with local consequences

In accidents rated as INES Level 4, a radioactive emission causes a radiation dose of more than one mSv for the most exposed individual living in the vicinity of the power plant. In such an accident, fuel failures are the result of the partial breakdown or melting of the reactor core. Measures that aim to protect members of the public outside the power plant are usually unnecessary, with the exception of the control of local foodstuffs. The level also includes events in which one or more power plant worker is exposed to a radiation dose which is likely to result in the worker's quick death. Examples of INES Level 4 events are given below.

Radioactive substances were released into the premises of the reprocessing plant of Windscale (now Sellafield) in the UK in 1973, as a result of a heat-generating chemical reaction that occurred in a process tank. Based on the plant's internal effects, the accident is a Level 4 event.

A metal plate that came loose from the reactor structures at the gas-cooled Saint Laurent nuclear power plant in France in 1980 blocked the cooling flow of two fuel bundles. This resulted in severe fuel failures, but there were no emissions of radioactive substances into the environment. Based on the plant's internal effects, the accident is a Level 4 event.

A sudden short-term increase of power (criticality accident) took place in a RA-2 research reactor in Buenos Aires, Argentina, in 1983. The accident proved fatal to an operator working some 3–4 metres away from the reactor. A criticality accident occurred in the uranium vessel of the Tokaimura nuclear fuel plant in Japan in 1999. As a result, three workers were exposed to significant radiation. Two of them later died as a result of the exposure. Based on the radiation doses, both these accidents are rated as Level 4 events.

INES 5 – Accident with wider consequences

In accidents rated as INES Level 5 events, a relatively small portion of a power plant's radioactive substances is released into the environment. Such an emission would result in the partial initiation of protective measures. This level also includes accidents in which the nuclear facility is severely damaged without significant amounts of radioactive substances being released into the environment.

The accident which occurred at the Three Mile Island power plant in the United States in 1979 – in which the power plant unit's reactor core melted, but the radioactive emissions into the environment remained small – is rated as an INES Level 5 event.

INES 6 – Serious accident

In accidents rated as INES Level 6, a large quantity of radioactive substances is released into the environment. Such an emission probably leads to the large-scale initiation of environmental protection measures to avoid serious health effects in the vicinity and to reduce the radiation doses of members of the public further away.

A tank containing high activity radioactive liquid waste exploded at the reprocessing plant known as Chelyabinsk-65, near the city of Kyshtym in the USSR (in what is now Russia) in 1957, resulting in the emission of radioactive substances. Detrimental health effects were limited by counter measures like the evacuation of the area's population. Based on the environmental impact, the accident is a Level 6 event.

INES 7 – Major accident

In an accident rated as an INES Level 7 event, a significant portion of a nuclear power plant's or other nuclear facility's radioactive substances are released into the environment. What is typical of the emission of this type of accident is that it includes both short and long-lived fission products. An emission of this kind may cause immediate and direct detrimental health effects, late effects and long-term environmental impact. Large-scale measures aiming to protect members of the public are initiated to avoid serious detrimental health effects. Accidents rated as INES Level 7 events are listed below.

The largest earthquake in Japan's history, on 11 March 2011, and the subsequent tsunami severely damaged the Fukushima Daiichi nuclear power plant on the eastern coast of Japan, due to which the reactor cores of three power plant units melted. Radioactive substances from the plant were released into the air and the sea. Based on its environmental impact, the accident is rated as a Level 7 event.

The reactor of the Chernobyl nuclear power plant was destroyed explosively in the USSR (in what is now Ukraine) in 1986. The reactor's full breakdown resulted in a large emission of radioactive substances, and dozens of people involved in the management of the accident died due to the radiation doses to which they were exposed during the accident. Based on the environmental impact, the accident is a Level 7 event.

7.5 NUCLEAR SAFETY

Loviisa power plant's power plant units and interim storages for spent fuel employ functions which aim to reliably guarantee nuclear safety. The purpose of these functions is to control chain reactions and the fuel's reactivity, ensure the cooling and integrity of the fuel, and confine the radioactive substances within the plant. At the initial stage of decommissioning, when the spent nuclear fuel is transferred from the power plant units to an interim storage for spent fuel that has been made independent, the related nuclear safety risks are removed from the power plant units.

The safety level of Loviisa power plant is determined by the plant's technical principles of operation and solutions, and the expertise and safety-focused attitude of the organisation operating the power plant.

7.5.1 Safety functions and principles

Safety functions aim to prevent the emergence of incidents and accidents, prevent their spread, and mitigate the consequences of accidents. The principal short-term safety functions start up automatically. In the longer term, the necessary functions can be started up by an operator. The most important safety functions are as follows:

- reactivity control, which aims to stop the chain reaction generated by the reactor;
- the removal of the residual heat generated after the chain reaction is stopped, which aims to cool the fuel and by doing so to ensure the integrity of the fuel and the primary system;
- prevention of the dispersion of radioactivity, which aims to isolate the containment building and ensure its integrity, and by doing so, to control radioactive emissions during accidents.

The general nuclear safety principles applicable to safety functions are the defence-in-depth principle, the redundancy principle, the diversity principle, the separation principle and tolerance of environmental conditions, all of which are presented in this chapter. The safety functions also apply to the pools of spent fuel located next to the reactor in the power plant units and to the separate interim storages for spent fuel. However, the implementation of their safety functions differs significantly from the solutions applicable to a reactor.

The safety functions are no longer relevant when the nuclear fuel has been removed from the plant as part of preparing for decommissioning. Naturally, a nuclear facility about to be decommissioned invests in preventing the dispersion of radioactivity.

Defence-in-depth safety principle

In accordance with the defence-in-depth principle, safety at Loviisa power plant is ensured through a series of successive functional levels that are mutually redundant. The defence-in-depth safety principle covers all areas of the power plant, from the organisation to practices and devices. The levels of a functional defence-in-depth safety principle are:

1. prevention;
2. incident management;
3. accident management;
4. limiting emissions in the event of a severe r eactor accident;
5. mitigating consequences.

The first two levels aim to prevent accidents, while the other levels intend to protect the plant and its users as well as the environment from the detrimental effects of an accident. Level 4 is not applicable to the pools of spent fuel as presented in section 9 of STUK Regulation Y/1/2018.

The systems executing the safety functions of Loviisa power plant's power plant units are described at levels 2–3 of the functional defence-in-depth principle in Chapter 7.5.2 (operational occurrences, postulated accidents and design extension conditions) and at level 4 of the principle in Chapter 7.5.3 (severe reactor accident). The organisation's functions at level 5 (emergency preparedness operations) are described in Chapter 7.6.

The defence-in-depth principle is also applied to preventing the dispersion of radioactive material, in which the successive levels preventing dispersion can be divided into five barriers. The dispersion barriers can be divided as follows:

1. the nuclear fuel which is in fuel rods in the form of solid pellets;
2. the gas-tight cladding of a fuel rod;
3. the primary system;
4. the containment building surrounding the reactor;
5. the reactor building.

Security arrangements are also subject to the defence-in-depth principle as presented in Chapter 7.7.

Redundancy principle

The redundancy principle refers to the implementation of a safety function with several parallel devices or partial systems independent of one another. The most important safety systems of Loviisa power plant have been designed to meet the single failure criterion, even if the maintenance of an individual device or piece of equipment was underway at the same time. This means that the system executing the safety function can carry out its task even if two individual devices are disabled. Other systems executing safety functions are largely designed to meet the single failure criterion, i.e. the systems are able to carry out their tasks even if one device is disabled. The safety systems of Loviisa nuclear power plant are divided into two different redundancies.

Separation principle

At Loviisa nuclear power plant, the application of the separation principle means planning the placement of parallel devices and systems executing the same function and mutually redundant systems in such a way that a fire, or another internal or external event, cannot break them all simultaneously. In practice, this results in placing parallel partial systems in different spaces or their protection by physical means. The separation principle is also applied to automation and electric systems, and the different systems have been separated from one another to the extent necessary. This prevents a possible failure from spreading from one system to the next. Loviisa power plant's safety systems have been divided into two redundancies, separated from one another structurally and functionally.

Diversity principle

The diversity principle refers to the execution of a safety function with a number of systems based on the operating principle, manufacturing method or physical parameters. At Loviisa power plant, the diversity principle is applied as follows, for example:

- a reactor shutdown with a control rod system or by feeding boron into the primary system;
- removing residual heat to the sea, and with the secondary system's blowdown valves or cooling towers, into the atmosphere;
- In exceptional situations, the electricity required by the safety functions can be produced with diesel generators cooled with either seawater or air;
- automation relies on both digital and analogue technology in such a way that the most important functions can be implemented with either technology.

Tolerance of environmental conditions

The equipment and systems used at Loviisa power plant have been designed for the temperature, pressure, moisture and radiation conditions required from each piece of equipment/system.

The functionality of the mechanical equipment, as well as the electric and automation equipment, and systems used at the power plant in the conditions serving as the design basis, is proved by qualification. The tolerance of environmental conditions is shown during both normal operation and in incident and accident conditions.

7.5.2 Systems executing safety functions

Loviisa nuclear power plant has operating systems and safety systems with which to implement reactivity control, the removal of fission or residual heat, and the prevention of the dispersion of radioactivity during normal operation as well as during incidents and accidents. An incident or accident may arise as a result of equipment failure, for example, or a spill, broken piping or fire. The safety systems also ensure safety functions when the normal operating systems are unavailable. The systems most relevant for the

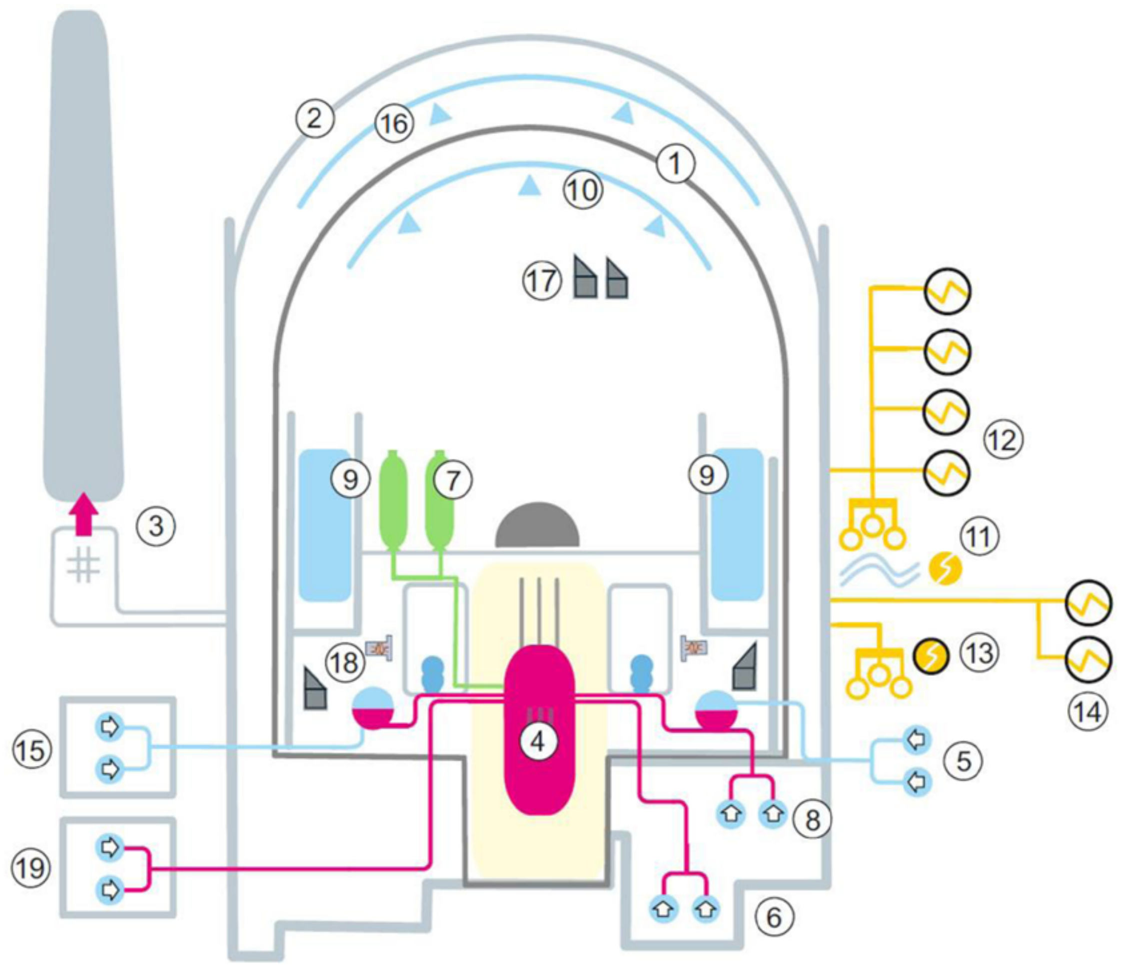

Figure 7-6. The most relevant systems related to the execution of safety functions at Loviisa power plant's power plant units.

execution of the safety functions of Loviisa power plant's power plant units, their placement and the placement of the reactor building's structures are shown in Figure 7-6.

1. Containment
2. Reactor building
3. Filters for ventilation exhaust
4. Reactor and control rods
5. Emergency feedwater system
6. Low-pressure safety injection system
7. Pressurised hydro accumulators
8. High-pressure safety injection system
9. Ice condenser
10. Containment spray system
11. Power supply from hydro power station
12. Emergency diesel generators
13. Diesel generators plant
14. Severe accident diesel generators
15. Auxiliary emergency feedwater pumps
16. Containment external spray system
17. Hydrogen removal (passive autocatalytic recombiners)
18. Hydrogen removal (igniters)
19. Boron supply system

Reactivity control

Reactivity control during an incident or emergency can be performed by driving the control rods to the reactor core, or should the control rod system be damaged, by feeding boron water into the primary system. Boron is effective in absorbing the neutrons sustaining the nuclear reaction. Boron is present in both the steel of the control rods (Figure 7-6 system 4) and in a dissolved form in the boron system's water (Figure 7-6 system 19), the water in the emergency cooling system's water pool and tanks (Figure 7-6 systems 6, 7 and 8), and in the ice of the ice condensers (Figure 7-6 system 9).

Removal of residual heat

Following the reactor's shutdown, the fuel continues to produce heat. This "residual heat" is removed by various means, depending on the incident or accident. When the primary system is intact, the residual heat is removed through the steam generators to the secondary system, from which it is transferred into the atmosphere as steam, or with the aid of heat exchangers into the sea or the atmosphere. The steam blasting requires a constant feed of water to the steam generators, and this is achieved either with the emergency feedwater system or the auxiliary emergency feedwater system (Figure 7-6 systems 5 and 15). The pumps of the auxiliary emergency feedwater system are equipped with their own diesel engines, which means their operation does not depend on electricity sources.

If there is a leak in the primary system, or if the systems of the secondary system are unavailable, the residual heat is removed by feeding water into the primary system. The water supply used for the removal of residual heat can rely on the high-pressure make-up water system and the low-pressure emergency cooling system, as well as the attendant pressurised tanks (Figure 7-6 systems 6, 7 and 8). In the short term, the water supply for the pumps of these systems is the emergency cooling systems' separate water pool, and when the water in the pool runs out, the containment building's floor drains. The low-pressure emergency cooling system may be cooled, in which case the heat is transferred either into the sea or the atmosphere with the aid of heat exchangers. As the systems are used, residual heat is carried over to the containment building (Figure 7-6 number 1), increasing its pressure. The increase of pressure within the containment building can be reduced, and the pressure eased, by removing the heat from the containment building's airspace. In the short term, the ice condenser (Figure 7-6 system 9), with the structures of the containment building, absorbs heat and thereby effectively prevents pressure in the containment building from increasing. After this, the containment building's spray system is used if necessary (Figure 7-6 system 10), or the amount of heat entering the containment building is influenced by cooling the water fed into the primary system. The spray system may be cooled, in which case the heat is transferred either into the sea or the atmosphere with the aid of heat exchangers.

Containment of radioactivity

The dispersion of radioactive substances in an incident or accident is prevented by ensuring the fuel's sub-criticality and removing the residual heat from the fuel, whereby the fuel remains intact. The primary system's water normally contains a small quantity of radioactive substances. The aim is to contain these substances and any radioactive substances released from possibly leaking fuel rods or fuel rods damaged during the accident within the primary system or the containment building (Figure 7-6 system 1), thereby preventing the dispersion of radioactivity into the environment. This goal is achieved by isolating the primary system and the containment building – i.e. by closing the valves of the pipes leading to them, and the plates of the channels leading to the containment building. The primary system's main coolant piping and the steam generator's secondary system side can also be isolated if the tubes of the steam generator begin to leak, and coolant from the primary system ends up in the secondary system. Any radioactive substances leaking from the containment building are collected from the reactor building (Figure 7-6 number 2) and treated to the extent possible before their discharge into the environment. The treatment is carried out with the ventilation system's filters (Figure 7-6 system 3) and the treatment system for liquids.

Automation

The different levels of defence in depth rely on a number of automation systems which direct the required measures. Instrumentation and control is charged with ensuring undisrupted production and the operations of the required support functions. For operational occurrences, the plant has automation systems executing preventive protection and tasked with bringing the plant to the desired condition by lowering the reactor's power, for example. If the operational occurrence is severe, and the preventive protections cannot control the situation, the reactor and plant protection systems activate systems that execute safety functions to the extent required. Such functions include a reactor trip, the isolation of the containment building, and the emergency cooling of the reactor and containment building.

The controls are carried out either automatically or by an operator. Any functions required in the short term are automated.

Ensuring power supply

Loviisa power plant has at its disposal a number of power sources which secure the execution of safety functions in incidents and accidents. Both power plant units have four 2.8 MW emergency diesel generators (Figure 7-6 system 12) and a shared 9.7 MW diesel-powered emergency power plant (Figure 7-6 system 13). There is also a connection to the power plant from the nearby Ahvenkoski hydro power plant (Figure 7-6 system 11). These power sources can be used to operate the aforementioned systems and to recharge accumulators that secure the power supply of automation.

7.5.3 Management of a severe reactor accident

A severe reactor accident refers to a situation in which a considerable portion of the reactor fuel fails. A severe reactor accident could occur if the reactor's safety systems do not function in an accident. Systems for the management of a serious reactor accident are in place at Loviisa power plant. With the instructions on accident management, these systems ensure the containment building's integrity and prevent it from breaking down.

A melt-through of the reactor pressure vessel and any resulting steam explosion in the reactor cavity, and any interaction between the reactor cavity's concrete and the core melt, is prevented by confining the core melt within the reactor pressure vessel. The residual heat arising in the melt will transfer, through the reactor pressure vessel's wall, into the water in the reactor cavity. To ensure this, the primary system has special depressurisation lines for a severe reactor accident which help reduce the stress on the pressure vessel's wall, which will have been thinned down by the melt. Routes along which water can flow have been ensured, allowing the water discharging from the primary system and the water melting from the ice condenser to reach the reactor cavity via the steam generator space and come into contact with the reactor pressure vessel's external surface. The resulting steam will be fed back to the steam generator space. Coupled with the structures of the containment building, the ice condenser is effective in limiting the containment building's pressure increase, resulting from the increased temperature and steam generation. In the long run, the containment external spray system (Figure 7-6 system 16) which transfers heat into the sea will also be employed.

As the core melts down, it produces hydrogen which, should it explode, would risk the containment building's integrity. The containment building has passive autocatalytic recombiners (Figure7-6 system 17), which remove hydrogen from the entire containment building. The ice condenser's (Figure 7-6 system 9) doors can also be opened, allowing the containment building's airspace to blend, diluting the high local concentrations of hydrogen. If hydrogen is generated very rapidly, this hydrogen is removed with the hydrogen igniters (Figure 7-6 system 18) in the steam generator space, which enables the controlled creation of small hydrogen burns that do not pose a risk to the containment building's integrity.

For the purpose of a severe reactor accident, the plant has an automation system that is separate from other safety systems and two diesel generators (Figure 7-6 system 14), shared by the power plant units and intended for the management of a severe reactor accident. These secure the required equipment's power supply.

7.5.4 Storages for spent fuel

There is one fuel pool within the containment building next to the reactor of both Loviisa power plant units. In addition, the auxiliary building of the power plant unit Loviisa 2 houses two interim storages for spent fuel, each containing several fuel pools. The same safety functions that are applied to the reactor are also applied to the safety of the fuel pools.

Sub-criticality is ensured with the structures of the fuel pools and is further supported by the use of boron water in the storage pools.

If the cooling of the pools is interrupted, the removal of residual heat from the fuel is not compromised in the short term due to the fuel's very low residual heat power and the great amount of water in the pools. To remove residual heat in the long term, the cooling systems normally used must be restored to working order or alternative cooling systems – such as the system for treating pool water or feeding make-up water to the pools to compensate for any possible boiling – must be employed. The make-up water can be fed with the plant's active systems or through the connection points made for fire trucks, for example. The systems' power supply is ensured with emergency diesel generators and a diesel-powered emergency power plant (Figure 7-6 systems 12 and 13). Furthermore, the feed of the make-up water of the fuel pool within the containment building is secured with diesel generators intended for a severe reactor accident (Figure 7-6 systems 14).

The radioactive substances in the containment building's pools can also be effectively isolated within the containment building in the event of the pools boiling. A small amount of the radioactivity in the waters of the pools of the interim storages for spent fuel, located outside the containment building, may be released into the environment in a situation involving boiling.

7.5.5. Fires

A fire can cause an initiating event at the power plant in such a way that a normally used device/piece of equipment is incapacitated due to the fire, or that a function may start up unnecessarily. Safety systems may need to be activated in the event of a fire. The impact of fires is limited by applying the redundancy and separation principles, in which case only some of the required equipment can be damaged by the fire. The safety systems' parallel subsystems are widely separated into different rooms or located at a sufficient distance from one another. The equipment and cables are treated with fire retardants if necessary. A fire's spread between rooms is prevented by wall structures, fire doors and fire dampers.

The control of fires is described in more detail in Chapter 9.22.

7.5.6 Preparing for external threats and climate change

The original planning of Loviisa power plant's safety systems did not account for extreme external events in an entirely exhaustive manner. Examples of events of this kind include powerful lightning storms, wind, variations in sea levels, high seawater temperatures, and high and low outdoor temperatures. The impact of external events has subsequently been assessed extensively, and the changes necessary to lessen their impact have been made. In terms of the key safety systems, natural phenomena manifesting at a frequency of once every ten thousand or a hundred thousand years are accounted for, depending on the consequences of such an event. Events that recur once every ten million years are prepared for with the systems, and if necessary, in the special arrangements of Loviisa power plant. Special arrangements include additional inspections, the preventive shutdown of the plant, flood control measures and special instructions related to an event's management. In some cases, a state of preparedness can also be announced proactively.

Climate change has an impact on the strength of external events and the probability of powerful phenomena. As a result of climate change, the average temperatures of seawater and air close to the surface of the earth will increase in the future, for example, in addition to which heatwaves in air and seawater will become more common. Precipitation is also likely to increase. The sequestration of heat and carbon dioxide in seas will change the stratification and pH conditions of seawater. Yet increasing precipitation will dilute the salinity of seawater directly through precipitation, but also through run-off. Changes in these physical quantities of the environment will form complex feedback loops between each other, which makes assessments of the magnitude of the changes difficult and sensitive to error. Based on research, the trends are nevertheless clear. (Bolle et al. 2015)

The magnitude of climate change will depend primarily on humanity's realised greenhouse gas emissions. Climate change is therefore assessed with the aid of various emission scenarios, which make assumptions concerning the future development of greenhouse gas emissions. In addition, the impact of climate change varies considerably according to both region and seasons. For example, according to climate models, temperatures and total rainfall in Finland will increase most during winters. (Climate Guide 2021a)

From the perspective of the operation of Loviisa power plant, one of the threats posed by climate change is a rise in sea levels. In Finland, the surface of the earth is still rising after the most recent Ice Age, and in the Loviisa region, the land is currently rising by approximately 3.5 mm a year (National Land Survey of Finland 2021b). Thanks to this rate of rebound, the average sea level in Loviisa was actually declining until the 1990s. Nowadays, however, the rate at which the sea level is rising around Loviisa is already slightly faster than the prevailing rate at which the land is rising. In the future, the global sea level will probably continue to rise faster than landmasses. It is nevertheless noteworthy that even according to the most pessimistic climate change or emission scenarios, the sea level in Loviisa will not rise dramatically by 2050.

According to the Intergovernmental Panel on Climate Change (IPCC), the global rise in sea levels would be roughly 0.3 m compared to the average level in 1986–2005, even according to the worst climate change scenario. The IPCC's results are presented illustratively on the Finland's Changing Climate website (Climate Guide 2021b). At Loviisa power plant, the impact would be less than half of this due to the rising landmass. Loviisa power plant has prepared for a sea level of N2,000 + 4.01, a level which, with the expected climate of 2030, will be exceeded once in a hundred million years.

In the future, the increase in the temperature of the air and seawater may result in power restrictions at the power plant due to the conditions of the environmental permit and the requirements imposed on the equipment's cooling capacity. Increasing violent storms may cause disruptions in the main grid, which the plant has prepared for in the form of numerous diesel generators and engines securing the safety functions.

Studies related to climate change are monitored continuously, and modifications are carried out as necessary on the basis of the assessed effects, as explained in Chapter 7.8.

Wilfully unlawful events attributable to people are prepared for, in addition to what is explained above, with the security arrangements described in Chapter 7.7 and by complying with the separation principle.

7.6 EMERGENCY PREPAREDNESS

Emergency preparedness arrangements are arrangements carried out in preparation for accidents or situations in which the safety of the nuclear power plant has been compromised. Emergency situations are classified into three groups on the basis of their severity, with Group 3 the most severe (YVL C.5):

1) An alert situation is set when the power plant's safety level must be ensured in exceptional situations. In such a case, the power plant's emergency preparedness organisation is convened in the numbers deemed fit.
2) A site area emergency is set when the power plant's safety deteriorates or is at risk of deteriorating significantly. In this case, the power plant's emergency preparedness organisation is called in in its entirety.
3) A general emergency is set when there is a risk of radioactive substance releases that may require protective measures in the vicinity of the nuclear power plant. In this case as well, the power plant's emergency preparedness organisation is called in in its entirety.

In all emergency situations, the alert is also sent to STUK and the regional emergency services, which alert the rescue authorities.

Loviisa power plant has declared only one emergency situation during the history of its operation. This took place on 9 January 2005, when the power plant set an alert situation due to the high sea level. While the situation was potentially detrimental in nature, it did not cause problems at the power plant and was rated an INES Level 0 event.

To mitigate the consequences of an accident, the power plant and the authorities maintain emergency preparedness operations with the objective of protecting the people working at the power plant and members of the public in a situation involving a radiation hazard. More detailed information on measures aiming to protect members of the public can be found in Chapter 9.21. The emergency preparedness organisation of Loviisa power plant consists of personnel from the power plant and Fortum's headquarters in Espoo, trained for different tasks. The premises and staff of Loviisa power plant's rescue station also constitute part of the emergency preparedness organisation. In these premises, the emergency preparedness organisation has at its disposal suitable facilities as well as communication connections and devices. Among other things, the emergency preparedness organisation is tasked with the control measures carried out by control room personnel, the operations of repair teams, predicting the course of an accident, monitoring radiation levels and emissions, predicting a potential emission and its migration, determining any possible action to be taken, and submitting a proposal on the event's INES rating to STUK (Chapter 7.4).

Protective equipment and iodine tablets are available for the personnel in the event of a radiation hazard. To protect members of the public in the power plant's environs in the event of a possible radiation hazard, Loviisa power plant distributes iodine tablets to permanent residents and holidaymakers in the power plant's precautionary action zone (an area extending to a distance of approximately 5 km from the power plant). Guidelines for situations involving a radiation hazard have been delivered to people living or holidaying within the emergency planning zone as well as to any workplaces within the zone. The guidelines have been prepared in cooperation with the Eastern Uusimaa Emergency Services Department, STUK and Fortum, and a hardcopy of the guidelines is delivered to the aforementioned locations every three years, but it is also available on Fortum's website (Fortum Power and Heat Oy 2019c). The guidelines provide instructions on what to do in the event of a radiation hazard.

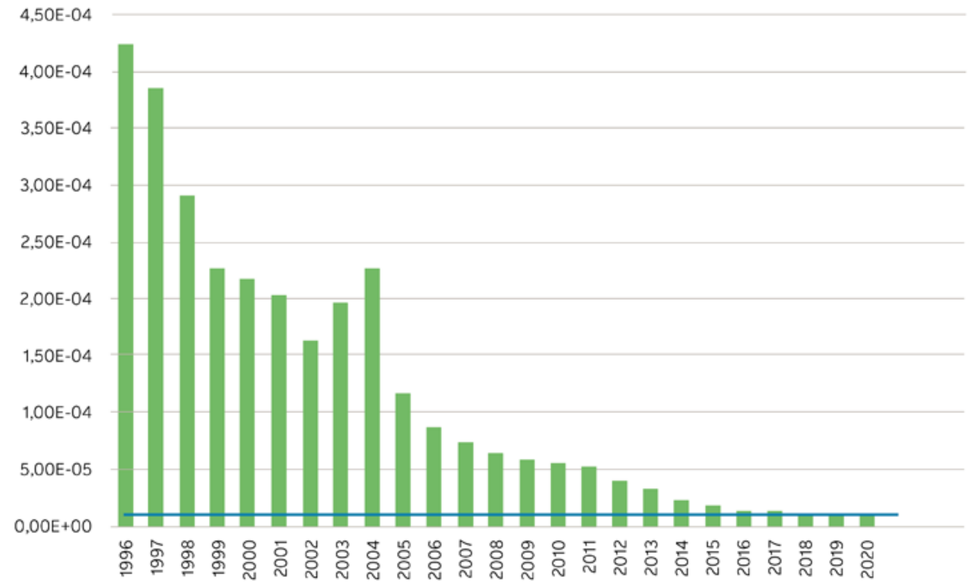

Figure 7-7. The frequency of considerable reactor core damage and nuclear fuel damage of spent fuel in the fuel pools in Loviisa power plant unit 1, assessed by means of PRA. The blue line indicates the requirement level (10–5/year) for new nuclear power plants presented in STUK's YVL Guide A.7.

In an emergency situation, the power plant's personnel are informed of the situation through the power plant area's public address system, IT devices and an information session insofar as this is possible. Notices and bulletins prepared by Fortum for members of the public and the media are published on Fortum's website. Depending on the severity of the situation, a news briefing can also be arranged for the media and members of the public. The authorities are responsible for preparing and communicating any official guidelines aimed at members of the public.

The emergency preparedness plan is maintained and developed continuously, and the operations are practised in annual emergency preparedness drills and in cooperation exercises organised every three years, in cooperation between the power plant and several authorities (including STUK, the police, rescue services, the emergency response centre, hospitals and the Finnish Meteorological Institute).

7.7 SECURITY ARRANGEMENTS

Security arrangements are an important part of radiation safety, even though they are usually processed as an independent part of it due to their different nature. Security arrangements refer to advance preparations for a threat of illegal activity directed against the nuclear power plant or its operations. Examples of such activities include sabotage and the unauthorised removal of nuclear material. Security arrangements safeguard the plant's normal undisrupted operation, its systems and the personnel working at the plant. Cybersecurity is an important aspect of the security arrangements.

Loviisa power plant has a separate security organisation. The plans and guidelines concerning the security arrangements have been prepared in cooperation with the relevant police authorities and aligned with the rescue, emergency and abnormal situation plans prepared by the authorities. Security arrangements and their related plans and guidelines are maintained and continuously developed, and the operations are regularly practised with the authorities, both in separate drills and as part of the emergency exercises. The security arrangements have been planned according to the defence-in-depth principles, based on nested security zones.

7.8 ASSESSING AND IMPROVING SAFETY AND SECURITY

In accordance with STUK Regulation Y/1/2018, the nuclear facility's safety and the technical solutions of its safety systems must be assessed and substantiated analytically and experimentally if necessary. Incident and accident analyses verify the fulfilment of the set approval criteria. The principal analysing tool at Loviisa power plant is the Apros® simulation software, developed in cooperation with VTT Technical Research Centre of Finland. The software is also widely used in the planning of modification work. Other analytical methods include strength analyses, fault and effect analyses as well as Probabilistic Risk Assessment (PRA). PRA is used widely in the determination of the power plant's risk level and as support for decision making in the risk management of the safety of the nuclear power plant when assessing the opportunities to perform measures that improve safety, for example, and the need for such measures.

According to STUK's YVL Guide A.7, a new nuclear power plant must be designed in such a way that in the PRA, the mean value of the frequency of reactor core damage is less than once in a hundred thousand years. Figure 7-7 shows the frequency of considerable reactor core damage and fuel failure of the spent fuel in the fuel pools in Loviisa power plant unit 1 in 1996–2020, assessed by means of PRA.

Regardless of the analysis model's development over time and the expanded risk assessment, the frequency has, with the exception of some individual years, reduced significantly, and nowadays corresponds to the level required of new nuclear power plants. While the frequency has reduced due to partly more precise assessments, most of the reduction is attributable to measures carried out to improve safety.

A periodic safety review is an extensive review assessing the licence holder's operations and the plant's technology. The review consists of 14 reviewed aspects and a summary. The content requirements for these aspects are provided in STUK's YVL Guide A.1, while the IAEA's document SSG-25, Periodic Safety Review for Nuclear Power Plants (IAEA 2013), provides more details on the objectives, methods and content of the review. One important aspect of the review relates to proving the fulfilment of the requirements. In 2020, Fortum submitted the periodic safety review concerning Loviisa power plant and the final disposal facility to STUK. In the review, the fulfilment of the requirements is reviewed in terms of the relevant STUK Regulations and YVL Guides, encompassing more than 6,000 requirements.

For new nuclear power plants, the YVL Guides and requirements are valid as they are, whereas for existing nuclear facilities such as Loviisa power plant STUK prepares an implementation decision – i.e. how and to what extent a Guide's requirements are applied – for each YVL Guide. Based on these implementation decisions, Loviisa nuclear power plant meets the safety requirements pursuant to the Nuclear Energy Act and the requirements of national authorities insofar as they are applied in accordance with section 7 a of the Nuclear Energy Act. STUK delivers the safety review to the Ministry of Economic Affairs and Employment as part of any operating licence process. This safety review is based on the periodic safety review submitted by the licence applicant, any other documents delivered, and on STUK's views.

In accordance with the safety and quality policy of Loviisa power plant, the plant's operations are based on a first-rate safety culture and quality as well as continuous improvement. In accordance with a good safety culture, the licence holder is committed to the continuous improvement of the plant's safety until the end of the plant's operation. At a practical level, the determination of modifications is influenced by the ageing of plant parts, the operating experiences of Loviisa power plant and other nuclear power plants, changes in STUK's YVL Guides and international requirement levels as well as technological advances.

In addition to the requirements set by the authorities, the operations of Loviisa power plant account for international principles and guidelines such as the guidelines and recommendations published by the IAEA, and the recommendations of the World Association of Nuclear Operators (WANO). The IAEA and WANO collect and distribute the operating experiences of plants and facilities, and conduct regular assessments for Loviisa power plant. The operating experiences of other plants and the results of the assessments conducted for the plant are used to develop and improve operations and safety. In addition, Loviisa power plant engages in active information exchange with individual power plants with the aim of improving safety and operation.

Numerous projects improving safety have been carried out during the operation of Loviisa power plant, and the power plant is now considerably safer than it was when it was originally commissioned, although it already complied with the requirements at the time. Several modifications and even new systems have been completed at the plant on the basis of PRA, which has also functioned as the basis for improving the management of various incidents and accidents almost throughout the plant's service life. The modifications carried out after the Fukushima accident included building an alternative heat sink independent of the sea, i.e. air-cooled cooling towers, and preparations for a high seawater level, improvements related to the availability of the fuel of diesel generators and engines, the implementation of an alternative residual heat removal of fuel pools by boiling the pool water, and increasing battery capacities. Extensive reforms have also been carried out on the plant's automation, and ageing systems and equipment have been modernised. An ongoing assessment focuses on the seismic resistance of the plant and its safety functions. The expectation is that the seismic resistance must be improved in some respects for the plant to meet STUK's requirement level.

Safety improvements will also be carried out at Loviisa power plant during the potential extension of operation. The requirements (YVL Guides) published primarily in 2019 and 2020 are not expected to result in significant modification work, given that the requirements have not been subject to any material changes. The measures with regard to some previously changed requirements are yet to be completed in some respects, including the improvement of seismic resistance. The most significant modifications are attributable to ageing equipment, but in some cases, these modifications also affect safety.

Fortum is unaware of any changes to the plant's operation, legislation or international obligations which would have a significant effect on the licence holder's capability for the safe extension of operation in compliance with the requirements.

7.9 LOW AND INTERMEDIATE-LEVEL WASTE'S FINAL DISPOSAL IN THE L/ILW REPOSITORY

The low and intermediate-level nuclear waste (operational waste and decommissioning waste) generated as a result of the operation and decommissioning of Loviisa power plant will be deposited for final disposal in the L/ILW repository, i.e. facilities built or to be built at a depth of approximately 100 metres in the bedrock of the island of Hästholmen, which will constitute a separate nuclear facility as referred to in the Nuclear Energy Act.

The L/ILW repository was built in the 1990s, and its construction was preceded by studies on the location of a final disposal facility, which began shortly after the completion of Loviisa power plant and which investigated the suitability of Hästholmen's bedrock for the final disposal of operational waste and decommissioning waste. The location studies and the subsequent follow-up programmes (including rock mechanics, groundwater chemistry and hydrology) have provided extensive data on the properties of the final disposal location and its surroundings. They also allow the future development of these properties to be assessed. A number of long-term safety assessments and safety cases have been prepared alongside the location studies, and the subsequent construction and operation of the L/ILW repository, and as part of the decommissioning planning. The work aiming to ensure the long-term safety of final disposal will continue right up until the repository is permanently closed. The operations of the L/ILW repository are described in more detail in Chapter 4.

In 2020, Fortum submitted to STUK the periodic safety review of the L/ILW repository alongside the periodic safety review of the power plant, mentioned in Chapter 7.8. This safety review also discussed the long-term safety of the final disposal of the radioactive waste generated during the operation and decommissioning of Loviisa power plant, i.e. its safety after the repository has been closed.

7.9.1 Operational phase

Although the L/ILW repository is a separate nuclear facility as referred to in the Nuclear Energy Act and Decree, it is used regularly in connection with Loviisa power plant and is integrated in the power plant's operations. The organisation, maintenance, procedures, radiation protection and radiation control as well as the emergency preparedness and security arrangements therefore also cover the L/ILW repository. After the power plant's operation has ended, the parts of the organisation and infrastructure necessary for implementing the nuclear operations continuing on the island of Hästholmen – including the interim storage of spent fuel and the final disposal of operational waste – will be retained.

In terms of operational safety, the L/ILW repository differs considerably from the power plant's power plant units and the interim storages for spent fuel. Operational waste is low or intermediate-level waste, and chain reactions in waste of this kind are impossible. Nor does the waste generate an amount of heat that would require cooling.

The waste's radioactivity is relatively low. The waste is primarily packed in barrels or solidified in cement, due to which a normal situation during the operational phase will not generate emissions of radioactive materials. Nor will even exceptional situations cause significant radioactive emissions, given that most of the activity has been solidified in cement. Any 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 significant activity is detected in the waters, they can be treated if necessary, but this has as yet proved unnecessary.

7.9.2 Long-term safety

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. Long-term safety is based on technical release barriers built or installed separately and on the thick layer of rock, impeding any entry by humans and slowing down the release of radioactive substances. The technical release barriers differ according to the types of waste. In respect of low and intermediate-level waste, they are largely concrete structures. The premise in depositing nuclear waste in bedrock is that monitoring is no longer necessary after closure.

Requirements for long-term safety and its proof are provided in the Nuclear Energy Act and Decree, the STUK Regulation concerning the safety of the final disposal of nuclear waste (Y/4/2018) and in the YVL Guides (primarily in YVL Guide D.5). YVL Guide D.5, published by STUK, also sets radioisotope-specific emission limits for the final disposal of nuclear waste, applicable after extremely long periods, i.e. after several thousands of years.

The long-term safety of final disposal is presented as a long-term safety case which, according to the internationally adopted definition, means all the technical and scientific data, analyses, observations, trials and tests, and other evidence used as grounds for the reliability of the assessments made of the safety of the final disposal.

The long-term safety case defines what is referred to as the long-term safety concept, the cornerstones of which are the adequate prevention and deceleration of the release and transport of the radioactive materials in the waste, and the isolation of the waste from the surface environment. The safety concept is implemented with the help of what are referred to as the safety functions of long-term safety, shown in Figure 7-8.

The long-term safety case (Nummi 2019) assesses the functionality of various release barriers (i.e. their capacity to limit and delay the release of radioactive substances and their migration to the surface environment) and the entire final disposal system's development over a period of 100,000 years. Various developments have been modelled as scenarios. The long-term safety case also reviews the impact that various rare events such as earthquakes would have on the release of radioactive substances. The main sections of the long-term safety case are as follows:

- a description of the development of the final disposal system and the design basis;
- a performance analysis and preparation of scenarios;
- an emission and dose analysis;
- a summary.

The release of radioactive substances from waste is extremely slow. The waste is placed in facilities quarried to a depth of more than 100 metres inside release barriers made primarily from reinforced concrete which, with the stable state of the waste, considerably limits the release of radioactive substances for several hundreds and even thousands of years, reducing the radioactivity of the waste to a fraction of the original.

In addition to the technical release barriers, the bedrock surrounding the final disposal facility further limits the release of radioactive materials to ground level. Even over a long period, only a small amount of the radioactive substances contained by the waste can end up on the surface. These phenomena are covered in the long term safety case by describing and modelling the long-term trend of waste and the technical release barriers, including the release of

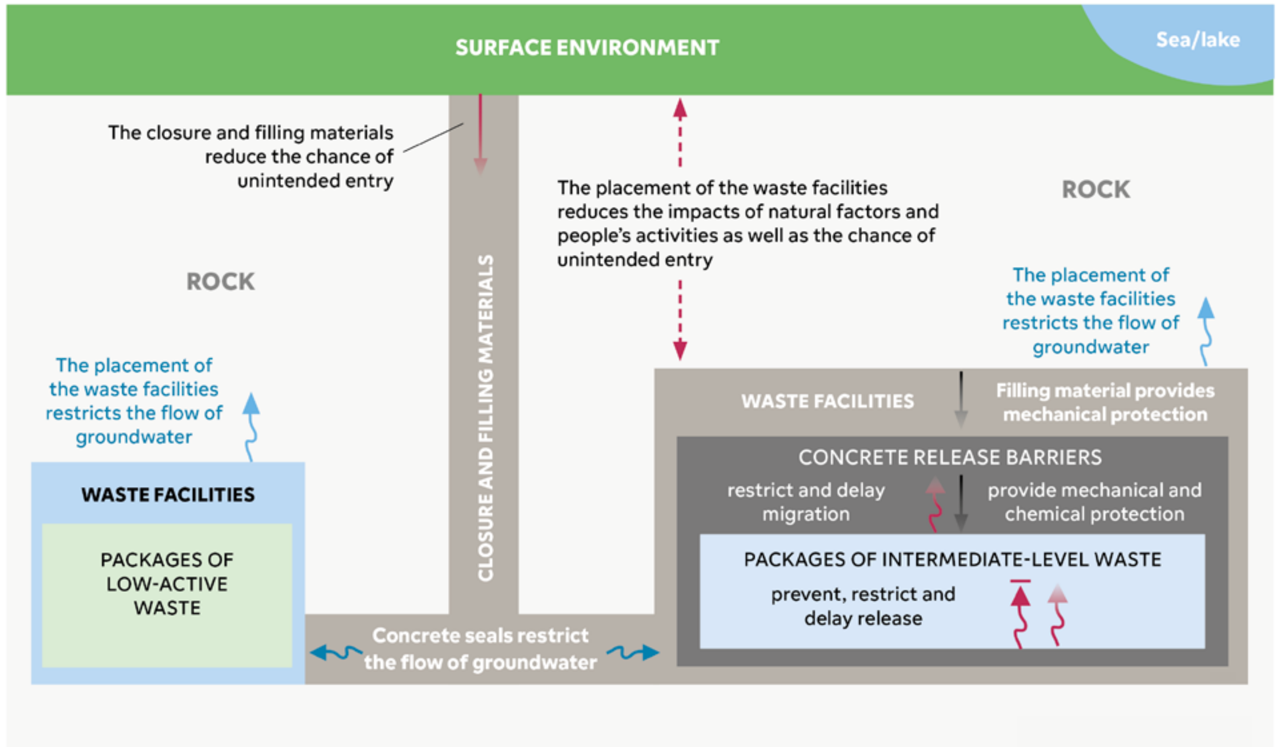

Figure 7-8. Diagram of the safety functions of long-term safety determined for the different components of Loviisa's final disposal (Nummi 2019, edited).

radioactive isotopes from the waste, their interaction with the release barriers, migration with the flow of groundwater and through diffusion, among other factors, and further in the food chains above the ground and in waterways.

A large portion of the radioactivity of operational waste is in intermediate-level waste. The most important technical release barriers for intermediate-level operational waste are a waste container made from reinforced concrete, in which the waste is solidified with cement and blend components, and a reinforced concrete basin, in which the waste packages will be placed, after which the spaces between the waste packages will be filled with concrete. This transforms the final disposal basin into a massive solid block of concrete, the deterioration of which in the final disposal conditions is very slow, given that the conditions are stable, and the concrete structures are not subject to such above-ground deteriorating mechanisms as carbonation or frost attack, for example. Closing the waste facilities with reinforced concrete seals contributes to the deceleration of the mechanisms by restricting the flow of groundwater through the waste facilities. The radioactivity of low-level waste is so low that the closure of the waste facilities, coupled with the rock above them, is enough to isolate the waste from the surface environment.

The technical release barriers for decommissioning waste are basically similar to those of operational waste, the significant difference being that most of the radioactivity of decommissioning waste is in activated steel parts, i.e. steel parts that have become radioactive due to the effects of neutron radiation. In such cases, the radioactivity is released from the waste only when the steel parts in question corrode. The corrosion of steel in final disposal conditions is extremely slow, given that soon after closure, the conditions of the final disposal facility turn anoxic (anaerobic), and the concrete release barriers retain the facility's high pH. Thanks to both these factors and the final disposal facility's relatively low temperature (roughly 10 °C), corrosion is slow.

7.9.3 Radioactive waste generated elsewhere in Finland

Regarding radioactive waste generated in Finland outside Loviisa power plant, the long-term safety impacts of the decommissioning waste of VTT's FiR 1 research reactor and the Otakaari 3 research lab have been reviewed in a separate safety analysis. The final disposal of all waste generated elsewhere is planned, and its impact will be reviewed more carefully when the subject matter becomes topical. More precise data on the waste's properties will also then be available, allowing for a more accurate review of long-term safety, and when necessary, supporting it with the design solutions of the waste packaging, for example.

In principle, the handling and final disposal of radioactive waste generated elsewhere in Finland complies with Loviisa power plant's established practices, procedures and instructions, which ensure both the personnel's radiation protection and the long-term safety of the waste's final disposal. These practices include a review of the long-term safety impacts of any new types of waste.

8. Environmental impact assessment procedure

8.1 STARTING POINTS

The purpose of the EIA procedure is to promote the assessment and consideration of environmental impacts as early as during a project's planning stage, and to increase access to information and opportunities to participate in the planning. The EIA procedure is carried out before the permit procedure, and its purpose is to influence the planning of the project and decision-making. The authority may not grant permission for the project implementation until it has received the assessment report and the coordinating authority's reasoned conclusion as well as the documents concerning the international hearing related to transboundary impacts.

Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (the EIA Directive) has been implemented in Finland by means of the Act on the Environmental Impact Assessment Procedure (the EIA Act, 252/2017) and the Government Decree on the Environmental Impact Assessment Procedure (the EIA Decree, 277/2017). The first EIA Directive dates back to 1985 (85/337/EEC), and took effect in Finland in 1995. The Directive has been amended on several occasions, as have the EIA Act and EIA Decree.

Appendix 1 of the EIA Act lists the projects subject to an EIA procedure. Pursuant to point 7b of the list of projects, an assessment procedure in accordance with the EIA Act applies to nuclear power plants and other nuclear reactors, including the dismantling or decommissioning of these facilities or reactors. In addition, according to point 7d, the EIA procedure is applied to facilities which have been designed for, among other things, the handling of spent nuclear fuel or high-level waste, the final disposal of nuclear waste or other radioactive waste, or for the long-term storage of spent nuclear fuel, other nuclear waste or other radioactive waste elsewhere than its production location.

8.2 PARTIES

The parties to the EIA Procedure in this project are shown in Table 8-1. The experts who participated in the preparation of the EIA report are presented in Appendix 1.

Table 8-1. Parties to the EIA Procedure.

	Parties
Project owner	Fortum Power and Heat Oy (the operator responsible for the preparation and implementation of the project)
Coordinating authority	The MEAE (responsible for ensuring that the project's environmental impact assessment procedure is organised in accordance with the EIA legislation)
EIA consultant	Ramboll Finland Oy (in charge of the preparation of the EIA programme and report in accordance with the EIA legislation)
Other parties	• The Ministry of the Environment (arranges the international hearing) and the participant countries in the international hearing • Town of Loviisa and local stakeholders • Other authorities and experts that the coordinating authority consults for statement • The EIA procedure audit group • Other parties whose conditions or interests the project may impact, including the public • Media

8.3 STAGES AND CONTENTS

The EIA procedure has two stages. Both stages include the production of a report, these reports being the Environmental Impact Assessment Programme (EIA Programme) and the Environmental Impact Assessment Report (EIA Report). In addition, this project involves what is referred to as an international hearing, which is conducted alongside the EIA procedure (Chapter 8.3.3). Figure 8-1 shows a summary of the EIA procedure's stages in Finland and how the international hearing is linked to it.

8.3.1 EIA Programme

The Environmental Impact Assessment Programme is drawn up during the first stage of the EIA procedure. The programme presents a plan for the arrangement of the environmental impact assessment procedure and the required studies. According to the EIA Decree, the assessment programme must, to a sufficient extent, include the following:

- a description of the project, its purpose, planning stage and location;
- reasonable options for the project, one of which is not to implement the project;
- information about the plans, licences and decisions required by the implementation of the project;
- a description of the present state of the environment in the affected area, the planned or completed studies, the methods to apply and assumptions;
- a plan for organising the EIA procedure and participation;
- the schedule.

The EIA procedure of this project commenced on 13 August 2020, when the project owner submitted the EIA Programme to the coordinating authority. The coordinating authority made an announcement on the project's EIA procedure on 27 August 2020, and the EIA Programme was made available to the public for statements and opinions between 27 August and 26 October 2020. The coordinating authority then collated the statements and opinions, and gave its own statement on the EIA Programme on 23 November 2020. The international hearing was conducted at the same time (Chapter 8.3.3).

8.3.2 EIA Report

The actual environmental impact assessment is carried out during the second stage of the EIA procedure, based on the EIA Programme and the statement issued on it by the coordinating authority. The results of the assessment are collected in the EIA Report, which is submitted to the coordinating authority. According to the EIA Decree, the EIA Report must include the following information to the extent required:

- A description of the project and its purpose, location, size, land use requirement and key characteristics, accounting for the various phases of the project and exceptional situations.
- Information on the project owner; the project's planning and implementation schedule; the plans, permits and equivalent decisions required by the implementation as well as the project's involvement with other projects.
- An account of the project's and its options' relationship with land use plans, and any plans and programmes pertaining to the use of natural resources and environmental protection that are materially relevant to the project.
- A description of the present state of the environment in the affected area and its probable development if the project is not implemented.
- An assessment and description of the potentially significant environmental impact of the project and its reasonable options, and a description of any transboundary environmental impact. The assessment and description of potentially significant environmental impacts must cover the project's direct and indirect, accumulative, short, medium- and long-term, permanent and temporary, positive and negative effects, as well as its joint effects with other existing and approved projects.
- An assessment of possible accidents and their consequences, and of the preparedness for such events, including preventive and mitigation measures.
- A comparison of the options' environmental impact.
- Details on the principal reasons that led to the selection of the selected option or options, including the environmental impact.
- A proposal on measures for avoiding, preventing, confining or eliminating any identified significant harmful environmental impact.
- A proposal on any monitoring arrangements related to significant adverse environmental impacts.
- An account of the stages of the assessment procedure, including participation procedures, and their connection with the project's planning.
- A list of the sources used to draw up the descriptions and assessments included in the report.
- A description of the methods used in identifying, projecting and assessing significant environmental impacts, and information on any shortcomings and key uncertainties observed when collecting the required information.
- Details on the qualifications of those who draw up the assessment report.
- An account of how the coordinating authority's statement on the assessment programme has been accounted for.

Similarly to the EIA Programme, the coordinating authority makes the EIA Report available for public viewing for a period that, in this project, has been agreed with the coordinating authority to last for 60 days. An international hearing will also be held during the EIA Report stage (Chapter 8.3.3). 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 should be considered in the subsequent licensing processes. The assessment report and the reasoned conclusion by the coordinating authority are appended to the licensing application documents.

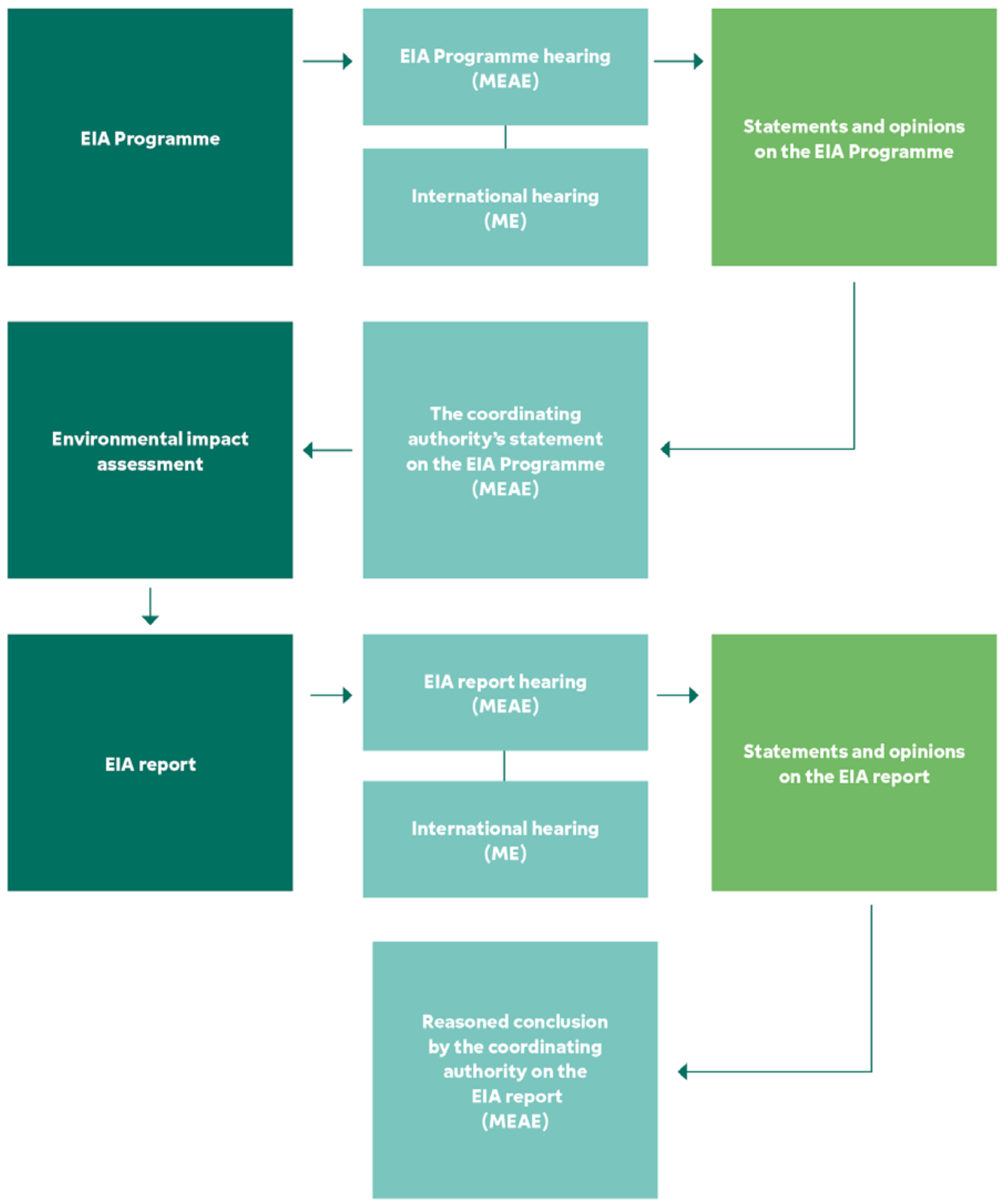

Figure 8-1. The stages of the EIA procedure. MEAE = Ministry of Economic Affairs and Employment, ME = Ministry of the Environment.

8.3.3 International hearing

The principles of international cooperation in the environmental impact assessment have been defined in the UN's Convention on Environmental Impact Assessment in a Transboundary Context (SopS 67/1997, the Espoo Convention). The Espoo Convention lays down the general obligations for organising a hearing for the authorities and citizens of the member states in all projects that are likely to have significant adverse transboundary environmental impacts. The EIA Directive also includes provisions on communications related to the project, and further requires that a member state must be able to participate, at its request, in the assessment procedure of another member state. In addition to the EIA Directive, the rights of the public to participate and their right of appeal are also regulated internationally by the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (SopS 121—-122/2004, the Aarhus Convention).

Among other things, the objectives of the Aarhus Convention include enabling the public to participate in environmental decision-making. The Aarhus Convention has been implemented in the EU by means of several directives, including the EIA Directive.

The obligations concerning the hearing included in the Espoo Convention, the EIA Directive and the Aarhus Convention have been implemented in Finland through the EIA Act and the EIA Decree, for example. The coordinating authority in the international hearing of the EIA procedure in Finland is the Ministry of the Environment.

In terms of this project, the Ministry of the Environment notified, during the EIA Programme stage, the environmental authorities of the neighbouring countries about the commencement of the EIA procedure and enquired about their desire to participate in it. A document summarising the EIA Programme, translated into the language of the relevant country, and the EIA Programme translated into Swedish or English, were appended to the notification. In the international hearing pursuant to the Espoo Convention, Sweden, Estonia, Russia, Norway, Denmark, Lithuania, Germany and Austria indicated their intention to participate in the project's EIA procedure. Latvia and Poland did not consider themselves affected parties and therefore did not participate in the EIA procedure. All other parties to the Espoo Convention were furthermore notified of the project's EIA procedure. Of these parties, Austria and the Netherlands indicated their desire to be provided with a notification pursuant to the Espoo Convention, which was delivered to them. The Finnish Ministry of the Environment submitted the feedback it received from the affected states to the coordinating authority (MEAE) for consideration in the coordinating authority's statement concerning the EIA Programme.

A corresponding international hearing procedure will also be arranged during the EIA Report stage for those affected parties which have indicated their participation in the EIA procedure.

8.4 SCHEDULE OF THE EIA PROCEDURE

The key stages and tentative schedule of the EIA procedure are illustrated in Figure 8-2. The EIA Procedure concludes once the coordinating authority has given its reasoned conclusion on the EIA Report.

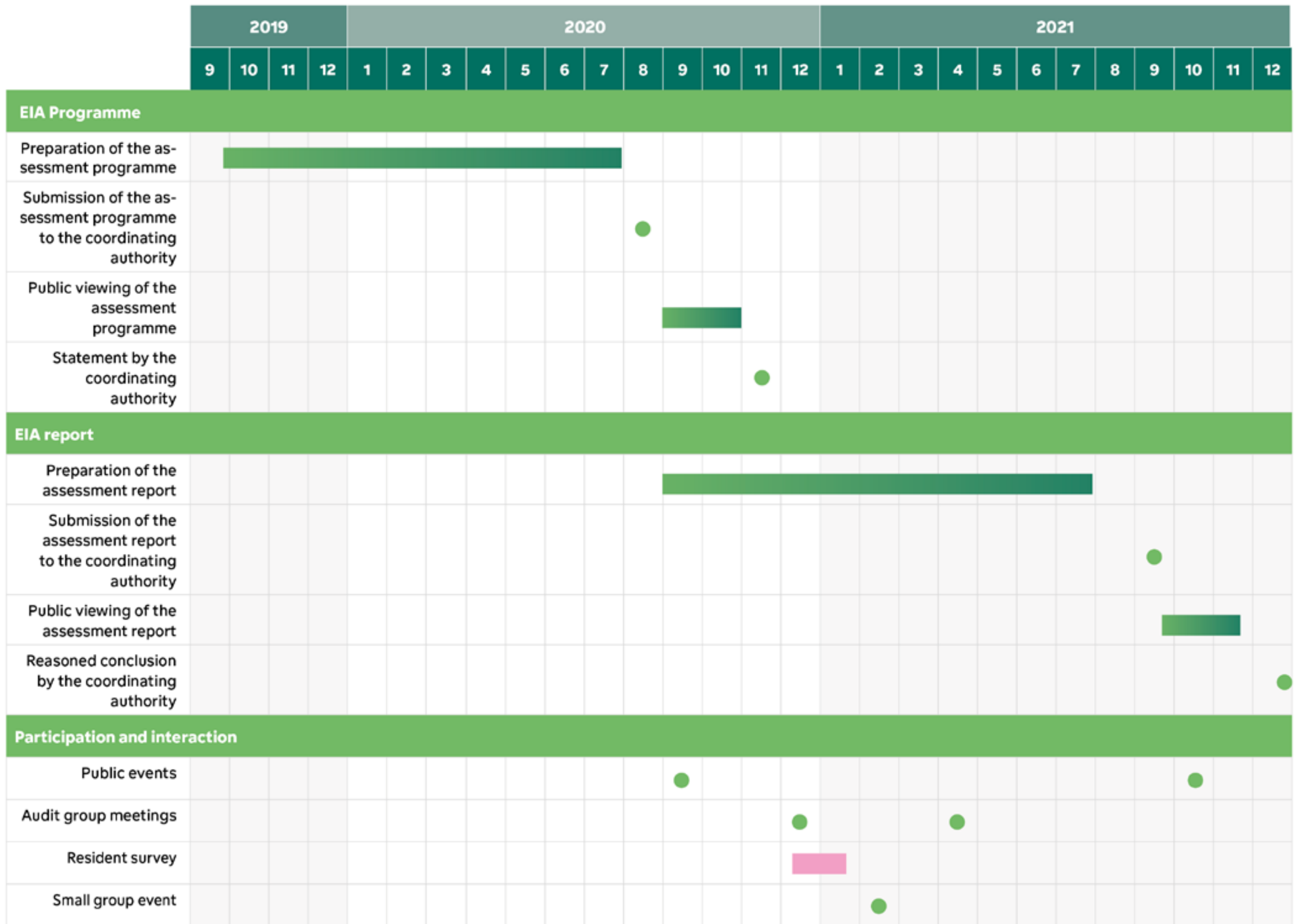

Figure 8-2. Indicative schedule of the EIA procedure.

8.5 PARTICIPATION AND INTERACTION

The EIA procedure is interactive and enables different parties to discuss and express their opinion about the project and its impacts. One of the key objectives of the EIA procedure is to promote communication about the project and improve opportunities for participating in its planning. Participation allows for the different stakeholders to express their views.

Everyone whose conditions and interests – including housing, work, transport, leisure activities and other living conditions – may be affected by the project to be implemented can participate in the environmental impact assessment procedure. In accordance with EIA legislation, citizens can submit their opinions on an EIA programme and report to the coordinating authority during the period that these are available for viewing.

The EIA procedure's interaction plan covers the project's communication, acquisition of information from the different parties, dialogue events open to all and cooperation between different stakeholders.

8.5.1 Pre-negotiation

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 objective of the pre-negotiations was to promote the overall management of the assessment, planning and licensing procedures required in the project, and the information exchange between the project owner and the authorities. They also aimed to improve the quality and usability of surveys and documents, and streamline the procedures.

8.5.2 Public events in the EIA procedure

The EIA procedure's public events enable citizens to express their views on the project and the impacts to be assessed, and to receive more information.

Following the completion of the EIA Programme, a public event on the project and EIA procedure was held at a local school (Lovisavikens skola) on 3 September 2020. Due to the restrictions related to the coronavirus pandemic, the possibility of attending the event via live streaming was also arranged.

Another public event will also be held once the EIA Report has been completed and announced. The details of this event will be given in the announcement concerning the EIA Report.

8.5.3 Audit group

An audit group was set up for the assessment procedure with the purpose of promoting the flow and exchange of information between the project owner, the authorities and the key stakeholders in the area whilst drawing up the EIA Report. The following parties were invited to the audit group:

- Ministry of Economic Affairs and Employment
- Radiation and Nuclear Safety Authority
- Ministry of the Environment
- Uusimaa Centre for Economic Development, Transport and the Environment
- Southwest Finland ELY Centre, fisheries authority
- Regional State Administrative Agency for Southern Finland
- Town of Loviisa (the town's management, housing and environment, social welfare and healthcare services, economic affairs and employment)
- Municipality of Pyhtää
- Municipality of Lapinjärvi
- Helsinki-Uusimaa Regional Council
- Regional Council of Kymenlaakso
- Eastern-Uusimaa Emergency Services Department
- Eastern Uusimaa Police Department
- Finnish Safety and Chemicals Agency
- Posiva Oy
- VTT Technical Research Centre of Finland Ltd.
- Loviisan Vesiliikelaitos
- Posintra Oy
- Cursor Oy
- Lovisa skärgårds fiskeriområde
- Loviisan Smoltti
- Itä-Uudenmaan luonnon- ja ympäristönsuojeluyhdistys
- Natur och miljö.

Representatives of the project owner and the EIA consultant also participate in the audit group's work. The audit group convened for the first time on 17 December 2020 and for the second time on 14 April 2021.

8.5.4 Resident survey

A resident survey was conducted during the EIA Report stage to study the area's residents' attitudes toward the project. The resident survey material also served as data for the impact assessment. Further information about the resident survey and its results is available in Chapter 9.19.

8.5.5 Small group event

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. A link provided in connection with the resident survey allowed people to sign up for the event. Further information on the event is provided in Chapter 9.19.

8.5.6 Information and communication

The EIA Programme and EIA Report was published on the website of the Ministry of Economic Affairs and Employment. The documents were available for viewing in accordance with the announcement made by the coordinating authority. 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.

8.6 COORDINATING AUTHORITY'S STATEMENT ON THE EIA PROGRAMME AND CONSIDERATION THEREOF

The Ministry of Economic Affairs and Employment requested the following parties to submit a statement on the EIA Programme:

- Ministry of the Environment
- Ministry of the Interior
- Ministry for Foreign Affairs
- Ministry of Defence
- Ministry of Agriculture and Forestry
- Ministry of Transport and Communications
- Ministry of Social Affairs and Health
- Ministry of Finance
- Radiation and Nuclear Safety Authority
- Advisory Committee on Nuclear Safety
- Regional State Administrative Agency for Southern Finland
- The Uusimaa Centre for Economic Development, Transport and the Environment
- Helsinki-Uusimaa Regional Council
- Finnish Safety and Chemicals Agency
- Finnish Environment Institute (SYKE)
- Eastern Uusimaa Emergency Services Department
- Eastern Uusimaa Police Department
- Town of Loviisa
- Municipality of Pyhtää
- Town of Porvoo
- Municipality of Lapinjärvi
- Municipality of Myrskylä
- City of Kouvola
- Akava – Confederation of Unions for Professional and Managerial Staff in Finland
- Confederation of Finnish Industries
- Finnish Energy Industries
- Geological Survey of Finland
- Greenpeace
- Fennovoima Oy
- Fingrid Oyj
- Central Union of Agricultural Producers and Forest Owners
- The Finnish Heritage Agency
- Porvoon museo
- Natur och Miljö rf
- Posiva Oy
- VTT Technical Research Centre of Finland Ltd.
- Teollisuuden Voima Oyj (TVO)
- The Finnish Confederation of Professionals (STTK)
- Finnish Association for Nature Conservation (FANC)
- Suomen yrittäjät ry
- Central Organisation of Finnish Trade Unions
- WWF Finland.

The coordinating authority received a total of 39 statements and opinions in the EIA Programme's national hearing. A total of 20 statements submitted by EU citizens and organisations was also received. The statements and opinions can be found in full on the website of the Ministry of Economic Affairs and Employment.

The Ministry of Economic Affairs and Employment gave its statement on the project's EIA Programme on 23 November 2020 (Appendix 2). In its statement, the Ministry of Economic Affairs and Employment states that the Environmental Impact Assessment Programme meets the content requirements pursuant to section 3 of the EIA Decree.

The table in Appendix 3 shows a summary of the main points to which attention, according to the coordinating authority's statement, should be paid during the impact assessment work, or which should be supplemented when drawing up the assessment report. The table also shows how the statement was accounted for when preparing this EIA Report.

8.7 STATEMENT AND OPINIONS ON THE EIA PROGRAMME

In its own statement on the EIA Programme, the coordinating authority considers the statements and opinions received in a collated form (including statements requested by the coordinating authority, statements submitted in the international hearing, and other statements and opinions). Key comments, as well as questions presented in the statements and opinions and the responses to them, are provided in Appendix 3.

8.8 CONSIDERATION OF THE EIA PROCEDURE IN PLANNING AND DECISION-MAKING

While the project will be planned at the same time as the environmental impacts are being assessed, the planning will be continued and specified after the assessment procedure as part of the licensing and other processes. Various phases of the planning, licensing procedure and implementation aim to account for the mitigation and prevention of the environmental impacts as efficiently as possible.

The EIA Report and the coordinating authority's reasoned conclusion on it will be appended to the licence and permit applications pertaining to the project, used by the licensing authorities in their decision-making. The issues raised in the reasoned conclusion will be accounted for in the coming licensing phases. The licences, permits, plans and decisions required by the project are described in Chapter 12.

9. Environmental impact assessment

9.1 PREMISE OF THE ASSESSMENT

9.1.1 Impacts to be assessed

The purpose of this environmental impact assessment is to assess the environmental impact of the project under review in the manner and accuracy required by the EIA Act and 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. The results of the environmental impact assessment work per each impact are presented in Chapters 9.2–9.24.

The following matters, as applicable, have been addressed in connection with the various parts of the impact assessment:

- the principal results of the assessment;
- the baseline data and assessment methods;
- the present state of the environment;
- the environmental impact of extended operation;
- the environmental impact of decommissioning;
- the environmental impact of the handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland;
- a comparison of the options and an assessment of the impacts' significance;
- measures to prevent and mitigate adverse impacts;
- any uncertainties related to the assessment.

The structure of the Chapters concerning incidents and accidents (9.20 and 9.21) differs slightly from what is described above.

9.1.2 Timing and review of impacts

The options reviewed in the EIA Procedure are described in Chapter 2. The impact assessment in Chapter 9 includes a review of the operational phases involved in the options. These operational phases are the extension of operations, decommissioning, and the reception of radioactive waste generated elsewhere in Finland. Chapter 10 contains a comparison of the options, composed of different operational phases.

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 is part of Options VE1 and VE0+, and has been reviewed as a separate function.

The operational phase of extended operation extends until approximately 2050. The 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.

The impact assessment in Chapter 9 is divided into the following operational phases:

Extended operation

Extending the operation of Loviisa power plant by a maximum of approximately 20 years after the current operating licence period (2027/2030). The review extends until roughly 2050.

During the extended operation, the operation of the power plant will be similar to its current operation. The potential modifications to be carried out in the power plant area include:

- additional construction in the area;
- the power plant's service water and wastewater arrangements;
- increasing the capacity of or expanding the interim storage for spent fuel.

The impact assessment examines the environmental impact of the operations related to extended operation, and any changes they may cause. The assessment work focuses particularly on any impacts that will change in terms of or differ from the impacts of current operation, and result from the additional years of operation.

Decommissioning

The operational phase involves a review of Loviisa nuclear power plant's decommissioning. The impact assessment focuses particularly on examining the environmental impacts of the following phases related to decommissioning:

- expansion of the L/ILW repository;
- dismantling phase 1;
- the operation of the plant parts to be made independent;
- dismantling phase 2;
- the closure of the L/ILW repository.

The L/ILW repository will remain in operation continuously until its closure.

The assessment concerning the environmental impact of decommissioning is 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). The review also covers the environmental impact related to the dismantling of plants parts and the handling of waste that is not radioactive, and the power plant area's further use (the greenfield principle). The assessment work focuses particularly on any impacts that will change in terms of or differ from the impacts of current operation.

Radioactive waste generated elsewhere in Finland

The operational phase covers the handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland within Loviisa power plant area.

9.1.3 Power plant area and impact area

In this environmental impact assessment, the power plant area refers to the Hästholmen area, which is the location of the current operations of the power plant and the changes planned for them in the project (Figure 1-5).

The confinement of the environmental impacts within the power plant area or their reach beyond it describes the actual impact area. It varies according to impact. The results of the environmental impact assessment, including impact areas, are described in Chapters 9.2-9.24. The sizes of the areas to be observed in terms of environmental impact, specified in connection with the impact assessment, are sufficiently large to rule out any assumption of significant environmental impacts occurring outside the observed areas.

9.1.4 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 to the present state of the environment caused by the project, an option of the project or a related function. The environmental impacts may be either negative or positive, or neutral, in that no changes at all to the present state can be observed.

In this EIA Report, "present state" refers to the current status of the power plant area's environment, within which the power plant operates. 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 assessment of each impact progresses systematically as follows:

1. identifying the origin of the impact, and describing the baseline data and methods used in the assessment;
2. describing the present state of the aspect affected, and based on this, assessing its sensitivity, i.e. capacity to absorb the impact observed;
3. describing the environmental impacts and the magnitude of the change in which they result;
4. assessing the impact's significance on the basis of the affected aspect's sensitivity and the magnitude of the change concerned and drawing conclusions on the significant impacts;
5. comparing the different options and identifying the differences between them from the perspective of feasibility;
6. presenting the potentially necessary measures for mitigating the adverse impacts;
7. reviewing the uncertainties that affect the impact assessment.

An **impact** is a change to the environment caused by a planned function.

The **change** is assessed in relation to its scope, duration or intensity.

Sensitivity of affected aspect

The sensitivity of the affected aspect refers to the environment's capacity to absorb changes. The sensitivity is determined on the basis of the characteristics and present state of the aspect or area concerned. The characteristics may include current traffic conditions; the present state of noise and air quality; or the natural, landscape or recreational value of the area concerned.

The affected aspect's sensitivity to change describes its capacity to absorb, endure or tolerate the changes caused by the project. A recreational area is usually more sensitive to change than an industrial area, for example. Sensitivity is also influenced by whether the area is protected by law, or whether the impact is subject to specified guideline values, norms or recommendations (such as noise guidelines or environmental quality norms). When the impact concerns people, the number and experience of the aspect's users or experiencers is also taken into account.

The sensitivity of the affected aspect is assessed on a four-step scale: minor, moderate, high or very high sensitivity; and it is based on the present state of the environment. The properties influencing the affected aspect's sensitivity and the assessment of sensitivity are presented at the end of the present state of each part of the assessment.

The sensitivity of the affected aspect describes the aspect's legal regulation, societal value and capacity to absorb the change caused by the project.

Magnitude of change

The magnitude of the change caused by the project is determined and assessed on the basis of several variables. An assessment of the magnitude of change accounts for its scope, duration and intensity. The direction of the change is also determined – i.e. whether the change is positive or negative. In terms of its geographic scope, the impact may be regional, local or extend beyond the borders of Finland. In terms of its temporal duration, the impact may be temporary, of a short or long term, or permanent. Other factors – such as the recurrence, time, cumulative nature and reversibility of the change – are also reviewed.

In some cases, the intensity of measurable changes can be modelled on the basis of the baseline data (the spread of cooling water, for example). An expert assessment is carried out to determine the intensity of the qualitative changes, and the subjectivity of this assessment will be reduced by presenting the baseline data on which it is based as transparently as possible. Several methods are used to acquire baseline data:

- monitoring data on existing operations;
- visits to and studies of the terrain;
- various modelling techniques (such as cooling water modelling);
- a survey of the affected aspects and areas with the aid of a geographical information system;
- the utilisation of literature, databases and research results;
- the use of participatory data acquisition methods (including questionnaires for residents, public events, events for small groups);
- the expertise and previous experience of the assessment team;
- the analysis of issues raised in statements and opinions.

The magnitude of the change is assessed on a four-step scale: a minor, moderate, considerable and major change. It is also possible for the project not to have an impact on the present state.

The **magnitude of the change** is influenced by, among other things, its geographical scope, temporal duration, intensity, recurrence, cumulative nature and reversibility.

Significance of impact

The significance of the impact (Figure 9-1) is determined by the affected aspect's capacity to tolerate the observed impact, i.e. its sensitivity, and the magnitude of the change.

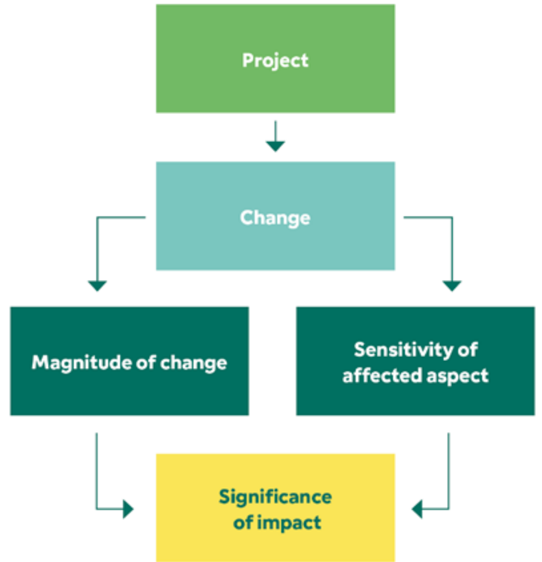

Figure 9-1. Factors affecting the significance of the impact.

Formation of impact's significance

Aspect's sensitivity \ Magnitude of change (Negative → Positive)	Very high	High	Moderate	Minor	No impact	Minor	Moderate	High	Very high
Minor	High*	Moderate	Minor	Minor	No impact	Minor	Minor	Moderate	High*
Moderate	High	High*	Moderate	Minor	No impact	Minor	Moderate	High*	High
High	Very high	High	High*	Moderate	No impact	Moderate	High*	High	Very high
Very high	Very high	Very high	High	High*	No impact	High*	High	Very high	Very high

*If the sensitivity or change is at the lower limit of the class, the significance can be deemed lesser

Signifinance of impact

Very high	High	Moderate	Minor	No impact	Minor	Moderate	High	Very high

Figure 9-2. The significance of the impact based on the aspect's sensitivity and the magnitude of the change.

The significance of the impact is determined by cross-tabulating the sensitivity of the affected aspect and the magnitude of the change in terms of the different options in connection with the assessment of each impact (Figure 9-2). 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.

9.1.5 Reports and other materials used in the assessment

The baseline data used in the EIA report's description of the present state of the environment and impact assessment are presented per impact in Chapters 9.2-9.24.

Environmental surveys and reviews have been carried out in the vicinity of the Loviisa power plant area since the 1960s. The preparation of the EIA report has relied on the reviews, studies and surveys conducted in the area (concerning, among other things, cooling waters and wastewaters, the sea area's nutrient load and currents, fishing, the population in the surrounding area, economic life, traffic, flora and fauna, as well as the radiation monitoring of the environment).

The following separate surveys have also been carried out to support the assessment and the existing data:

- survey of harmful substances in sediments;
- sub-bottom profiling of the seabed;
- cooling water modelling;
- avifauna survey;
- ichthyofauna surveys (test net fishing and fry research);
- assessment of the impacts on the regional economy;
- resident survey and small-group interviews;
- accident modelling and dose calculation.

9.2 LAND USE, LAND USE PLANNING AND THE BUILT ENVIRONMENT

9.2.1 Principal results of the assessment

In extended operation, the impacts on land use are similar to those in the current operation. Extending operation will continue to determine the land use of both the project area and the areas surrounding it in the decades to come. In terms of land use planning, the area's current activities and extended operation are in line with its land use planning. On the other hand, the impact area's land use planning accounts for the restrictions attributable to the operation of the nuclear power plant. The significance of the impacts has been deemed minor and negative, given that the area's land use restrictions will continue.

After decommissioning, the current impacts on the land use resulting from the operation will come to an end. Depending on the area's further use, the area or a part of it could be put to industrial use, for example. The area's further use may require changes to the land use plan. The removal of the precautionary action zone indicated in the land use plans would ease the restrictions on the planning of the surrounding land. The significance of the impacts is minor and positive.

The reception of radioactive waste generated elsewhere in Finland would not cause changes to the land use or require changes to the land use planning.

9.2.2 Baseline data and assessment methods

The impact assessment concerning the community structure and land use is based on a survey of the existing community structure and the land use planning situation. The assessment studied whether the changes related to the extension of the power plant's operation or its decommissioning affect the current and future land use in the vicinity. The baseline data used for this consisted of an analysis of the existing community structure, as well as the regional land use, and master and local detailed plans valid in the power plant area and its vicinity. The survey accounted for the national and regional goals, as well as any pending plan projects.

The assessment included a comparison of the area's current and planned land use. The perspective when reviewing the project's impacts and the significance of the impacts has been to assess to what extent the project would change the areas' present nature. The project's direct land use impacts concern primarily the power plant area and its immediate vicinity, but the impacts concerning land use also accounted for impacts on the nearest residential population. The result of the survey of land use plans was used to assess the project's impact on the fulfilment of the plans' goals and any needs to prepare or change plans. The impact assessment was carried out in the form of an expert assessment.

9.2.3 Present state

9.2.3.1 Community structure and population

Loviisa power plant is located on the island of Hästholmen in the village of Lappom, in Loviisa. The island is approximately 12 km from the centre of Loviisa and about 7 km southeast of the village of Valko. The island may be reached by a 200-metre causeway and bridge over the Kirmosund inlet. The island of Hästholmen is located outside the built-up area and in the areal division of the community structure, primarily in an uncategorised area. The mainland side and the farthest north-western parts of the island of Hästholmen are sparsely populated rural areas (Figure 9-3).

Fortum owns the island of Hästholmen and the southern edge of the peninsula north of the island – a total land area of approximately 170 hectares, and about 240 hectares of water areas in the vicinity of the power plant (Figure 9-4). The power plant area borders both publicly (the government, town of Loviisa) and privately owned land. The areas owned by private citizens are primarily used for recreation, while the government's areas are conservation sites.

The power plant structures and buildings are located in the northern and eastern parts of the island of Hästholmen. Approximately half of the area of the island of Hästholmen is being used for the power plant operation. There are structures related to the intake and discharge of cooling water and power transmission on the island's waterfront areas. The buildings and structures needed for the power plant's support operations (including security and the temporary accommodation for annual outage employees) are on the mainland. The Oy Loviisan Smoltti Ab fish farm, which raises fry, is located north of the power plant area on the island of Hästholmen. The fish farm uses cooling water that has been warmed in Loviisa power plant's condensers. Stenören and Vastaholmen, the fish farms of Oy Semilax Ab, are located immediately south of the island of Hästholmen. There is no other industry in the vicinity.

There is a precautionary action zone extending to a distance of five kilometres from the nuclear power plant, where land use restrictions are in force (STUK Y/2/2018). The precautionary action zone may not contain, for example, facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities, shops, or significant places of employment or accommodation that are not related to the nuclear power plant (YVL A.2).

The closest residential buildings shown on the map (Figure 9-3) are located at a distance of approximately 800 metres northwest of the power plant. These buildings are residential buildings that belong to the power plant's accommodation area and are not permanently inhabited. The closest residential buildings in private use are located in Bodängen, at a distance of roughly 900 metres from the power plant area. The secondary

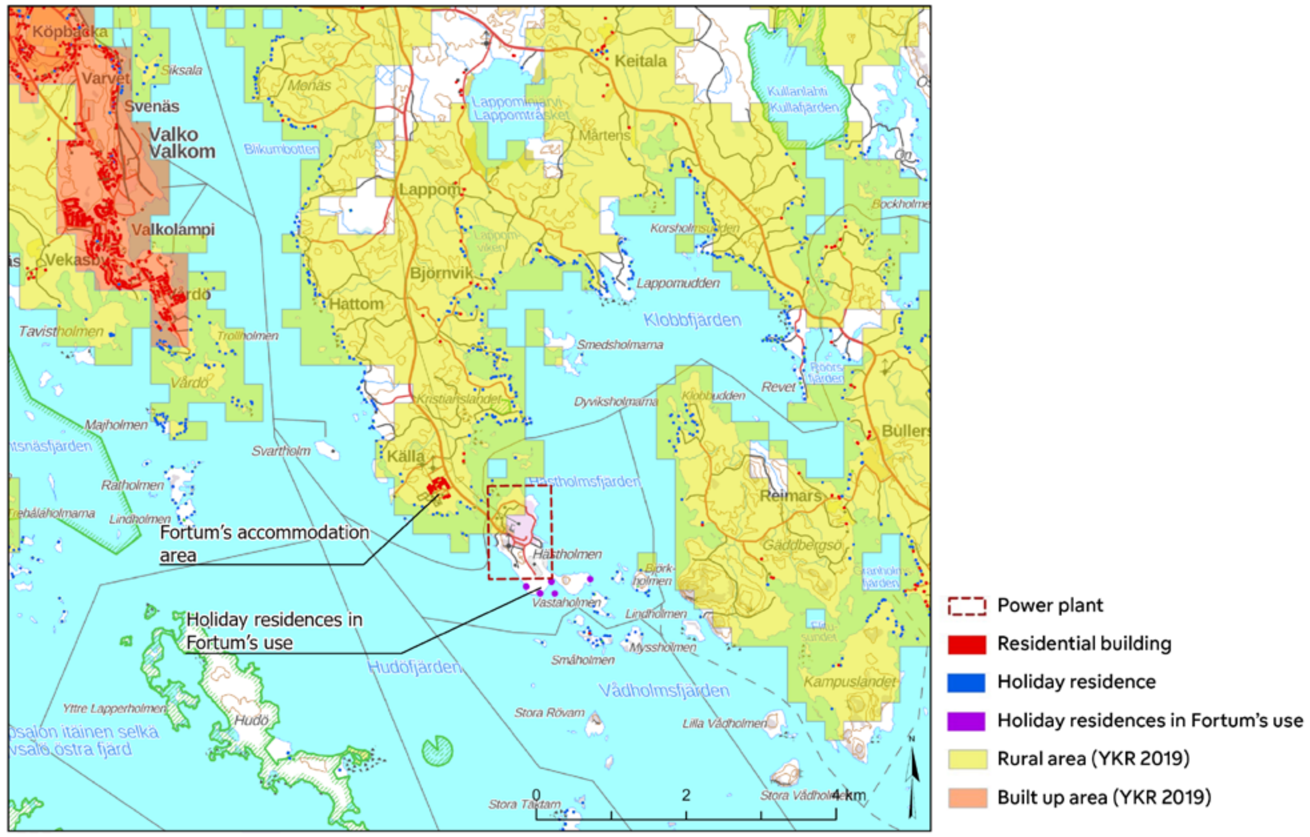

Figure 9-3. The community structure in accordance with the community structure monitoring data (YKR data, SYKE 2021) in 2019, as well as the residential and holiday buildings.

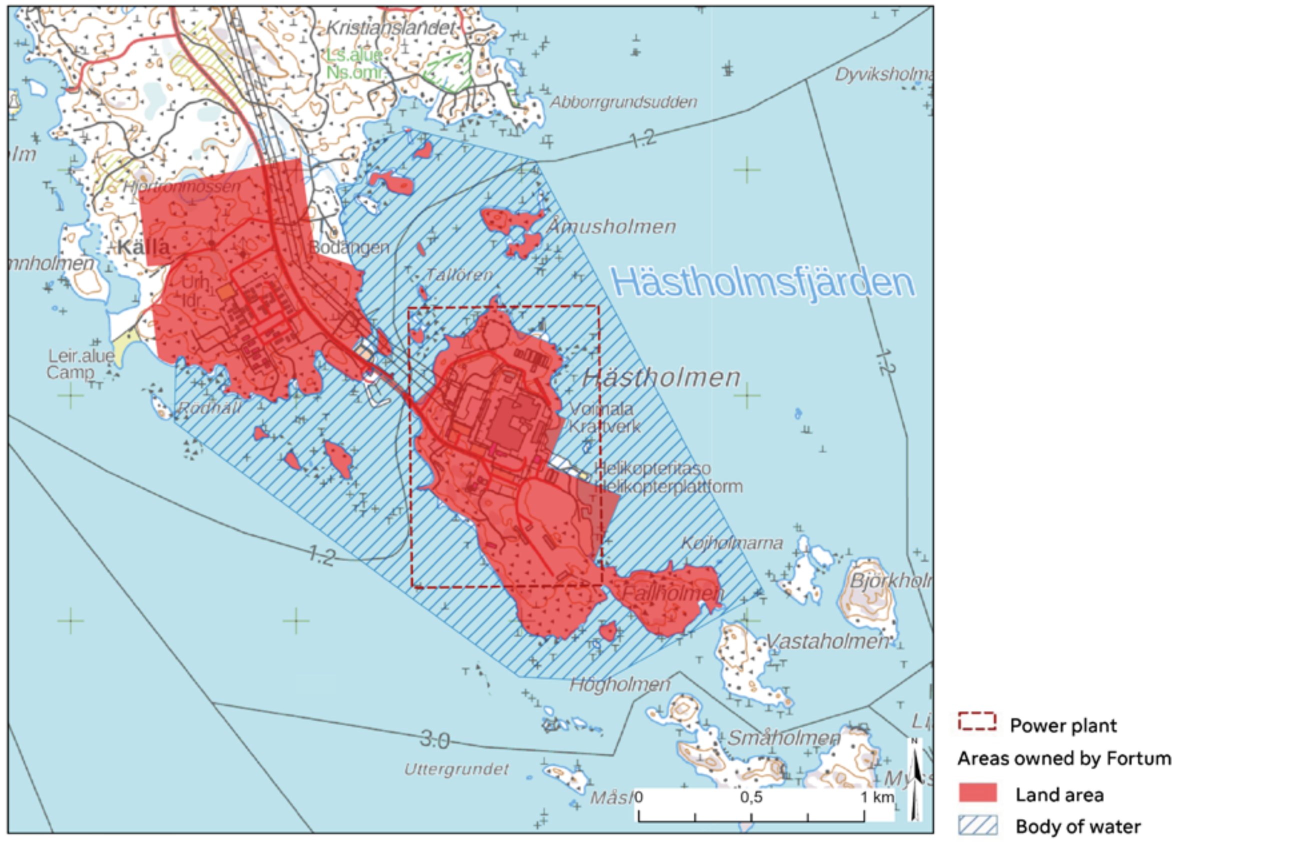

Figure 9-4. Land and water areas owned by Fortum Power and Heat Oy (National Land Survey of Finland 2021 and Fortum 2021).

residences closest to the power plant area shown on the map (Figure 9-4) and located on the southern shore of Hästholmen and the eastern and southern sides of the support operations area on the mainland are owned by Fortum. The other closest secondary homes are located on the islands to the south and southeast of Hästholmen (Vastaholmen, Småholmen, Måsholmen, Högholmen, Myssholmen, Björkholmen and Kojholmarna), and on the mainland, no closer than 1.3 km from the power plant.

The closest recreational areas are the Källa camp area, located at a distance of a little more than a kilometre west of the power plant, and the Svartholma fortress, a little more than two kilometres northwest of the power plant. Svartholma is a popular tourist attraction accessible by a regular service vessel or private boats (nationalparks.fi 2021, Visit Loviisa 2021). The island also has a restaurant, open in the summer. Islands in the impact area are also used for recreation, hiking and camping.

On the map (Figure 9-3), a built-up area (red areas) refers to a densely populated area with a minimum of 200 residents, in which the number, floor area and concentration of the buildings, in addition to the number of inhabitants, have been considered. The areas which have at least one inhabited building within a radius of one kilometre but which are not included in the built-up areas, villages and small villages, belong to the sparsely populated rural area. The project environment does not include villages in accordance with the community structure monitoring data (SYKE 2021; Figure 9-3).

9.2.3.2 National Land Use Guidelines

The National Land Use Guidelines are part of the system of land use planning pursuant to the Land Use and Building Act. The government decided on the revised National Land Use Guidelines on 14 December 2017, and the new guidelines took effect on 1 April 2018. The guidelines for land use aim, among other things, to facilitate the achievement of the objectives of the Land Use and Building Act, as well as land use planning, the most important of which are a favourable living environment and sustainable development. According to the Land Use and Building Act, the objectives must be taken into account and their implementation must be promoted in regional planning, municipal land use planning and the actions of government authorities.

The revised National Land Use Guidelines concern the following matters:

- functioning communities and sustainable traffic;
- efficient transport systems;
- healthy and safe environment;
- a viable natural and cultural environment and natural resources;
- an energy supply capable of renewal.

9.2.3.3 Regional land use plan

The power plant area is located in the area of the Helsinki-Uusimaa Land Use Plan 2050 (Helsinki-Uusimaa Regional Council 2020a). The Assembly of the Regional Council approved the Land Use Plan on 25 August 2020, and the Board of the Regional Council decided on its entry into force on 7 December 2020. The plans enter into force once the decision has been publicised in the municipalities of the region pursuant to section 93 of the Land Use and Building Decree. However, in its provisional decision of 22 January 2021, Helsinki Administrative Court, as the appeals authority, prohibited the enforcement of the Assembly's approval decisions due to complaints filed in relation to the plans. Because of the prohibition, the regional land use plans will not be valid before the Administrative Court's actual decision settles the matter. The complaints filed in relation to the plans do not pertain to the plan notations concerning the nuclear power plant or matters which could have a material impact on the project.

The Helsinki-Uusimaa Land Use Plan 2050 supersedes all effective and legally valid regional land use plans. An exception to this is the wind power solution presented in the Phased Regional Land Use Plan for Uusimaa 4, which designates four areas suitable for the production of wind power in Eastern Uusimaa. In addition, a separate regional land use plan is being prepared for the Östersundom area. Figure 9-5 shows an extract of the plan map of the Helsinki-Uusimaa Land Use Plan 2050.

The plan solution concerning nuclear power plants and their precautionary action zones of the regional land use plans for Uusimaa was updated in the Helsinki-Uusimaa Land Use Plan 2050 (Helsinki-Uusimaa Regional Council 2020a). The reservation for a designated area for nuclear power plants was converted into a reservation for a designated site, and the land use plan regulation was updated. 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 (EN/y). According to the plan regulation *"The planning and implementation of the zone must prevent significant disruption to the environment with technical solutions and adequate precautionary zones. The Radiation and Nuclear Safety Authority must be provided with an opportunity to issue a statement on the zone's planning."*

The nuclear power plant's approximately 5 km precautionary action zone is indicated with the symbol sv-y. According to the plan regulation, *"Plans may not place new densely populated areas, hospitals or facilities inhabited or visited by a considerable number of people, or significant production operations that could be affected by an accident in the nuclear power plant, in an area included in a precautionary action zone. When planning to locate a holiday residence or recreational activities in the zone, it must be ensured that conditions for the appropriate rescue operations are not compromised. The Radiation and Nuclear Safety Authority and the emergency authorities must be provided with an opportunity to issue a statement on the zone's planning."*

A 400-kV transmission line and a connecting road have been designated north of the power plant. The Svartholma fortress, some two kilometres northwest of Hästholmen, the islands on the eastern and southern side of Hästholmen, and the western and southern parts of Gäddbergsö are designated as areas important for the preservation of a cultural environment or landscape. A major small craft track runs south of Hästholmen, and a shipping lane with a pass to Hästholmen is located southwest of the island. Site areas have also been designated for recreational use north, south and northwest of the power plant area.

The land use plan also indicates the need for a district heat transfer connection ('kl', a red dashed arrow) with a development principle symbol. The development principle symbol is used to indicate a transfer connection need related to the utilisation of the waste heat from the Kilpilahti oil refinery and Loviisa nuclear power plant, as well as the technical maintenance utility tunnel to the Helsinki metropolitan area.

The following general plan regulations in the regional land use plan are related to nuclear power production: A transition to an energy system sustainable in terms of the climate must be

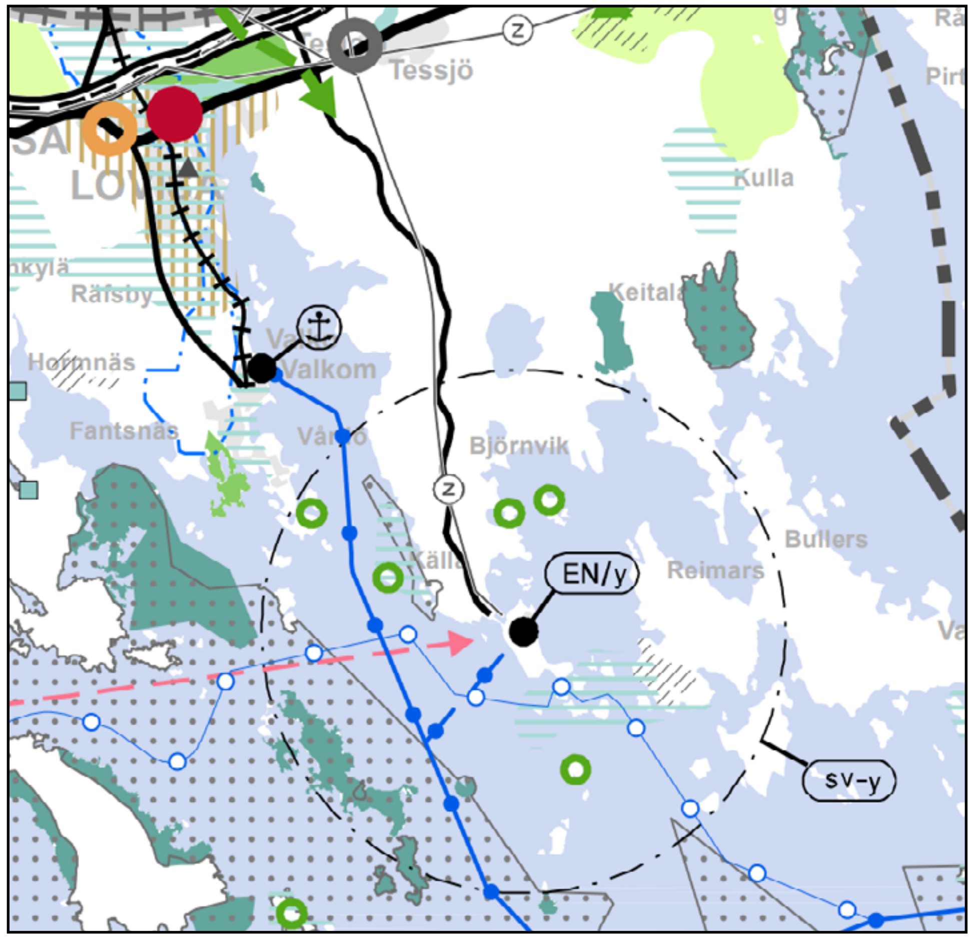

Figure 9-5. An extract of the land use plan map of the Helsinki-Uusimaa Land Use Plan 2050.

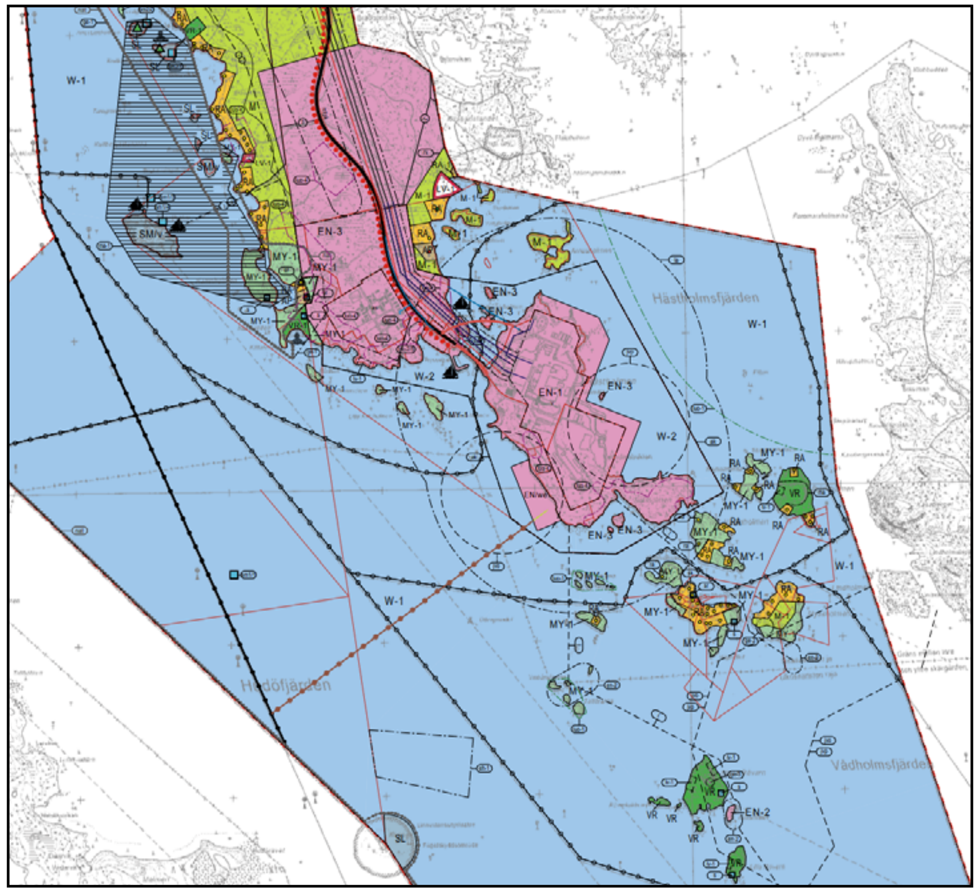

Figure 9-6. An extract of Loviisa's component master plan for shores.

Figure 9-7. An extract of the revision and expansion of the local detailed plan of the Hästholmen nuclear power plant area.

promoted. More detailed planning must promote the sustainable use of natural resources, the circular and bio-economy, the production of renewable energy and the recovery of waste heat. According to the general plan regulations, construction must promote sustainable soil material management. The operating conditions and development needs of the community management networks and facilities must be accounted for in the more detailed planning.

9.2.3.4 Master plan

The power plant area is located in the area of Loviisa's component master plan for shore areas, approved on 10 December 2008 (Figure 9-6) (Town of Loviisa 2021a). The island of Hästholmen is indicated as an energy management zone (EN-1). A component area symbol (v) indicates an area where the construction of nuclear power plants is allowed. The areas on the mainland for the support functions of the nuclear power plant are indicated in the land use plan as an area for the service and support functions of energy management (EN-3), where it is possible to build research facilities serving the construction of nuclear power plants, energy management and energy production as well as storage, production and office buildings.

On the eastern side of the Loviisa component master plan for shore areas is the Gäddbergsö-Vahterpää component master plan, and on the northern side, the Kulla-Lappom component master plan for shore areas as well as the change to the Kulla-Lappom component master plan affecting a minor area. The component master plan for Valko and its vicinity is pending on the western shore of Loviisanlahti bay. The component master plan's participation and assessment plan was dated 31 May 2018. The plan drafts of the component master plan were available for public viewing between 21 May – 30 June 2021. Among other things, the plan aims to steer the building of the western shores of Loviisanlahti bay and the planning of areas with no land use plan.

9.2.3.5 Local detailed plan

The revision and expansion of the local detailed plan of the Hästholmen nuclear power plant area are in effect in the Hästholmen area and the tip of the headland (approved on 21 January 2009, section 26, legally valid on 3 March 2009) (Town of Loviisa 2021a; Figure 9-7).

Most of Hästholmen is designated as an energy management zone (EN) where it is possible to construct nuclear power plants and buildings, and structures supporting their operation. Special areas intended for the support functions of the nuclear power plant (EN-1, EN-2) have also been designated on Hästholmen and on the mainland as well as in the area between them. In these special areas, building must be adjusted to the landscape due to landscape values. Underground construction is allowed in all of the aforementioned areas. A harbour area (LS-4), where a lane and a wharf can be built, is designated in the southwestern part of Hästholmen with an area reservation symbol. Nearby water areas have been designated as water areas where dredging is possible, and where buildings and structures necessary for energy management (W/en-1) can be built. An accommodation area is designated as a quartering area for residential buildings serving energy management (AS/en).

Table 9-1. Sensitivity of affected aspect: land use, land use planning and the built environment.

Sensitivity of affected aspect: land use, land use planning and the built environment	
The aspect's sensitivity to impacts affecting land use and land use planning is determined by the land use of the power plant area and its surrounding areas. Areas which have, or are close to, valuable natural sites, populated areas, or other land use that could be disrupted due to a change are sensitive to changes. In land use planning, sensitivity is influenced by whether the land use planning of the power plant area is in line with the project and by the use for which the project's impact area has been planned.	
Minor	Land use and land use planning's sensitivity to the planned operations is minor; the power plant area is the area of the current nuclear power plant and safe distances to sensitive aspects are already accounted for. Nevertheless, there are population and recreational use values in the surroundings of the power plant area. The power plant area's land use planning accords with nuclear power operations.

Table 9-1 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.2.4 Environmental impact of extended operation

Impact formation

The impacts on the community structure and land use are formed by how the extension of operation and any additional construction would prevent or restrict the current or planned land use of the power plant area and its surroundings. The magnitude is influenced by the duration of the operation. The project's operations have a direct impact within the project area. Indirectly, they restrict the forms of land use in the vicinity, and may impair the quality of housing and recreational use due, among other things, to impacts extending elsewhere (including noise, traffic or landscape impacts).

9.2.4.1 Relation to National Land Use Guidelines

The national land use guidelines are, above all, put into practice in regional land use planning. In regional land use planning, the guidelines are reconciled with the regional and local conditions and objectives. A new regional land use plan, discussed below in this Chapter, has been prepared for Uusimaa. The guidelines are also accounted for in the regional plan and programmes. Uusimaa's regional plan contains no special objectives with regard to nuclear power. Whether the production of nuclear power in Loviisa will continue in the future has been raised as a separate issue in the regional plan. The nature of some of the national land use guidelines is such that they are accounted for directly in municipal land use planning. In municipalities, the master plan is the key level of land use plans in implementing the national land use guidelines and the regional land use plan. The area has a valid master plan and local detailed plan which are discussed below in this Chapter.

The extension of operation would not result in changes to the regional or community structure. Extending operation within the existing power plant area would be favourable for low-carbon and resource-efficient community development, given that it would rely directly on an existing structure. The extension of operation would also contribute to low-carbon electricity production in Finland.

The current operation of the power plant is prepared for – and any plans concerning new construction should prepare for – extreme weather phenomena and flooding, for example. Any adverse effects on the environment and health caused by noise, vibration and poor air quality (the objective of a healthy and safe living environment) would also be prevented in the case of extended operation.

A sufficient distance between operations causing adverse health effects or a risk of accidents and operations sensitive to the impacts has been left in the project. Among other things, the power plant area is surrounded by a precautionary action zone extending to a distance of five kilometres. The restrictions concerning land use and risks related to nuclear power in this zone are managed in many different ways. The nuclear power plant and its operations have been established at a sufficient distance from residential areas and those that are sensitive in terms of nature, for example.

9.2.4.2 Impact on land use and land use planning

During the extended operation, the operation of the power plant will be similar to its current operation. During operation, the power plant area will be closed, and movement in the area will be prevented for people not working there. Any new buildings and structures will be in the current power plant area, and there will be no need to bring new areas into use.

Extended operation would also restrict land use in the area surrounding the power plant in the coming decades. The land use plan for Uusimaa indicates the Loviisa nuclear power plant area and the precautionary action zone for nuclear power plants. The plan solution secures the operating conditions of the current power plant units and the area's future development. The roughly five-kilometre precautionary action zone indicated in the regional land use plan is based on the existing power plant units' location on the island of Hästholmen. On the one hand, the indication of the precautionary action zone prevents the establishment of such operations in the vicinity of the power plant on which the plant could have adverse effects, and on the other, the establishment of such operations which could compromise the safe operation of nuclear power plants. For example, no facilities inhabited or visited by a considerable number of people may be established in the power plant's approximately five-kilometre precautionary action zone (YVL A.2). Furthermore, land use and building solutions within the area of the precautionary action zone must principally retain the size of the permanent and holiday population in such a way that the population does not increase materially during the construction and operation of a nuclear power plant. The nuclear power plant does not restrict land use outside the precautionary action zone.

In the area's Loviisa component master plan for shore areas, the island of Hästholmen has been indicated as an energy management zone, and the plan indicates the area on which nuclear power plants may be built. The nuclear power plant's current operation accords, and the extension of operation and any additional construction will accord, with the master plan. The revision and extension of the valid local detailed plan for the Hästholmen nuclear power plant area allows for extending operation. It also allows for modification work within the power plant area, and the construction of additional structures and buildings.

Overall, the environmental impact that the extended operation would have on land use would be minor and negative in magnitude. The impacts would be similar to those of the current operation. Extended operation would continue to restrict the land use of both the power plant area and the areas surrounding it in the decades to come. The nuclear power plant's operation accords, and its extended operation would accord, with the area's land use planning and would not require changes to the land use plans.

9.2.5 Environmental impact of decommissioning

Impact formation

The impacts on the community structure and land use are constituted by how the decommissioning enables or, depending on the options for extending operation, continues to restrict the current or planned land use of the power plant area and its surroundings. The current operations have a direct impact within the project area. Indirectly, they restrict the forms of land use in the vicinity and may impair the quality of housing and recreational use due to impacts extending elsewhere (including noise, traffic or landscape impacts), for example.

9.2.5.1 Impact on land use and land use planning

The decommissioning is not expected to have a strong interface to the national land use guidelines. To promote the objective of low-carbon community development, electricity in Finland must be produced with low-carbon alternatives. The impact that the decommissioning will have on the energy market and security of supply and on greenhouse gas emissions is assessed in Chapter 9.11 and Chapter 9.12 respectively.

The area's valid local detailed plan allows for the power plant's decommissioning. Needs for changes to land use plans may emerge after decommissioning when planning the area's further use if the land use restrictions resulting from the power plant's operation change or are removed. The removal of the precautionary action zone restricting land use in the impact area can be considered when the operation of the plant parts to be made independent ends. The area's further use will determine the nature of the plan regulations which will remain in force in the area. The L/ILW repository will impose restrictions on the area even after the repository is closed. For example, deep excavations in the area of the repository are prohibited.

The area's final use will be determined on the basis of whether the further use will comply with the "greenfield" or "brownfield" principle. According to the brownfield principle, the area could be used as an industrial area. In this case, the buildings cleared from regulatory control pursuant to the Nuclear Energy Act that can be used will be put to use as industrial or warehouse buildings, for example, following the necessary renovations. The area's good power transmission connections enable its use for new electricity production, which could be based on the modular nuclear reactors under development, for example. From the perspective of land use and regional structure, there are no impediments to establishing industrial operations in the area.

According to the greenfield principle, all buildings and structures in the power plant area would be dismantled and the power plant area would be restored to its natural state to the extent possible. In this case, land use restrictions would be removed in many respects, and the area's partial use for recreation, for example, could be allowed, accounting for the restrictions imposed by the L/ILW repository.

Overall, the environmental impact that decommissioning will have on land use will be minor and positive in magnitude. Once operation concludes, the power plant's impacts on the vicinity will end.

The area's current land use plan allows for the power plant's decommissioning, but the area's further use may require changes to the land use plan. The removal or reduction of the precautionary action zone restricting the impact area's land use would remove the restrictions on the surrounding areas' land use planning.

9.2.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland at the power plant would not cause changes to the land use or require changes to the land use plan.

9.2.7 Significance of impacts

Table 9-2 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.2.8 Mitigation of adverse impacts

Adverse impacts in both construction and dismantling operations can be mitigated by accounting for the surrounding land use.

9.2.9 Uncertainties

The environmental impact assessment aims to consider the project's impacts as extensively as possible. The assessment does not include significant uncertainties in terms of current land use. The assessment of the impacts on land use planning is based on the valid regional land use, master and local detailed plans.

It is too early to make precise assessments of the changes to land use or any need for changes to be made to land use plans after decommissioning.

In the future, the community structure and land use development of the power plant area and its surrounding areas will also be influenced by factors other than the decommissioning of the nuclear power plant.

Table 9-2. Significance of impacts: land use, land use planning and the built environment.

Significance of impacts: land use, land use planning and the built environment			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extending operation	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** given that extended operation would continue to restrict the land use of both the power plant area and the areas surrounding it in the decades to come. The impacts on land use would be similar to those of the current operation. The nuclear power plant's operation accords, and its extended operation would accord, with the area's intended use pursuant to the land use planning and would not require changes to the land use plans. On the other hand, the impact area's land use planning accounts for the restrictions attributable to the nuclear power plant.
Decommissioning	**Minor**	**Minor positive**	**The significance of the impacts is minor and positive,** given that the adverse effects caused by the operation will end once the operation comes to an end. Depending on whether the decommissioning is implemented according to the greenfield principle of the brownfield principle, the power plant area will either be restored to a state as close as possible to its natural state or a part of it can be taken into industrial use, for example. Depending on the area's further use, changes to the land use plan may be necessary if the area's intended purpose is changed.
Radioactive waste generated elsewhere in Finland	**Minor**	**No change**	**No impact,** given that the operations would have no impact on land use or require changes to the land use plan.

9.3 LANDSCAPE AND CULTURAL ENVIRONMENT

9.3.1 Principal results of the assessment

In extended operation, the power plant's additional construction would result in only minor negative impacts on the landscape, most of which would concern solely the vicinity of the power plant. The power plant would also remain part of the area's landscape as it currently is in the coming decades. The significance of the impacts would be minor and negative.

In the decommissioning, the landscape will be subject to positive impacts, the magnitude of which will depend on the principles of the area's further use. Should all buildings and structures in the power plant area be dismantled, the positive impacts would be greater in both the project area and the surrounding areas than in an option in which some of the buildings would remain in the area. In the brownfield principle, the significance of the impacts will be minor and positive and in the greenfield principle, moderate and positive. The magnitude of the positive impacts will be diminished by the long timespan of the dismantling activities, given that they will be carried out in phases, and the landscape will change over several decades. The dismantling of the power plant's buildings can also be seen as a negative matter, given that the power plant is part of the area's landscape and built environment.

In terms of radioactive waste generated elsewhere in Finland, there will be no impact.

The archaeological cultural heritage will not be subject to impacts.

9.3.2 Baseline data and assessment methods

The landscape impact assessment reviewed changes to the landscape caused by work and additional construction related to the extension of the power plant's operation and its decommissioning. A description of the area's landscape structure, overall landscape and cultural environment was prepared. The materials used in the assessment of impacts on the landscape and the built environment included maps, aerial photos, land use plans and other surveys of the area, as well as register information from the authorities.

The assessment of the impacts on the landscape and the cultural environment focused on the change in the overall landscape: how visible the changes caused by the project would be, how extensive the change in the landscape would be, and which parts of the landscape would experience the greatest change. Special attention was paid to the changes in the landscape that concern holiday housing.

9.3.3 Present state

9.3.3.1 Overview of the landscape

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 the Eastern Uusimaa landscape structure, where the landscape regions have been further divided into landscape types, the power plant area is located in the landscape zone of the coastal archipelago and mainland coast (Helsinki-Uusimaa Regional Council,

Figure 9-8. Aerial image of the surroundings of Loviisa power plant (National Land Survey of Finland, 2021). The image shows the direction of the oblique aerial photographs.

2007). With regard to the landscape, the zone is very detailed and varied, largely due to the formation of bays, coves and inlets between chains of islands and the folds of the broken shoreline (Figure 9-8).

The profile of Hästholmen and the islands south of it is flat. The highest point of Hästholmen is approximately 16 metres above sea level. The area surrounding the power plant consists of a fairly natural coast and archipelago landscape, with numerous red granite boulders and cobbly areas a special characteristic (Figure 9-9). In addition to the power plant, the Port of Valko stands out as a clear exception to the landscape's natural state. Some of the holiday housing on the coast is located very close to the waterfront, which is why buildings are discernible in the landscape from far away.

The eastern shore of Hästholmen has undergone drastic changes as a result of the land filling carried out in the construction of the power plant. There is no protective green zone on the island's eastern shore and part of the northern shore (Figure 9-10), which is why there is an unobstructed view of the power plant and its associated structures to Hästholmsfjärden on the eastern side of the island. The unbuilt south and west shores of Hästholmen are, for the

Figure 9-9. Oblique photograph from the front of Småholmen towards the northwest.

Figure 9-10. Oblique photograph from Hudofjärden towards the east.

Figure 9-11. Oblique photograph from Hudofjärden towards the northeast.

most part, in their natural state. Although the power plant buildings, stack and masts are visible to a large part of the Hudöfjärden sea area west and southwest of the island, the forest zone on the southern and western shores softens the landscape considerably (Figure 9-11). In open areas, the power plant area's lights are visible from afar during the dark.

9.3.3.2 Valuable landscape and cultural environments and sites

The islands to the east and south of Hästholmen, the western and southern parts of Gäddbergsö, and the water areas between them belong to the regionally significant built cultural environment of *Vådholmsfjärden* (Figure 9-12). According to royal sea charts, there was a haven in Vådholmsfjärden in the 1790s. Structures related to fishing, the haven and log driving have been discovered in the area. In addition, the area features the Kasaberget fire direction tower, dating back to World War II. The area values are based on the haven, log driving and fortresses dating back to World War II (Helsinki-Uusimaa Regional Council, 2016a). The shortest distance from the power plant's operations to the cultural environment in question is around 500 metres.

The Svartholma Fortress (Finnish Heritage Agency, 2021), located northwest of Hästholmen, at the mouth of the Loviisanlahti bay, is a nationally significant built cultural environment, or RKY (RKY, 2009). The Svartholma fortress and a land fortress in Loviisa are the eastern bulwark of the Suomenlinna main fortress located off Helsinki, which was built after Sweden's territorial losses in the 1740s (Helsinki-Uusimaa Regional Council, 2016a). The shortest distance from the power plant's operations to the cultural environment in question is around 1.5 kilometres.

There are no permanent archaeological sites in Hästholmen or its surroundings. The Svartholma fortress (site ID 1000001910) is an extensive archaeological site. (Finnish Heritage Agency, 2021)

A cultural heritage survey was conducted in the area of Loviisa's component master plan for shore areas in 2008. According to the survey, there are no cultural heritage sites on the island of Hästholmen. The nearest cultural heritage site is located on the Stora Kalvholmen island west of Hästholmen. This site is not designated in the component master plan for shore areas. There are also cultural heritage sites on the mainland in the surroundings of the regionally significant built cultural environment of Svartholma and on the islands south of Hästholmen, which are part of the regionally significant cultural environment. The nearest known underwater relics found in the Finnish Heritage Agency's Ancient Relics Register are located at a distance of two kilometres on the western side of the power plant. The wreck of the frigate Fortuna, which sank in 1822, is closest to the power plant. It is located on Hudofjärden to the east of the current shipping lane (Finnish Heritage Agency, 2021).

Table 9-3 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

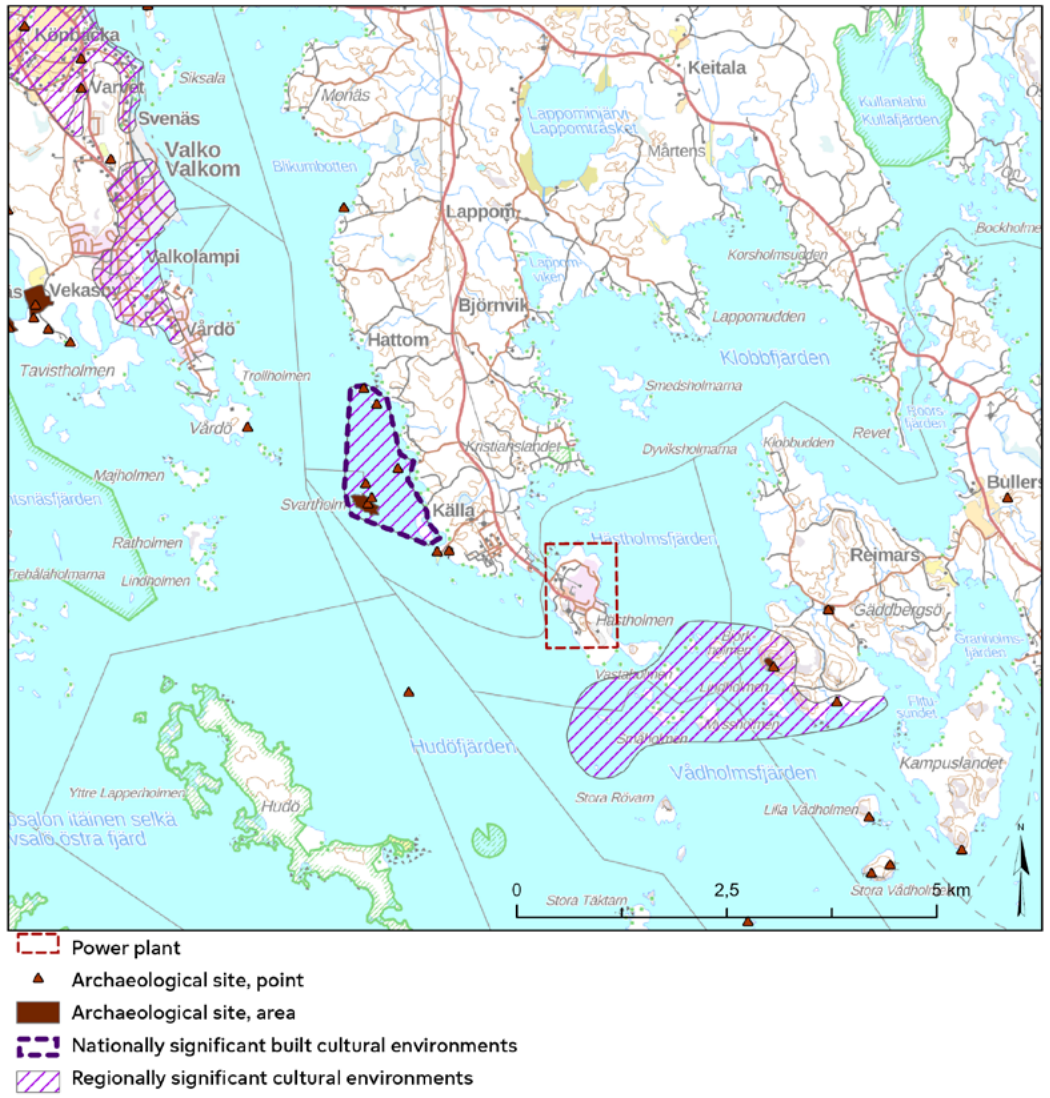

Figure 9-12. Landscape areas and cultural environments as well as fixed archaeological sites located in the surroundings of the power plant. (Source: Finnish Heritage Agency, 2021; Helsinki-Uusimaa Regional Council, 2019)

Table 9-3. Sensitivity of the affected aspect: landscape and cultural environment.

Sensitivity of the affected aspect: landscape and cultural environment	
The level of sensitivity to landscape impacts and the retention of the cultural environment's specific characteristics is determined according to the area's intended use and history. The sensitivity is also influenced by the quality of the surrounding built environment and the quantity of the earlier impacts of change on the historical features. Particularly characteristic scenic view areas located at high altitudes (such as esker landscapes and extensive field landscape or lake/sea views with their possible landmarks), landscapes that have remained in their original state, built and environmental sites, or the layouts of roads, as well as landscape or cultural heritage areas which have retained a harmonious appearance are sensitive to change.	
Moderate	The landscape's and cultural values' overall sensitivity to changes resulting from the project is moderate: the project is located within the existing power plant area, which has already shaped the landscape of the island of Hästholmen and its vicinity. The project is not located in the area of a valued landscape or built cultural environment, and there are no fixed archaeological sites in the power plant area or its vicinity. On the other hand, the closest sites of national value are located at a distance of roughly 1.5 kilometres to the northwest, and the distance to a regionally valuable landscape at its shortest is 500 metres southeast. Holiday residences are located in the shore area of the power plant's impact area, and the power plant's location makes it visible from the surrounding sea area from both short and long distances.

9.3.4 Environmental impact of extended operation

Impact formation

The impacts on the landscape and cultural environment are caused by the additional construction in the area. In principle, additional construction that is of a small scale, consists of low-rise buildings or is located behind other structures within the power plant area will not cause notable changes to the landscape beyond its immediate vicinity. Replacing existing structures with new ones would cause markedly fewer impacts than any additional construction located in a new area.

In extended operation, additional new buildings could be built in the power plant area. Such new buildings could include a cafeteria building in the vicinity of the office building, an inspection or reception warehouse, a wastewater treatment plant and a storage hall for waste as well as a welding hall. The interim storage for spent nuclear fuel may also be expanded. These buildings would be located within already built areas or would replace old buildings, meaning that the power plant area on the island of Hästholmen would not expand. The buildings in question would not be very tall or clearly discernible within the landscape from far away, given that they would be located in the existing power plant area. The changes to the landscape would be only minor, and they would concentrate primarily in the vicinity of the power plant. In open areas, the power plant area's lights would continue to be visible from afar during the dark.

Extended operation would not have an impact on the archaeological cultural heritage. There is a regionally significant cultural environment, Vådholmsfjärden, southeast of the power plant. The area is also home to locally valuable building sites. Structures of the power plant are partly visible from the cultural environment's shore and waters. If the operation of the power plant is extended, the landscape impacts would largely correspond with the current impacts. Minor construction would have no appreciable impact. On the other hand, the values of the cultural environment are based, above all, on the haven, log driving and the fortresses dating back to World War II.

No such open or important views which would be impacted by additional construction open up from the Svartholma fortress, northwest of the power plant, which is a nationally significant built environment. The views from Svartholma's viewing platform open up to the south and northwest, whereas the power plant is located southeast of the fortress and cannot be seen from there.

9.3.5 Environmental impact of decommissioning

Impact formation

In the decommissioning option, the impacts on the landscape and cultural environment are largely attributable to the dismantling of structures. In principle, dismantling activities that are of a small scale, do not rise to great heights, or that are located behind remaining structures within the power plant area will not cause notable changes to the landscape beyond its immediate vicinity. The dismantling of sizeable buildings or structures in a visible location in an open area may be visible from further away than the vicinity, and have an impact on the landscape from far away.

The expansion of the L/ILW repository will be carried out underground, due to which it will have no impact on the landscape. Instead, the possible interim storage of the quarry material resulting from the expansion in the power plant area may have a minor impact on the landscape in the vicinity.

The first dismantling phase will consist of the dismantling of the reactor building's activated and contaminated parts. Buildings which do not contain activity can be cleared from regulatory control and possibly put to other use (in line with the brownfield principle). Currently, however, there is no specific information concerning which buildings would remain in place, and which would be dismantled. The reactor buildings are the power plant's largest and tallest buildings. The possible dismantling of these buildings would clearly change the shape of the power plant, and this change would be visible both in the vicinity and from far away. Viewed from afar, the power plant's silhouette would change. The other buildings that may be dismantled are lower, and the dismantling would be visible primarily in the power plant's vicinity.

The second dismantling phase would possibly also cover the dismantling of all plant parts to be made independent, such as the interim storage for spent nuclear fuel, the liquid waste storage and the solidification plant. These buildings are significantly lower than the reactor buildings, and their dismantling would not be clearly visible beyond the vicinity.

According to current plans, the preparation phases and the first dismantling phases will be conducted in gradually so that dismantling phase 1 of Loviisa power plant unit 1 and the preparation phase of Loviisa power plant unit 2 will be carried out simultaneously. The power plant's shape will therefore change over a period of several years before the dismantling phases are completed. For example, the reactor building of Loviisa power plant unit 1 will be dismantled a couple of years before the reactor building of Loviisa power plant unit 2.

According to current estimates, the dismantling of the power plant units in phases will take around seven years (first dismantling phase). The plant parts which have been made independent would not be dismantled until the second dismantling phase, some 20–30 years after the dismantling of the power plant units. This being the case, the overall decommissioning will take a long time, due to which the landscape will change over a number of decades. During the dismantling work, the dismantling of the buildings will result in sudden changes to the view, and the tall cranes possibly used in the dismantling work will result in momentary changes to the landscape. These will have temporary negative impacts on the views opening up in the direction of the power plant from the surrounding areas. On the other hand, the dismantling of tall and big buildings will reduce the power plant's discernibility, especially from a distance. The lighting of the power plant area will change in the long term, due to which the night-time brightness and its visibility to open areas will reduce.

The area's final use and final shape will be determined according to whether the further use will follow the greenfield or brownfield principle, and according to the activity planned for the area after decommissioning.

According to the brownfield principle, buildings cleared from regulatory control will be left in place for possible future use. It is currently unknown which buildings would be left standing for further use. Because of this, this assessment relied on the assumption that the reactor buildings would be dismantled in full, but buildings used in the power plant's support functions would be left in the area. The buildings that would remain in the area would not be clearly discernible from afar, which would reduce the power plant's impact on the landscape when viewed from a distance. The positive impacts would especially concern the areas surrounding the power plant: the sea area and its shores, holiday residences included, from which a view in the direction of the power plant opens up.

According to the greenfield principle, all buildings and structures in the power plant area would be dismantled, and the area would be thoroughly landscaped. In this case, the power plant area would be restored as closely as possible to its natural state, and the landscape of the areas surrounding the power plant would return to the state preceding the power plant's construction. This would have clearly positive landscape impacts on the area of Hästholmen and the areas surrounding it. On the other hand, the power plant is Finland's first nuclear power plant and has been located there since the 1970s. It is therefore already part of the area's landscape and built cultural environment. The dismantling of the power plant can also be seen as a negative matter. In some countries, old nuclear power plants or parts of them have also been protected because the buildings are considered to constitute a significant part of the area's cultural heritage.

The option of decommissioning would not have an impact on the archaeological cultural heritage. The decommissioning of the power plant would mitigate the visual impact on *Vådholmsfjärden*, a regionally significant cultural environment located southeast of the power plant. The dismantling of the reactor buildings and other large buildings, clearly discernible from a distance, would have a positive impact on the views opening up from the cultural environment in the direction of the power plant.

No such open or important views of the power plant's buildings or structures open up from the Svartholma fortress, northwest of the power plant, on which the buildings' dismantling would have a noticeable impact.

9.3.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the power plant area would not result in changes to the landscape and cultural environment.

9.3.7 Significance of impacts

Table 9-4 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

Table 9-4. Significance of impact: landscape and cultural environment.

Significance of impact: landscape and cultural environment			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extending operation	Moderate	Minor negative	**The significance of the impacts is minor and negative,** given that the power plant's additional construction would result in only minor negative impacts on the landscape, most of which would concern solely the vicinity of the power plant. The power plant would also remain part of the area's landscape as it currently is in the coming decades. The archaeological cultural heritage would not be subject to impacts.
Decommissioning	Moderate	Minor positive	**The brownfield principle: The significance of the impacts is minor and positive,** because the potential dismantling of some large buildings would have positive landscape impacts when viewed from either a short or long distance. The positive landscape impact would be diminished by the long timespan of the decommissioning, given that the dismantling work would be carried out in phases, and the landscape would change over several decades. The dismantling of the power plant's buildings can also be seen as a negative matter, given that the power plant is part of the area's landscape and built environment. The archaeological cultural heritage will not be subject to impacts.
		Moderate positive	**The greenfield principle: The significance of the impacts is moderate and positive,** because the dismantling of all the power plant's buildings would have clearly positive landscape impacts when viewed from either a short or long distance. The area would return to its natural state. The positive landscape impact would be diminished by the long timespan of the decommissioning, given that the dismantling work would be carried out in phases, and the landscape would change over several decades. The dismantling of the power plant's buildings can also be seen as a negative matter, given that the power plant is part of the area's landscape and built environment. The archaeological cultural heritage will not be subject to impacts.
Radioactive waste generated elsewhere in Finland	Moderate	No change	**No impact,** given that the operations would have no impact on the landscape and cultural environment.

9.3.8 Mitigation of adverse impacts

In the case of extending operation, the impacts can be mitigated by complying with good building practices in the planning and implementation of new buildings and structures, and by paying attention to their colour, for example, and making sure they suit the environment. The retention of the precautionary action zones, which mitigate the landscape impacts, will also be a focus during both construction and dismantling work.

9.3.9 Uncertainties

Detailed plans for the area's dismantling and the phasing of such dismantling do not yet exist, due to which the impact of the buildings' dismantling has not been illustrated with illustrations supporting the verbal assessment. This leaves some uncertainties in the assessment concerning the visual landscape impacts. The area's final use and the impacts it will have on the landscape will be determined by the principle applied in the further use. The assessment assesses the impacts that the differences between the principles would have on the landscape, which reduces the assessment's uncertainties.

9.4 TRAFFIC

9.4.1 Principal results of the assessment

If the power plant's operation continues, the traffic impact would remain roughly on a par with the current impact, but continue for approximately another 20 years. Additional construction would result in some temporary additions to the volume of traffic. Road safety on the roads leading to the power plant area will remain unchanged. However, especially during annual outages, when traffic volumes would be at their greatest, just as in the current operation, the smooth flow of traffic on Atomitie and Saaristotie could be temporarily hindered and increase road safety risks. According to the assessment, the significance of the impacts is minor and negative.

The greatest addition to the traffic volumes during decommissioning will be seen during the dismantling phases, when the maximum volumes of traffic will be temporarily equivalent to the traffic volumes experienced during annual outages in current operation. The increase in traffic volumes is not expected to affect the flow of traffic significantly, considering the current capacity of the roads. Yet it is possible that the smooth flow of traffic on Atomitie and Saaristotie will be temporarily hindered. The increase in the volume of traffic, especially on Atomitie and Saaristotie, will increase risks related to road safety when taking into account the duration of the increased traffic volumes, and the lack of pedestrian and bicycle lanes on Atomitie and Saaristotie. The significance of the impacts is moderate and negative.

The number of transports related to radioactive waste generated elsewhere in Finland would be low and their impact on the roads' daily traffic volumes would be negligible.

9.4.2 Baseline data and assessment methods

The traffic impacts have been reviewed by assessing the traffic volumes and their changes on the roads leading to the power plant area. The review has accounted separately for the changes in overall traffic volumes, passenger traffic volumes and the volumes of heavy vehicle traffic. The impact assessment has accounted for traffic arriving at and departing from the power plant area. The impacts on the transport network's load, the smoothness of traffic and road safety caused by the change in traffic volumes have been assessed in the form of an expert assessment. Special attention has been paid to any sensitive aspects along the transport routes, such as housing, daycare centres and recreational areas. Data describing the present state have been compared to the maximum volumes of traffic, in terms of which it has been assumed that the majority of employees drive to work in a passenger car.

The road connections leading to the power plant area and their current traffic volumes have been compiled from the Finnish Transport Infrastructure Agency's data (Finnish Transport Infrastructure Agency, 2020). The transport arrangements in the power plant area have also been reviewed on the basis of the data presented in the project description. In terms of road safety, the review focused on the accident statistics of the roads leading to the power plant area (Ramboll Finland Oy). In addition, the assessment relied on various map surveys in terms of analysing the properties of the roads, for example, and sensitive aspects.

The emissions attributable to changes involving traffic and their impacts on air quality, noise and vibration are assessed in Chapters 9.5, 9.6 and 9.7. The transports of spent nuclear fuel are reviewed in Chapter 9.10.

9.4.3 Present state

Highway 7 from Helsinki to Vaalimaa, part of the main Finnish E18 east-west route, runs via Loviisa. There are highway junctions on the east and west side of Loviisa. The traffic connection from the eastern junction of Highway 7 to the island of Hästholmen runs via connecting road 1585, Mannerheiminkatu (170), Saaristotie and Atomitie (1583). Traffic arriving at the power plant via the western junction runs through the centre of Loviisa via Helsingintie and Mannerheiminkatu (170) before Saaristotie and Atomitie (1583). The distance from Highway 7 to the island of Hästholmen is approximately 15 km (Figure 9-13).

According to the 2019 traffic volume statistics of the Finnish Transport Infrastructure Agency, (Finnish Transport Infrastructure Agency, 2020), the average volume of daily traffic via the western junction of Highway 7 was roughly 10,558 vehicles per day, of which 10% (1,023 vehicles a day) were heavy vehicles. The corresponding traffic volume via the eastern junction was at most some 8,750 vehicles per day, of which heavy vehicles accounted for 12% (1,066 vehicles a day).

The average volume of daily traffic on Helsingintie, diverging from the western junction, was around 7,350 vehicles. Heavy vehicles accounted for 6% (445 vehicles per day) of this. The vehicles on connecting road 1585, continuing from

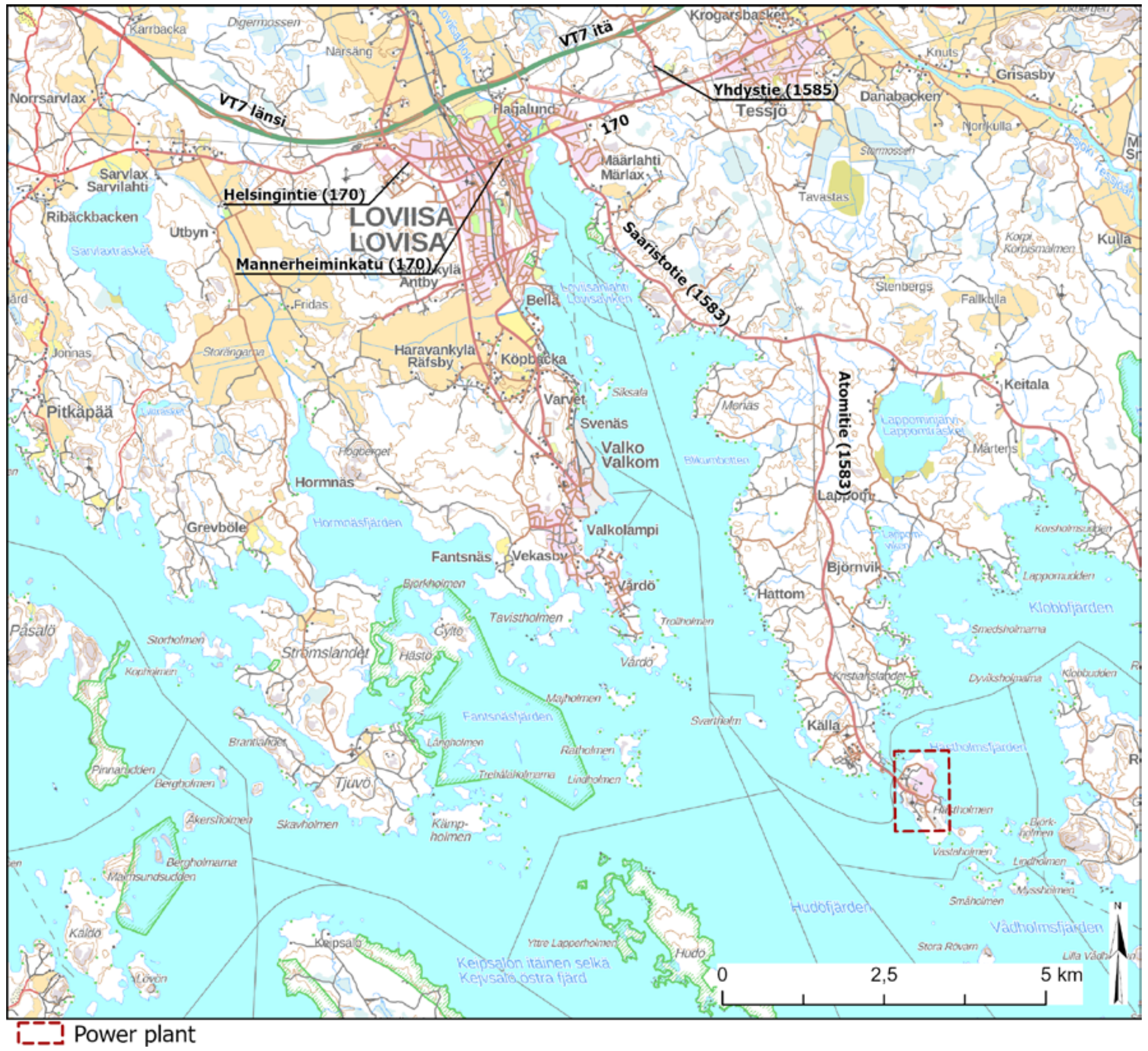

Figure 9-13. The roads, including their road numbers, leading from Highway 7 to Loviisa power plant (Source: National Land Survey of Finland 2021).

the eastern junction, amounted to some 1,466 vehicles per day, of which heavy vehicles accounted for 6% (88 vehicles a day). The traffic volumes from Mannerheiminkatu to Määrlahti amounted to 3,487 vehicles per day, with heavy vehicles accounting for 4% (154 vehicles a day) of the volume. The average volume of daily traffic on Saaristotie was 1,803 vehicles, of which heavy vehicles accounted for 4% (80 vehicles a day). The average daily traffic on Atomitie was approximately 693 vehicles, of which heavy vehicles accounted for roughly 5% (38 vehicles a day).

There is no separate pedestrian or bicycle lane on Atomitie or on Saaristotie, apart from a short stretch of Atomitie in the vicinity of the power plant and on Saaristotie, between Mannerheiminkatu and Määrlahti. Of the roads, only the Saaristotie section by Määrlahti is lit. The speed limit on Atomitie and Saaristotie is 80 km/h, excluding the northern end of Saaristotie, where the speed limit decreases when approaching the Mannerheiminkatu junction, first to 60 km/h, and then to 50 km/h. On Mannerheiminkatu, near the centre of the town of Loviisa, the speed limit is 40 km/h, and otherwise, depending on the location, 50 km/h.

A total of approximately 20 traffic accidents were recorded on Atomitie and Saaristotie between 2015 and 2019 (Ramboll Finland Oy 2021). Of these, 4 were bicycle accidents resulting in bodily injury at the intersection of Saaristotie (1583) and Mannerheiminkatu (170). One accident resulting in an injury also occurred on Saaristotie. The other accidents did not result in injuries. On Atomitie, most of the accidents were collisions with an elk, while the rest were head-on collisions or individual accidents.

Infrastructure building is underway at Kuningattarenranta, Määrlahti, in relation to which the location line of the northern end of Saaristotie will shift to the east. In addition, a pedestrian and bicycle lane will be constructed for a stretch of roughly 1 km along Saaristotie (Town of Loviisa, 2021b). The long-term goal in Loviisa is to construct a new road connection, running from the eastern roundabout of Highway 7 (E18) to Hästholmen, from which the new road connection would run to the intersection of Saaristotie/Atomitie, and from there further along the improved Atomitie to the island of Hästholmen. The planning of the road would take place during the 2021–2024 planning period. The town

Table 9-5. Sensitivity of affected aspect: traffic.

Sensitivity of affected aspect: traffic	
The affected aspect's level of sensitivity is determined according to the characteristics of the transport network and environment, as well as the surrounding land use.	
Moderate	The area's road network has been designed for a large volume of traffic, accounting for the power plant area's current volumes of heavy vehicle traffic. The sensitivity in terms of traffic is nevertheless deemed moderate, given that there is no pedestrian or bicycle lane on Atomitie or Saaristotie, apart from a short stretch of Atomitie in the vicinity of the power plant and on Saaristotie, between Mannerheiminkatu and Määrlahti. The area's sensitivity is emphasised during annual outages, when overall traffic volumes are greater than normal.

of Loviisa has proposed to the Centre for Economic Development, Transport and the Environment (ELY Centre) that the project's planning be initiated (Town of Loviisa, 2020).

The railway line nearest to the power plant area runs from the Port of Valko to Lahti. There is only freight traffic on this section of the railway.

The Loviisa harbour is located in Valko, Loviisa, some 22 kilometres from the power plant area. There are three shipping lanes near the power plant. The shipping lane to the Valko harbour runs along the southwestern side of Hästholmen, at a distance of at least a couple of kilometres from the shore. Within ten kilometres of the power plant there is also the Gulf of Finland coastal sea lane, which begins from the ports of Hamina and Kotka, and continues as the Helsinki-Orrengrund sea lane. The third more extensively used shipping lane to the ports of Hamina and Kotka is located slightly further out to sea.

To ensure the safety of the power plant and its surroundings, air traffic is prohibited in the Hästholmen area (Government Decree 930/2014). The no-fly zone covers the power plant surroundings within a four-kilometre radius and at an altitude of up to 2,000 metres. Hästholmen has an official heliport for use by the authorities.

Table 9-5 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.4.4 Environmental impact of extended operation

Impact formation

The impacts involving traffic consist of extended operation, such as the employees' passenger traffic in the power plant's current operation and various transports on the roads leading to the power plant area.

If the operation is extended, the power plant's traffic volumes will remain at the same level as during the current operation. The average daily traffic to the power plant is approximately 500 vehicles, of which approximately 40 are heavy vehicles. Among other things, these involve transports of fresh nuclear fuel, various equipment, chemicals, fuel oil, gases and waste management.

The following Table 9-6 shows the share of traffic volumes related to an extension of the power plant's operation in the overall traffic volumes and volumes of heavy vehicles (vehicles per day) on the roads. As the table indicates, the power plant accounts for roughly 1–4% of overall traffic volumes on Highway 7 and Helsingintie (170). On connecting road 1585, the power plant accounts for 24% of the overall traffic volume, while on Mannerheiminkatu (170) and Saaristotie, it accounts for 10% and 28%, respectively, of the overall traffic volume. The power plant's traffic in relation to other traffic is at its greatest on Atomitie, where the power plant accounts for approximately 72% of the road's overall traffic volume. The figures presented in Table 9-6 are based on a hypothetical situation in which some 70% of the power plant's traffic uses the junction on the eastern side of Highway 7, and 30% the junction on the western side of Highway 7.

On Highway 7, the volumes of the power plant's heavy vehicle traffic account for less than 3% of the overall volumes, but in terms of traffic driving in the direction of the power plant, the share of the power plant's heavy vehicle traffic in relation to the overall volume of heavy vehicle traffic increases considerably – by 100% on Atomitie.

The power plant's 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. In such cases, the share of the power plant's traffic volumes in relation to the roads' overall traffic volumes increases temporarily. The annual outage of one unit usually takes around 2–8 weeks.

In the case of extending operation, the traffic impacts will remain largely unchanged. The traffic volumes related to the power plant's operation increase only slightly during the additional construction work. However, the traffic-related impacts will continue for some 20 years from the present. Road safety on the roads leading to the power plant area will remain unchanged. However, especially during annual outages, when traffic volumes would be at their greatest, the smooth flow of traffic on Atomitie and Saaristotie could be temporarily hindered, and the lack of a pedestrian and bicycle lane could increase road safety risks, with the exception of the start of Saaristotie. There are no sensitive aspects in connection with Atomitie or Saaristotie which the power plant's traffic output would affect. The schools nearest to the power plant, the sport hall and other key services are located in the centre of Loviisa, and the impact on them will also remain unchanged. The magnitude of the change is expected to be at most *minor and negative.*

The noise impacts related to traffic are assessed in Chapter 9.5, the vibration impacts in Chapter 9.6, and the impacts on air quality in Chapter 9.7.

Table 9-6. The roads' overall traffic volumes and volumes of heavy vehicle traffic (Finnish Transport Infrastructure Agency, 2020), as well as the share of the power plant's traffic. The power plant's traffic volumes are the same in both the present state and if the operation is extended.

Road	Overall traffic volumes (vehicles/day))	Power plant's share of overall traffic volume	Volumes of heavy vehicle traffic (vehicles/day)	Power plant's share of the volumes of heavy vehicle traffic
VT7 west	10,558	1%	1,023	1%
VT7 east	8,750	4%	1,066	3%
Helsingintie 170	7,350	2%	445	3%
Connecting road 1585	1,466	24%	88	32%
Mannerheiminkatu 170	3,487	10%	154	18%
Saaristotie 1583	1,803	28%	80	50%
Atomitie 1583	693	72%	38	100%

Table 9-7. The traffic-related change of different decommissioning phases compared to the power plant's current operation.

	Current operation of the power plant		Expansion of the L/ILW repository		Decommissioning		Plant parts to be made independent and closure	
	Overall volume of traffic	Volume of heavy vehicle traffic	Overall volume of traffic	Volume of heavy vehicle traffic	Overall volume of traffic	Volume of heavy vehicle traffic	Overall volume of traffic	Volume of heavy vehicle traffic
Vehicles/day	500	40	530	50	900	100	300	50
Change to the power plant's current operation	–	–	6%	25%	80%	150%	-40%	25%

9.4.5 Environmental impact of decommissioning

Impact formation

The traffic-related impacts consist of various transports related to different phases of the decommissioning, and the employees' passenger traffic within the power plant area and on the roads leading to the power plant area.

In decommissioning, the traffic-related impacts vary between different phases of the decommissioning. The changes in traffic volumes compared to the power plant's current operation are shown in Table 9-7, and the changes in the overall traffic volumes of roads attributable to different

Table 9-8. The changes caused by the traffic in different decommissioning phases on different roads compared to the average daily traffic volume in the current situation.

Road	Current overall traffic volume (vehicles/ day)	Volume of heavy vehicle traffic (vehicles/ day)	Expansion of the L/ILW repository		Decommissioning of the power plant		The operation and decommissioning of the plant parts to be made independent and the closure of the L/ILW repository	
			Change in overall traffic	Change in heavy vehicle traffic	Change in overall traffic	Change in heavy vehicle traffic	Change in overall traffic	Change in heavy vehicle traffic
VT7 west	10,558	1,023	0%	0%	1%	2%	- 1%	0%
VT7 east	8,750	1,066	0%	1%	3%	4%	-2%	1%
Helsingintie 170	7,350	445	0%	1%	2%	4%	-1%	1%
Connecting road 1585	1,466	88	1%	8%	19%	48%	-10%	8%
Mannerheiminkatu 170	3,487	154	0%	2%	3%	12%	-2%	2%
Saaristotie 1583	1,803	80	2%	13%	22%	75%	-11%	13%
Atomitie 1583	693	38	4%	26%	58%	150%	-29%	26%

decommissioning phases in Table 9-8. In Table 9-7, the traffic volumes have been calculated according to the estimated maximum volumes, in which the quarry material would be transported outside the power plant for interim storage and finally back to the power plant area for the closure of the L/ILW repository. The calculation outcomes presented in Table 9-8 are based on the assumption that some 70% of the power plant's traffic uses the junction on the eastern side of Highway 7, and 30% the junction on the western side of Highway 7. The calculation does not account for the development forecasts of road traffic volumes. The colours used in the table denote the following: grey = no change; red = the traffic volume will increase; green = the traffic volume will decrease.

If the decommissioning is carried out according to the greenfield principle, the transports of the dismantling waste will generate more heavy vehicle traffic, in particular. The volume of passenger traffic will also increase in the long run. No specific plans on the dismantling activities for the greenfield level have been drawn up yet, and the resulting traffic volumes have not been accounted for in the following tables and impact assessment.

The power plant will continue to operate during the expansion of the L/ILW repository, meaning that the power plant's traffic volumes will be the same as during current operation. The quarrying work related to the expansion of the L/ILW repository and the additional personnel it requires will increase the power plant's overall traffic volumes to a slight extent. The quarrying work is expected to take around three years, during which the quarry material generated in the quarrying work of the L/ILW repository will be transported from the repository to the surface and into interim storage, either within the power plant area or outside it. In addition, passenger traffic volumes will increase slightly, and occasional heavy and oversized transports may be carried out.

The transports of the quarry material related to the expansion of the L/ILW repository are expected to amount to around 5,000–11,000 vehicles over a period of three years. In this case, the transports by heavy vehicles in the area would increase by around 5–10 vehicles a day. If the quarry material is placed in interim storage within the power plant area, the transports of the quarry material will not generate traffic-related impacts. Instead, the power plant area's internal traffic will increase. If the quarry material is transported elsewhere for interim storage, the volumes of heavy vehicle traffic, especially on Saaristotie and Atomitie, will increase (by about 13% and 26% respectively). The increase in overall traffic volumes would be approximately 2% on Saaristotie and approximately 4% on Atomitie. On other roads, all the way to Highway 7, the increase in overall traffic volumes would be very small (<2%), even if the quarry material was transported elsewhere for interim storage.

The traffic volumes will be at their greatest during the first and second dismantling phases of the power plant's decommissioning. The volume of traffic leaving the power plant area will amount to roughly 900 vehicles per day, which is around 400 vehicles a day more than in the current situation. The power plant's overall daily traffic volumes will increase by around 80% compared to the current volume. This will be particularly visible as an increase in the traffic volumes on Atomitie and Saaristotie. Overall traffic volume will increase by 58% (heavy vehicles 150%) on Atomitie and by 22% (heavy vehicles 75%) on Saaristotie. At most, the volumes will temporarily be in the region of their current levels during annual outages. Traffic volumes on other road sections will also grow, and the growth will be greatest on connecting road 1585.

The traffic volumes will be at their lowest during the operation of the plant parts to be made independent, which will follow the first dismantling phase. At this point, the maximum volume of traffic will amount to 290 vehicles a day (of which heavy vehicles will account for a maximum of 40 vehicles a day). During independent operation, overall traffic volumes will decline by a minimum of approximately 40% from the power plant's current traffic volumes. This will be visible as a decrease in the roads' overall daily traffic volumes. The decrease will be the greatest on Atomitie, where overall traffic volumes will decline by around 30%. The volumes of heavy vehicle traffic on the roads will remain on their current level.

The transports of spent nuclear fuel from Loviisa to Olkiluoto, Eurajoki, will be carried out during the operation of the plant parts to be made independent. The estimated number of road transports of spent nuclear fuel is 6–8 per year; alternatively, approximately 2 maritime transports per year. If the transports of spent nuclear fuel are carried out by road or as a road-maritime-road combination, these transports will result in momentary limitations on other road traffic. The impact assessment pertaining to the transport of spent nuclear fuel is presented in Chapter 9.10.5.1.

The power plant area will still be subject to some passenger and heavy vehicle traffic during the L/ILW repository's closing phase. Overall traffic volumes on all road sections will also decrease in the event that the quarry material would be transported back to the power plant area from an interim storage area located elsewhere for the purpose of filling the L/ILW repository. The increase in heavy vehicle transports on nearby roads will be in the region of the increase that will occur during the L/ILW repository's expansion phase.

Once the L/ILW repository has been permanently closed, the passenger traffic and transport with heavy vehicles related to Loviisa power plant will come to an end. However, depending on the area's further use, other traffic in the area is a possibility.

The traffic-related impacts of decommissioning have been determined on the basis of a maximum scenario in which the traffic volumes would be at their greatest. The greatest increase in traffic volumes will be visible during the first and second dismantling phase of decommissioning, when the magnitude of the maximum transport volumes related to the dismantling work will be temporarily comparable to the traffic volumes of annual outages during the power plant's current operation. The increase in traffic volumes is not expected to affect the flow of traffic significantly, considering the current capacity of the roads. Even so, it is possible that the smooth flow of traffic on Atomitie and Saaristotie will be hindered temporarily and to a slight degree.

The volume of passenger traffic and heavy vehicle traffic, which will increase during the decommissioning, especially on Atomitie and Saaristotie, will increase risks related to road safety when taking into account the duration of the increased traffic volumes, and the lack of pedestrian and bicycle lanes on Atomitie and Saaristotie. There are no sensitive aspects in connection with Atomitie or Saaristotie which the power plant's traffic output would affect. The schools nearest the power plant, the sport hall and other key services are located in the centre of Loviisa, but since the traffic is primarily expected to head east, towards the connecting road, from the junction of Saaristotie and Mannerheiminkatu, it will not have a significant impact on their road safety. The magnitude of the change in traffic is expected to be at most *moderate and negative*.

The heavy vehicle transports, which will increase particularly during the various phases of decommissioning, may cause slight temporary inconvenience in the form of traffic noise and vibration on roads near the power plant area. The impact will nevertheless be momentary and concern only the road's immediate surroundings. The increase in traffic will also generate tailpipe and dust emissions. The noise impacts related to traffic are assessed in Chapter 9.5, the vibration impacts in Chapter 9.6, and the impacts on air quality in Chapter 9.7.

The power plant area's internal traffic will also increase during decommissioning as the activated or contaminated waste generated during the decommissioning is transported to the L/ILW repository. The estimated number of internal transports within the power plant area during the first dismantling phase of the decommissioning (duration approximately 7 years) is 1–2 vehicles per day. During the second dismantling phase, which will involve the dismantling of the plant parts to be made independent, the estimated number of daily internal transports within the power plant area is 1 vehicle per day over the three-year dismantling phase. Most of the plant area's internal transports will be carried out by truck, but heavy transports will also be needed.

Attention will be paid to the smoothness and safety of the power plant area's internal traffic. The routes of the transports will be planned so that they will not inconvenience or put at risk other traffic in the area. The goal is to communicate any changes to traffic arrangements clearly with the help of traffic control and bulletins. Pedestrian routes in the area will be arranged so that they are separate from the routes for vehicle traffic and also intersect with vehicle traffic as little as possible. Car parks will be located apart from the power plant area, as is the case today.

9.4.6 Radioactive waste generated elsewhere in Finland and its impact

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. Among other things, the transports account for STUK's safety regulations (STUK, 2021f), required by the transport of radioactive materials.

The traffic routes in Loviisa are the same as for the power plant's own transports. Given that the estimated maximum number of transports of radioactive waste generated elsewhere in Finland is around 10 a year, the transports will have no impact on the overall daily traffic volumes on the roads leading to the power plant area.

Table 9-9. Significance of impacts: traffic.

Significance of impacts: traffic			
Operational phase	Sensitivity	Magnitude	Significance
Extending operation	Moderate	Minor negative	**The significance of the impacts is minor and negative,** given that additional construction would result in some temporary additions to the volume of traffic. Road safety on the roads leading to the power plant area will remain unchanged. However, especially during annual outages, when traffic volumes would be at their greatest, the smooth flow of traffic on Atomitie and Saaristotie could be temporarily hindered and increase road safety risks.
Decommissioning	Moderate	Moderate negative	**The significance of the impacts is moderate and negative,** because during the first and second dismantling phase, the maximum volumes of traffic will be temporarily equivalent to the traffic volumes experienced during annual outages in current operation. The increase in traffic volumes is not expected to affect the flow of traffic significantly, considering the current capacity of the roads. Even so, it is possible that the smooth flow of traffic on Atomitie and Saaristotie will be temporarily hindered. The increase in traffic volumes, particularly on Atomitie and Saaristotie, will increase risks related to road safety. Traffic volumes during the operation of the plant parts to be made independent and the closing of the L/ILW repository will be lower than they currently are.
Radioactive waste generated elsewhere in Finland	Moderate	No change	**No impact,** given that the number of transports attributable to the activities would be low and their impact on the roads' daily traffic volumes would be negligible.

9.4.7 Significance of impacts

Table 9-9 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.4.8 Mitigation of adverse impacts

Instead of driving though the centre of the town of Loviisa, traffic, and especially heavy vehicle traffic, should be directed via the connecting road to Highway 7. If realised, the planned new road connection, which would run through the eastern junction of Highway 7 (E18) to the intersection of Saaristotie and Atomitie, and from there, as an improved road connection from Atomitie to the island of Hästholmen, would mitigate the traffic-related impacts in the case of both extended operation and decommissioning. The town of Loviisa has proposed to the Centre for Economic Development, Transport and the Environment (ELY Centre) that the new road connection's planning be initiated (Town of Loviisa, 2020). In terms of Atomitie and Saaristotie, road safety could be improved with a pedestrian and bicycle way.

During decommissioning, traffic impacts on the transport network can be mitigated by placing quarry material in interim storage within the power plant area before its use as a material in the closure of the L/ILW repository.

The goal is to ensure traffic arrangements and road safety in the planning of both extended operation and decommissioning, particularly in the vicinity of the power plant. Attention will also be paid to transports taking place within the power plant area and the safety of these transports by planning transport routes, the scheduling of transports and communicating the arrangements. Attention is already being paid to separating the pedestrian routes within the power plant area from the vehicle routes.

9.4.9 Uncertainties

In the case of extended operation and decommissioning, the long period of operation during which traffic volumes may change introduces a little uncertainty to the assessment. Furthermore, the assessment does not account for the impact of the potential new road connection. According to forecasts, the total volume of domestic passenger traffic, for example, will grow by approximately 21% from the 2017 level by 2050, and the volume of domestic goods transport will grow by approximately 18% from the 2017 level by 2030, after which it is expected to begin to decline (Finnish Transport Agency, 2018).

The traffic volumes during decommissioning are indicative estimates and will be specified as the plan progresses. This may add some uncertainty to the assessment. While traffic volumes outside the power plant area are assumed to divide, at the northern end of Saaristotie, towards the east or west at a ratio of 70%/30%, in reality, there is no precise data on the division of the traffic volumes, and this introduces uncertainty to the calculation. The assessment has also assumed that the majority of employees drive to work in a passenger car, given that the power plant is far away from residential areas. In reality, some employees may use public transportation or rely on carpooling. Despite this, the values used may be considered sufficiently reliable to describe the impact's magnitude and significance.

9.5 NOISE

9.5.1 Principal results of the assessment

In the option of extended operation, the power plant's noise would remain unchanged, but the impacts would continue for another 20 years. Extended operation is not expected to have an impact on the noise in the environment, given that the current level of noise caused by the power plant is low.

The most significant sources of noise during decommissioning are the crushing of the quarry material related to the quarrying of the L/ILW repository and the material's placement in interim storage, as well as the occasional noise caused by the crushing of concrete during the phase of conventional dismantling work leading up to a potential greenfield result. The noise caused by any crushing of concrete taking place outdoors may carry over to the power plant area's surroundings. In addition, the machinery and transports may occasionally generate stronger noise than the power plant currently does. At most, noise may momentarily be audible in the residential and holiday buildings on nearby islands and on the mainland. All in all, the impacts are expected to be minor and negative. Any noise spreading into the environment can be influenced by the selection of the location where quarry material and concrete is crushed, and when necessary, noise shielding, among other things.

The reception of radioactive waste generated elsewhere in Finland will not have noise impacts, given that the operations would increase transports only slightly and their noise increasing effect would be negligible.

9.5.2 Baseline data and assessment methods

One-time environmental noise measurements have been conducted at several measurement points in the surroundings of the power plant and on nearby islands, most recently in 2013 and 2017 (Ramboll Finland Oy, 2013 and 2017). Long-term noise measurements were conducted in the period between July and October 2020 at eight measurement points, primarily located at the same points as the earlier one-time noise measurements. Seven of these measurement points are located at holiday residences in the surroundings, while one measurement point served as a reference point by the side of a road leading to the power plant. The power plant operated normally during the measurement, in addition to which the main safety valves of the steam lines of each unit's secondary system were tested. (APL Systems 2020a and 2020b)

The assessment of the noise impacts is based on the project's planning data and the results of the noise measurements conducted in the surroundings of the power plant area. Comparable measuring results exist concerning the noise emissions of construction and dismantling, as well as quarrying work of various magnitudes, and they are used in assessing the impact.

The results have been compared to the limit values of the power plant's environmental permit insofar as such values have been specified in the permit regulation. According to the current environmental permit, the noise attributable to the power plant's operation, with the exception of noise caused by mandatory testing, may not exceed an average sound level of L_{Aeq} 45 dB during the day (7 am–10 pm) or an average sound level of L_{Aeq} 40 dB during the night in areas used for holiday housing. The general guideline values for the noise level of permanent residences are 10dB greater (daytime guideline value 55 dB/night-time guideline value 50 dB) than the limit values imposed with regard to holiday residences in the permit. The environmental protection authority of the town of Loviisa, the Uusimaa ELY Centre as well as owners of the area's permanent and holiday residences must be notified of testing and other temporary noise of an exceptional nature.

As the noise measurements in the current status have indicated that the noise in the environment mainly consists of the sounds of nature and noise from the power plant, there is no need to assess any combined impacts with other noise generated in the vicinity.

9.5.3 Present state

Noise in the surroundings of the power plant area is currently affected by Loviisa power plant, traffic noise and the sounds of nature. In certain weather conditions, the sounds of nature, such as wind and waves, generate a lot of background noise. The power plant's most significant sources of noise include the ejectors, transformers and ventilation equipment which, according to observations made during the measurements, emit a steady subdued drone or hum. The testing of safety valves during annual outages generates a stronger short-term noise distinct from the usual hum and not included in the limit value obligation pursuant to the environmental permit's permit regulation.

The power plant's most significant sources of noise include the transformers, ventilation equipment and ejectors. The transformers between the concrete walls emit a clearly audible subdued periodic hum or buzz in the 100–300 Hz region, particularly in Hästholmsfjärden, north of the power plant area, where the noise easily carries over along the surface of the water. In addition, the power plant's ejectors generate a cyclic sound. The testing of safety valves during annual outages generates a stronger short-term noise distinct from the usual hum and not included in the limit value obligation pursuant to the environmental permit's permit regulation.

One-time measurements carried out during the day have revealed some degree of variation in noise levels between different measuring occasions. The continuous background noise caused by wind and waves has been detected at all measurement points. At the measurement points where the power plant's noise has been audible, the measured noise levels have remained below the limit value for noise during the day, 45 dB. The noise levels have complied with the requirements of the environmental permit, and the limit values have not been exceeded in the one-time measurements.

Table 9-10. Sensitivity of affected aspect: noise.

Sensitivity of affected aspect: noise	
The sensitivity of the affected aspect is influenced by the area's land use situation and the location of particularly sensitive aspects such as schools, daycare centres or important recreational areas. The sensitivity increases if there are nature conservation areas within the impact area whose grounds for protection depends on the noise level. In addition to exposed aspects, sensitivity is influenced by the area's current noise situation.	
Moderate	The aspects' sensitivity is moderate, given the number of holiday residences located within a radius of a few kilometres of the power plant area. However, there are no aspects that would be particularly sensitive to noise – such as schools or daycare centres – within the vicinity of the power plant area. The area currently has some operations that generate a degree of noise, mainly Loviisa power plant and waterborne traffic. In addition, the sounds of nature (wind and waves) function as a masking sound, due to which distinguishing the power plant's noise from the surroundings greatly depends on the weather conditions.

In the long-term noise measurements conducted in 2020, noise was measured in a variety of weather conditions. No measurement results exceeding the limit value of 45 dB were observed during the day. The measuring results at night were mostly within the limits of the 40 dB limit value, with the exception of one night, during which the measuring result was found to exceed the limit value at two measurement points. The measurement points in question are located at the holiday residences on the islands of Småholmen and Stora Täktarn, southeast and south of the power plant. The limit value being exceeded was probably attributable to the power plant.

Table 9-10 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.5.4 Environmental impact of extended operation

Impact formation

The operation of the power plant units would emit a level of noise similar to the current situation. The power plant's most significant sources of noise include the transformers, ventilation equipment and ejectors. During additional construction, noise could be caused by normal earthmoving machines, reach stackers and transport equipment, among other things.

The principal noise impacts of extended operation are similar to those in the current operations. While no changes in noise will take place in the event of extended operation, the possible modification and construction work may cause temporary noise.

In the noise measurements conducted in 2020, the power plant's noise level fell within the scope of the limit values, with the exception of a single individual occasion during which the night-time limit value was exceeded. The limit value being exceeded was probably attributable to the power plant. The noise measurements detected daytime and night-time noise levels from sound sources other than the power plant that exceeded the limit values. These were mainly the result of wind and waves.

Given that the measurements indicate that limit values may be exceeded under some operating and weather conditions even during current operation, the design of any new sources of noise or equipment to be placed in the power plant area will account for the fact that they may not significantly increase the operation's noise emissions, particularly during the night.

Any additional buildings to be built in the power plant area during the power plant's extended operation will not contain new sources of significant noise; rather, the building's ventilation equipment may generate a minor degree of noise. This noise will be detectable only at short distances.

During the construction of the additional buildings, noise will be generated by the earthworks and the erection of the buildings as well as equipment installation. The work will generate normal noise related to construction work and originating from earthmoving machines, reach stackers and other equipment used in construction. Traffic heading for the site, particularly heavy vehicle traffic, will also increase traffic noise near the transport routes to some extent.

Extending the operation of the power plant units is not expected to result in changes to the plant's current noise impacts, but the impacts will continue for another 20 years. The small-scale construction work to be carried out in the power plant area will not cause significant noise impacts.

9.5.5 Environmental impact of decommissioning

Impact formation

Noise in the expansion of the L/ILW repository is caused by the tunnelling and the transports of quarry material as well as the crushing of the material. The most significant noise in dismantling work is caused by the possible crushing of concrete and, to a lesser extent, by the other machinery in use and transports. Some functions generating noise will remain in the area during the operation of the plant parts to be made independent, but compared to the noise during the operation of the power plant, the noise is minor.

The power plant will still be in operation during the expansion of the L/ILW repository, generating noise in the same manner as during current operation.

Table 9-11. Significance of impacts: noise.

Significance of impacts: noise			
Operational phase	Sensitivity	Magnitude	Significance
Extending operation	Moderate	No change	**No impact,** given that the noise level caused by the power plant is low and is not expected to change.
Decommissioning	Moderate	Minor negative	**The significance of the impacts is minor and negative,** because the noise generated by various operations can carry over to the environment. The most significant sources of noise during decommissioning are the crushing and placement of the quarry material related to the quarrying of the L/ILW repository as well as the occasional noise caused by the crushing of concrete during the phase of conventional dismantling work leading up to a potential greenfield result. The noise caused by any crushing of concrete taking place outdoors may carry over to the power plant area's surroundings. In addition, the machinery and transports may occasionally generate stronger noise than the power plant currently does. At most, noise may momentarily be audible in the residential and holiday buildings on nearby islands and on the mainland.
Radioactive waste generated elsewhere in Finland	Moderate	No change	**No impact,** given that the option increases transports only slightly and their impact on increasing noise is negligible.

The most significant sources of noise in the expansion of the L/ILW repository are the transport of quarry material and its possible crushing. The drilling and blasting will take place within the rock, therefore generating very little noise or not generating noise that would spread into the environment. In tunnelling, the blasts and machinery generate gases and fumes which are removed from the tunnel with the help of ventilation. The fan operates with enhanced strength after a blast and may cause noise that spreads into the environment.

The standard noise emission of drilling, breaking and crushing equipment is approximately L_{WA} 120–125 dB per equipment which, as noise level, translates into L_{Aeq} at a distance of 10 m, for example, on open terrain 92–97 dB. The standard noise emission of excavators and wheel loaders is approximately L_{WA} 105–110 dB per equipment, meaning that the noise level is L_{Aeq} at a distance of 10 m, 77–82 dB. The noise emission of haul trucks and heavy earthmoving, or dump, trucks is typically 0–5 dB stronger than that of excavators and wheel loaders.

If the quarry material is broken and crushed above ground, rather than in the L/ILW repository, preliminary estimates deem the activity to be a stronger source of noise. The crushing and breaking activity will not be continuous, however. Instead, it will be carried out occasionally, when necessary. The noise caused by these work phases may be audible on the nearby islands and on the mainland. If the quarry material is placed in interim storage within the power plant area, its placement will result in a momentary noise impact on the vicinity. If the quarry material is transported elsewhere for interim storage, the transports will increase the noise generated by the heavy transports along the transport route.

Corresponding quarrying of the L/ILW repository has previously been carried out in the power plant area, due to which the noise impacts and the means by which to mitigate them are known. Based on them, the activities will be planned in such a way that the noise impacts can be mitigated. Of the activities to be carried out during the quarrying, the noise is nevertheless not expected to have a significant impact on areas beyond the power plant area.

The dismantling of radioactive plant parts to be carried out during the first dismantling phase will occur inside the reactor buildings, due to which the noise caused by the chipping and sawing of concrete and other dismantling work is likely to be confined within the power plant area.

If the buildings in the power plant area are dismantled entirely according to the greenfield principle, the activity causing the loudest noise will be the crushing of concrete, which will be carried out occasionally. The standard noise emission of concrete crushing is approximately L_{WA} 115 dB per mobile crushing equipment which, as noise level, translates into L_{Aeq} at a distance of 10 m on open terrain, 87 dB. The noise caused by concrete pulverisers and crusher buckets is more subdued than mobile crushing. The noise caused by the dismantling activities and concrete crushing may be audible on the nearby islands and on the mainland. Even so, the noise impact of such activities can be mitigated with the selection of the crushing location and dimensioned noise shields. Should the buildings be dismantled to the greenfield level, noise will also be generated by the dismantling equipment, the use of various machinery (excavators, wheel loaders and dozers) and the transport of dismantling waste within the power plant area and on nearby road networks.

Table 9-12. Example of the vibration limit values issued for a normal building with foundations on rock (the building's distance from the blasting site is 20 m) and an assessment of people's vibration experiences (Vuolio, 1999).

Human susceptibility	Maximum value of velocity amplitude (mm/s)	Vibration limit values for buildings with foundations on rock (distance 20 m)
Barely perceptible	2...5	
Detectable	5...10	Sensitive equipment
Unpleasant	10...20	
Disturbing	20...35	Historic ruins
Extremely unpleasant	35...50	
Extremely unpleasant	50...70	Normal building

Table 9-13. Sensitivity of affected aspect: vibration.

Sensitivity of affected aspect: vibration	
The aspect's sensitivity to vibration is determined through the current activities causing vibration in the area and the vibration tolerance of the buildings or equipment located in the impact area.	
Moderate	There are no other direct sources of vibration in the area than traffic. The nuclear power plant has been designed in such a way that its operations are not sensitive to vibration. The operation and design of the nuclear power plant also account for earthquakes, for example.

During the operation of the plant parts to be made independent, some functions generating noise will remain in use, but the noise will be minor compared to the noise during the power plant's operation. The second dismantling phase will generate less noise than the first dismantling phase, because there are fewer structures to be taken down within the buildings and because the noise consists mainly of transports hauling quarry material to the L/ILW repository.

The overall magnitude of the noise impacts during decommissioning is expected to be minor. Although the activity occasionally emits noise distinguishable from the background sound that can be detected on the nearby islands and on the mainland, the activities and functions can be planned in a way that allows for mitigating the noise impacts.

9.5.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the power plant area would not increase the noise impact.

9.5.7 Significance of impacts

Table 9-11 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.5.8 Mitigation of adverse impacts

In the event that operation is extended, the operations of noise sources are monitored and equipment will be serviced or replaced as necessary, if the noise level of a piece of equipment is deemed too high. If activities during decommissioning are expected to generate particular noise, attention can be paid to the planning of the required noise prevention measures and the scheduling of work phases. It may be necessary to inform the residents of nearby areas of the noisiest work phases.

9.5.9 Uncertainties

The noise measurements carried out have provided extensive data on the power plant's current noise. At their lowest, the measurement uncertainties have stood at ±3 dB during fair wind. In accordance with the guidelines on measuring environmental noise, a level of ±10 dB has been applied to the uncertainty, provided that the weather conditions during the measurement have not met the requirement of the guidelines.

The noise emissions of equipment used in construction and dismantling work are fairly well known. Some of the operations involved, however, may be decades away, when the equipment used may be different from the equipment in use now. Although the noise emissions are fairly well known, actual noise levels in the environment cannot be assessed with precision at this stage. Specified noise assessments can be carried out with the help of noise modelling, for example, and the possible noise prevention plans will be prepared once the work becomes topical and the implementation plans are sufficiently specific.

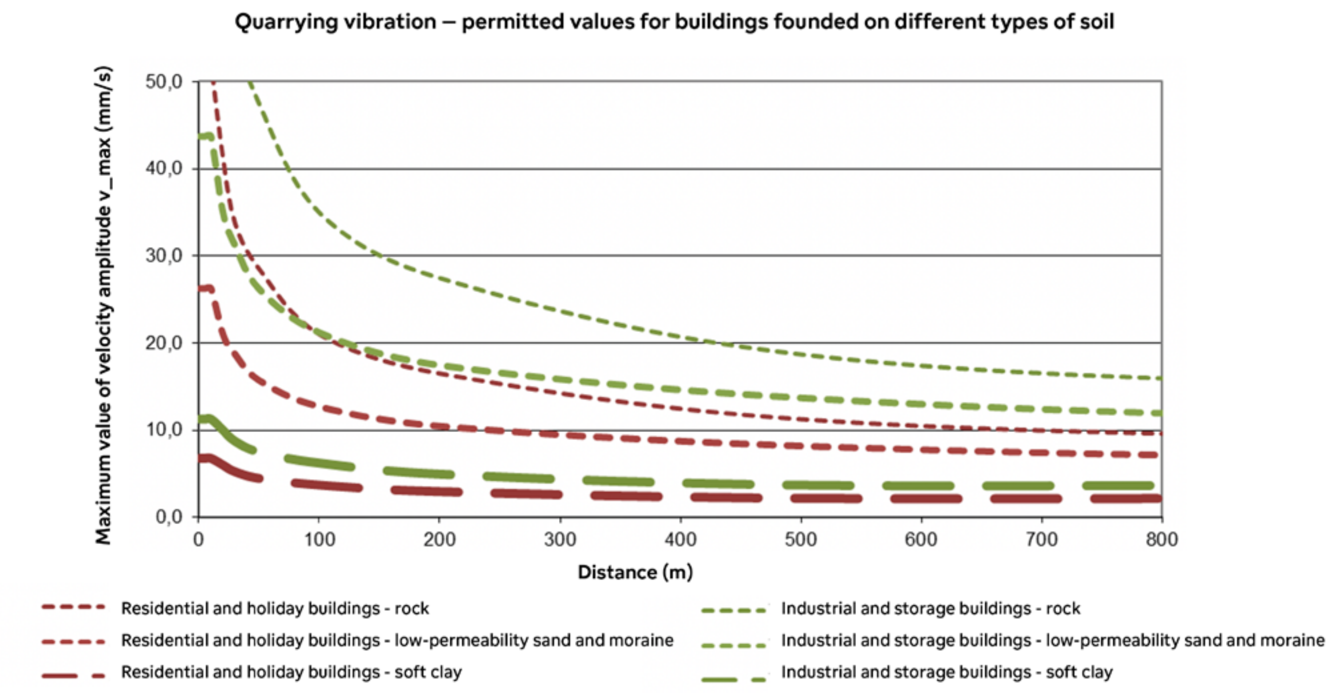

Figure 9-14. Velocity amplitudes values attributable to blasting and permitted for residential and holiday buildings as well as industrial and storage buildings on soft clay/sand or moraine with low permeability/ buildings with foundations on rock (RIL 2010).

9.6 VIBRATION

9.6.1 Principal results of the assessment

The power plant's operation does not cause vibration discernible to the senses beyond the power plant area, and extended operation would not change the situation. Nor would the minor vibration impact caused by traffic undergo a change compared to the current situation.

In decommissioning, the increased heavy vehicle transports may temporarily increase the discernible vibration caused by traffic to a slight degree in the immediate vicinity of the roads. Vibration will also be generated by the blasting related to the excavation of the L/ILW repository, which will be planned so that the vibration will not damage the operation of the nuclear power plant or the radioactive waste already in the L/ILW repository. The significance of the impact is, at maximum, minor and negative in terms of the decommissioning.

The reception of radioactive waste generated elsewhere in Finland is not expected to have vibration impacts.

9.6.2 Baseline data and assessment methods

Concerning vibration, the assessment examined particularly the impacts of vibration caused by the quarrying of the L/ILW repository and the dismantling activities. The assessment also considers the vibration impacts attributable to transports. The impacts of vibration have been assessed on the basis of the shock wave generated by the vibration source and the dispersion of the vibration. The assessment covered buildings and structures in the project area and the immediate vicinity as well as devices and equipment sensitive to vibration. The possible vibration disturbances experienced by people are assessed in Chapter 9.19.6.

The assessment was carried out in the form of an expert assessment based on, among other things, experiences gained from previous corresponding quarrying projects and the L/ILW repository's earlier blasting work, the vibration limit values applicable to normal buildings with foundations on rock and an assessment on people's vibration experiences (Vuolio 1999; Table 9-12 and Figure 9-14) as well as on empirical knowledge on the vibration impacts of heavy road and street traffic (e.g. Talja 2011).

9.6.3 Present state

In the current situation, the only source of vibration in the power plant area is the road traffic entering and exiting the area. The operation of the power plant does not cause vibration that can be detected by human senses outside the power plant area. 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.

Table 9-13 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

Table 9-14. Significance of impacts: vibration.

Significance of impacts: vibration			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extending operation	**Moderate**	**No change**	**No impact,** given that there would be no vibration discernible to human senses outside the power plant area. The minor vibration impact caused by traffic would remain unchanged compared to the current situation.
Decommissioning	**Moderate**	**Minor negative**	**The significance of the impacts is minor and negative,** because the increased heavy vehicle transports may temporarily increase the discernible vibration caused by traffic to a slight degree in the immediate vicinity of the roads. Vibration will also be generated by the blasting related to the excavation of the L/ILW repository, which will be planned so that the vibration will not damage the operation of the nuclear power plant or the radioactive waste already in the L/ILW repository.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No change**	**No impact,** given that the operations increase transports only slightly and their impact on increasing vibration is negligible.

9.6.4 Environmental impact of extended operation

Impact formation

Impact may be generated by traffic or any temporary vibration caused by the possible construction of additional buildings.

The operation of the power plant units does not currently generate vibration detectable by human senses outside the power plant area and will not do so if operation is extended. The vibration impact caused by traffic will remain unchanged in comparison to the current situation. Temporary vibration may be caused within the power plant area by the potential construction of additional buildings during the extended operation. The overall change in the vibration impacts is negligible.

9.6.5 Environmental impact of decommissioning

Impact formation

The vibration impacts will be generated by the underground blasting work related to the expansion of the L/ILW repository, the possible dismantling of buildings and the increased transports carried out by heavy vehicles.

During decommissioning, vibration will be generated by the underground blasting work to be carried out in relation to the expansion of the L/ILW repository, which will involve the construction of roughly 71,000 m^3 of new space in bedrock.

During excavation, the blasting will create a stress wave which results in not only the loosening of rock but movement, or vibration, in the particles of the medium. The magnitude of the vibration resulting from a blast is influenced by the quantity and quality of the explosive used as well as the blasting technique. The dispersion of the vibration depends, above all, on the soil conditions in the environment of the vibration source: the soil's softness, the thickness of the bedding planes and the variation therein (such as cross-bedding), the location of the surface of groundwater and the soil moisture. In connection with quarrying, the quality of the rock as well as the boundary between rock and soil also play an important role.

The quarrying of the L/ILW repository must be carried out with blasts small enough not to risk the safety of the power plant units still in use or damage the radioactive maintenance waste already being stored in the L/ILW repository. The L/ILW repository has existing spaces in bedrock through which the excavation related to the expansion will be carried out underground, on the same level as the current spaces are located. The right kind of planning and dimensioning of the explosive can prevent the risk of adverse impact on the area's equipment, buildings and structures caused by blast breaking conducted deep in the bedrock. The magnitude of the vibration caused by the breaking of very large boulders varies according to the breaking technique. According to studies, blast breaking does not cause significant vibration in the environment, even if the boulders to be blasted were in contact with solid bedrock. However, the shock wave moving through the air as a result of boulder blasting can be strong. The impact area of the vibration caused by the equipment used for rock crushing and other activities, such as drilling, is, in effect, very small. Crushing, for example, causes minor vibration, which is nevertheless undetectable other than within the immediate vicinity of the crusher.

The dismantling activities during decommissioning may generate momentary minor vibration right next to the site.

In addition, the increase in heavy vehicle transports may increase the vibration caused by traffic to a slight degree in the immediate vicinity of the roads. If the buildings in the power plant area are, in accordance with the greenfield principle, dismantled entirely, the dismantling work will cause momentary vibration, and the increased volume of dismantling waste will increase the need for heavy transports.

The vibration caused by traffic is the result of bumps in the road or changes to the surface of the road caused by vehicles. The ground begins to vibrate due to the interaction of the vehicle moving on the road, the road's properties and the soil beneath the road. The magnitude of the vibration caused by traffic is influenced by, among other things, the properties of the vehicle and the road as well as the driving speed. The soil's properties also have an effect on how the vibration wave progresses in the environment. The properties of the buildings located in the immediate vicinity of the road network also have an impact on the magnitude of the detectable vibration.

The adverse impact caused by vibration attributable to traffic depends on a number of parameters, which is why the assessment is largely based on empirical knowledge. The vibration of heavy road and street traffic may have adverse effects on housing located at a distance of 100 m from the road on soft soil and a distance of 15 m on hard soil (Talja, 2011).

The magnitude of the change in the vibration impact is expected to be, at maximum, *minor and negative* throughout the decommissioning. The blasting related to the expansion of the L/ILW repository must be planned and implemented in such a way that the adjacent nuclear power plant and its sensitive equipment or the radioactive waste in the L/ILW repository are not damaged. Corresponding measures were carried out during the previous quarrying of the L/ILW repository, when the barrels of maintenance waste in the repository were shielded from vibration damage by, for instance, supporting them with air-filled sacks and by limiting the vibration by cautious blasting and by protecting the spaces with temporary bursting panels.

The vibration caused by activities carried out in the power plant area during different phases of the decommissioning is not expected to extend, at maximum, beyond the immediate vicinity of the power plant area, and it will not have an impact on the nearest holiday or residential buildings, for example. The disturbance experienced by people due to traffic vibration is assessed in Chapter 9.19.6.

9.6.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the power plant area would not increase the vibration impact.

9.6.7 Significance of impacts

Table 9-14 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.6.8 Mitigation of adverse impacts

Harmful vibration can be mitigated by the proper planning and performance of work. While the vibration caused by blasting cannot be entirely eliminated, the adverse impacts caused by it can be mitigated with the right working methods and planned blasting. The dispersion of vibration can be influenced by the direction of excavating, and a correct specific charge helps ensure that the rock becomes loose in the desired boulder size. This also reduces the impact's spread into the environment compared to a situation where the charging is poor.

A risk analysis is usually conducted before excavation begins, surveying the measures that need to be conducted to ensure the safe performance of the blasting. The measures include investigating the need to inspect properties and identifying any risk aspects, mapping the need to investigate the conductivity of the vibrations caused by the blasting, and ensuring the use of suitable quantities of explosives. The risk analysis functions as a basis for determining the limit values for the velocity amplitude which measures vibration; these limit values may not be exceeded during blasting activities.

In terms of vibration, monitoring measurements conducted in facilities housing sensitive equipment are advisable. The measurements should also be conducted at sites with different types of soil and structure as well as from various distances and directions within the excavation area. The locations in which the vibrometers will be placed are determined in accordance with the preliminary risk analysis, based on the nearest buildings, structures or equipment confining the blasting. The vibration of sensitive equipment should be measured directly from the equipment, if possible.

The impacts of traffic vibration can be mitigated by, among other things, limiting driving speeds and ensuring that the roads are in good condition.

9.6.9 Uncertainties

The uncertainties in assessing vibration impacts relate mainly to the fact that there is no measured data on the current traffic vibration on the area's roads. Identifying the uncertainties involved in the blasting to be carried out during decommissioning relates to the quarrying plan to be prepared at a later date.

9.7 AIR QUALITY

9.7.1 Principal results of the assessment

In extended operation, the carbon dioxide, nitrogen oxide and sulphur oxide as well as particulate emissions into the air resulting from the power plant's operations will remain largely the same as they currently are, but will continue for another 20 years or so. According to the assessment, no limit or guideline values for air quality in the environment will be exceeded, and the extension of operation is not expected to have an impact on the area's current quality of air.

The impacts on air quality during decommissioning will vary during different phases of the decommissioning. The crushing of the quarry material related to the expansion of the L/ILW repository and the increased traffic will increase the area's dust and tailpipe emissions from time to time. These activities are neither simultaneous nor continuous. According to the assessment, the decommissioning will not cause the limit or guideline values for air quality in the environment to be exceeded. The significance of the impacts during the decommissioning phase is minor and negative.

The impact that the transports of radioactive substances generated elsewhere in Finland will have on the quality of air were deemed negligible.

9.7.2 Baseline data and assessment methods

The description of the present state of the air quality has relied on the results of studies related to air quality. Monitoring in the Uusimaa region has been carried out by the Helsinki Region Environmental Services (HSY), among others. The emissions caused by the operation of the power plant's emergency diesel generators and diesel-powered emergency power plant are presented based on the operating times and estimated fuel consumption of the current power plant. The impact assessment also accounts for traffic's tailpipe emissions and the emissions of the quarrying and dismantling activities of the decommissioning. The project's impacts on air quality have been assessed in the form of an expert assessment, based on data obtained on the present state of the area's air quality, the emissions into the air caused by the operation, and the traffic volumes.

The impact that emissions of radioactive substances have on the quality of air are assessed in Chapter 9.8. The impact assessment on greenhouse gas emissions is covered in Chapter 9.12.

9.7.3 Present state

Conventional emissions into the air (including nitrogen and sulphur oxides and dust) on the island of Hästholmen are so low that no monitoring of air quality in terms of them has been required in the area. The following is a general description of the air quality in the area of Loviisa, drawn up on the basis of available emission and air quality measurements.

No regular air quality measurements are carried out in the Loviisa area, but the most significant sources of emissions generating impurities are reported. The air quality in Loviisa is good, because there are no major industrial facilities that would impair the quality of air in the municipality. What most impairs air quality in the area of Loviisa is traffic and the combustion of wood. Wood combustion has a great impact on air quality, accentuated because the emissions are discharged from a low altitude. (Uusimaa Centre for Economic Development, Transport and the Environment, 2020)

In Loviisa, road traffic accounts for the majority of the nitrogen oxide and carbon monoxide emissions, which concentrate on the areas near Highway 7 and the town centre. Traffic volumes in Loviisa are relatively low, however. In 2018, the nitrogen oxide emissions caused by Loviisa's road traffic, energy production, industry and harbours were 192 tonnes, 42 tonnes, 0 tonnes and 23 tonnes, respectively. The particulate emissions caused by Loviisa's road traffic, energy production, industry and harbours were 5 tonnes, 8 tonnes, 0.1 tonne and 0.5 tonnes, respectively. The sulphur oxide emissions caused by Loviisa's road traffic, energy production, industry and harbours were 0.3 tonnes, 1 tonne, 0 tonnes and 0.7 tonnes, respectively. The carbon monoxide concentrations caused by Loviisa's road traffic were 203 tonnes, and that of its harbours 3 tonnes, in 2018. In addition to the local emissions, the area's air quality is also affected by long-range air pollution. Based on air quality measurements carried out in the Helsinki metropolitan area and elsewhere in Uusimaa, it has been estimated that the concentrations of nitrogen oxide, breathable particles and microparticles have been below the limit values. As a health protection measure, limit values have been set for certain air impurities in outdoor air to indicate the highest permitted value of air impurities (Government Decree 79/2017) (Uusimaa ELY Centre 2020).

The impact that residential wood combustion has on Loviisa's air quality was monitored in 2014 by measurements of benzo[a]pyrene at the intersection of Puutarhakatu and Vesikuja, in an area of low-rise buildings. In Loviisa, the annual concentration of benzo[a]pyrene was 0.7 ng/m^3, i.e. below the target value. The impact that wood combustion has on the air quality is nevertheless clearly detectable. (Uusimaa Centre for Economic Development, Transport and the Environment, 2020)

Air quality and its development in Uusimaa and eastern Uusimaa have been investigated with the aid of regular bioindicator studies since the 1980s. The studies assess air quality on the basis of the occurrence and condition of pine's epiphyte lichens. According to the results of the study conducted in 2014, the lichens were in decline and their condition had deteriorated compared to studies conducted in 2000 and 2009. According to the research results, the lichens in Loviisa were the most diverse among the municipalities covered by the study (the study included 22 municipalities). (Uusimaa Centre for Economic Development, Transport and the Environment, 2015) The bioindicator study was also conducted in late 2020, but the results are yet to be reported.

Table 9-15 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

Table 9-15. Sensitivity of affected aspect: air quality.

Sensitivity of affected aspect: air quality	
The sensitivity of the affected aspect is determined on the basis of the area's current activities impacting air quality and the sensitive aspects located in the area.	
Minor	The area is, to a slight degree, sensitive to changes regarding air quality. The area is not home to any major activity with an impact on air quality. There are no sensitive aspects, such as schools or daycare centres, in the area or in its immediate vicinity. There are no residential areas or nature reserves in the immediate vicinity of the area.

Table 9-16. The fuel powers and average emissions of Loviisa power plant's diesel plant and diesel-powered emergency power plant in 2014-2020.

	Fuel power	Carbon dioxide, CO_2 (t)	Nitrogen oxides , NO (t)	Sulphur dioxides, SO_x (t)	Particulates (t)
Diesel plant	8 x 6,7 MW	630	17,2	0,4	0,02
Diesel-powered emergency power plant	23 MW	94	2,2	0,06	0,003
Total		**724**	**19,4**	**0,46**	**0,023**

9.7.4 Environmental impact of extended operation

Impact formation

The impact that extended operation would have on air quality would be almost entirely attributable to the testing of the emergency diesel generators and diesel-powered emergency power plant and the traffic in the area. The emergency diesel generators and diesel-powered emergency power plant cause carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions. Any modification and additional construction work carried out in the area during extended operation could have a temporary impact on air quality.

Operations during extended operation will continue in their present form, due to which the emissions into air would remain largely the same as they currently are.

The AC supply for equipment important for the safety of both power plant units is backed up by four 2.8 MW emergency diesel generators separated from each other. 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 9.7 MW diesel-powered emergency power plant in the power plant area functions as a reserve supply connection independent of Loviisa's external connections. The diesel-powered emergency power plant undergoes a test run every six weeks, for about an hour at a time. The 20 kV connection from the nearby Ahvenkoski hydro power plant serves as an alternative power supply for the above.

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. The average annual carbon dioxide emissions have amounted to approximately 720 tonnes, while the equivalent figures for nitrogen oxides, sulphur oxides and particulate emissions have been approximately 19 tonnes, 0.5 tonnes and 0.02 tonnes, respectively. Table 9-16 shows the emergency diesel generators' and the diesel-powered emergency power plant's fuel powers and average emissions in 2014-2020.

The impacts on air quality attributable to the use of the emergency diesel generators and the diesel-powered emergency power plant are not continuous, because the equipment in question is operated only in connection with testing. When comparing the emissions of the emergency diesel generators and the diesel-powered emergency power plant to the total emissions of Loviisa's road traffic, energy production, industrial activity and harbours, the emissions are low and do not impair the local air quality.

The impacts on air quality in the area are caused by the road traffic (passenger traffic and other transport). The most significant tailpipe emissions generated by road traffic are nitrogen oxide and sulphur oxide emissions as well as particulate emissions. In addition, air quality is impaired by the higher particulate concentrations caused by road traffic during the road dust season. The road traffic's carbon dioxide emissions are calculated in Chapter 9.12. In the event of extended operation, the power plant's traffic volumes will remain at the same level as during current operation, due to which the maximum tailpipe emissions will be of the magnitude caused by current operation. Future tailpipe emissions may decline as old cars are replaced by new ones and electric cars become more common. The impact area of transport emissions covers the entire transport distance, and the emissions are part of the emissions of the region's other road traffic.

Modification and additional construction work may be carried out in the power plant area during extended operation. Such work may have temporary impacts on air quality. These impacts will not be continuous and any particulate (dust) emissions caused by construction, for example, will be local and occur in the immediate vicinity of the emission sources.

In the event of extended operation, the emissions into air resulting from the power plant's operation will remain largely unchanged from what they currently are, although they will continue for another 20 years or so. No limit or guideline values for air quality in the environment will be exceeded due to extended operation, and the extended operation is not expected to have an impact on the area's current quality of air.

9.7.5 Environmental impact of decommissioning

Impact formation

The power plant will continue to produce electricity during the preparation phase of decommissioning, and impacts on air quality will be generated in the same way as during extended operation – i.e. from the use of the diesel generators and emergency power plant and by the traffic in the area. The expansion of the L/ILW repository will have an impact on air quality. Dust emissions related to the expansion will be generated by the underground blasting work, for example, and by transports and the stacking of soil. The underground blasting also involves nitrogen and sulphur oxide emissions. The impacts on air quality will vary during different phases of decommissioning.

The most significant impacts on air quality will be attributable to the expansion of the L/ILW repository. The most significant emission into air during the L/ILW repository's expansion phase consists of dust. Dust emissions related to the expansion will be generated by the underground blasting work, for example, and by the crushing of the quarry material, transports and the stacking of soil. The dust emissions will not be continuous, and they will occur in the immediate vicinity of the emission source. The underground blasting also involves nitrogen and sulphur oxide emissions. Estimates put the amount of explosives used at approximately 50 tonnes. During the expansion of the L/ILW repository, there will be an increased volume of traffic in the area, especially if the quarry material is transported elsewhere from the power plant area, which will increase the operation's tailpipe emissions.

The emissions generated during the first dismantling phase in accordance with the brownfield principle would consist primarily of the tailpipe and dust emissions of traffic. The dust emissions will not be continuous, and they will occur in the immediate vicinity of the emission source. The radiation impacts of the dismantling work involving radioactive parts during the first dismantling phase are assessed in Chapter 9.10.5.

During the operation of the plant parts to be made independent, the diesel generators will continue to secure the power supply, and the testing of the generators will result in carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions. The number of diesel generators during the operation of the plant parts to be made independent will be lower than during the power plant's operation, due to which the emissions will be markedly lower. Traffic volumes will reduce during the operation and decommissioning phase of the plant parts to be made independent and during the closure of the repository, due to which tailpipe emissions will also reduce.

Table 9-17. Significance of impacts: air quality.

Significance of impacts: air quality			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extending operation	**Minor**	**No change**	**No impact,** given that no limit or guideline values in terms of the air quality in the environment would be exceeded and that the carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions into the air would remain largely unchanged.
Decommissioning	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** because the tailpipe and dust emissions attributable to traffic will increase and because the crushing of quarry material may cause dust emissions. The impacts on air quality will vary during different phases of the decommissioning. The activities are neither simultaneous nor continuous. The decommissioning will not cause the limit or guideline values for air quality in the environment to be exceeded.
Radioactive waste generated elsewhere in Finland	**Minor**	**No change**	**No impact,** because the number of transports is low.

During the operation of the plant parts to be made independent, the operation will be of a smaller scale than during current operation, due to which the impacts on air quality will be smaller than in connection with extended operation. During the operation of the plant parts to be made independent, the diesel generators and emergency power plant will nevertheless remain in use, and this use will result in carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions. Traffic volumes will reduce during the operation and decommissioning phase of the plant parts to be made independent and during the closure of the repository, due to which tailpipe emissions will also reduce.

Impacts on air quality during the second dismantling phase will be attributable to the dust emissions related to the repository's closure and to tailpipe emissions, Activities that raise dust during the closure of the repository include work related to the filling of the repository and the transport of the quarry material. Once the L/ILW repository has been permanently closed, the operations will generate very little emissions into air, given that the passenger traffic and transport with heavy vehicles related to the operation of the power plant will come to an end.

If the power plant area's buildings are dismantled entirely, in accordance with the greenfield principle, air quality impacts may be caused by the dismantling of conventional, non-active parts and the crushing of concrete, mainly in the form of dust emissions and the tailpipe emissions of traffic. The dust emissions will not be continuous, and they will occur in the immediate vicinity of the emission source.

The impacts on air quality will vary during different phases of decommissioning, being at their maximum during the expansion of the L/ILW repository. The impacts that all activities will have on air quality will not occur simultaneously during the decommissioning phase. Nor will the emissions be continuous, and the impact of dust will occur primarily within the immediate vicinity of the emission sources. The impact area of traffic emissions covers the entire transport distance. According to the assessment, the impact of the decommissioning operations will not cause the limit or guideline values for air quality in the environment to be exceeded. Overall, the magnitude of the change is expected to be *minor and negative.*

9.7.6 Radioactive waste generated elsewhere in Finland and its impact

The estimated maximum number of transports of radioactive waste generated elsewhere in Finland is some 10 transports a year, due to which the tailpipe emissions of these transports will have, in effect, no impact on the air quality. The magnitude of the change with regard to air quality is expected to be negligible.

9.7.7 Significance of impacts

Table 9-17 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.7.8 Mitigation of adverse impacts

The impacts of the quarrying of the L/ILW repository, the crushing and interim storage of the quarry material as well as the possible crushing of the concrete related to the dismantling operations can be mitigated by the scheduling of the operations (phases which raise more dust are not, insofar as possible, carried out simultaneously and wind conditions are taken into account). The emissions of transports can be reduced by optimising transport times and routes and by increasing the share of renewable energy sources in the transports' fuels.

9.7.9 Uncertainties

The tailpipe emissions caused by traffic are likely to reduce through technological advances, when looking at the average emissions of cars. Tailpipe emissions will reduce with the increased use of electric cars, for instance. The assessment of the dust impacts caused by construction involves uncertainties. The dust emission will be greater if several operations raising dust will be carried out at the same time and if the weather conditions furthermore have an impact on how the dust spreads into the environment. The greater the need for additional and new buildings is, the greater the impacts on air quality will be.

9.8 EMISSIONS OF RADIOACTIVE SUBSTANCES AND RADIATION EXPOSURE

9.8.1 Principal results of the assessment

In the case of extended operation, the radiation doses of Loviisa power plant's personnel are expected to remain on a par with the radiation doses caused by current operation. The impact that radioactive emissions resulting from normal operation has on the radiation load of the surrounding nature and the radiation exposure of residents in the surrounding area is expected to be very low, as in the current situation. The calculated radiation dose caused by the radioactive emissions of Loviisa nuclear power plant to residents in the surrounding area in 2010–2019 was 0.00014...-0.00029 mSv a year. The radiation dose caused has remained significantly less than one per cent of the dose constraint provided in the Nuclear Energy Decree (161/1988), which is 0.1 mSv a year. The dose constraint is approximately one sixtieth of the average annual radiation dose of a person residing in Finland (5.9 mSv).

The radiation doses of the personnel during the decommissioning phase of Loviisa power plant are also expected to remain significantly below the set dose limits. The emissions into the air and waterways during the decommissioning phase cannot be estimated accurately at this point. The methods used for the decommissioning will be selected so that the emission limits will not be reached, meaning that the radiation impact will be very low. The maximum impact of the decommissioning during the most active dismantling phase is expected to be minor and negative. In any case, the power plant's impact will reduce towards the end of the decommissioning and finally come

to an end once the last plant parts which have been made independent have been decommissioned and the L/ILW repository has been closed.

In principle, the handling of radioactive waste generated elsewhere in Finland complies with Loviisa power plant's established practices, procedures and instructions, which ensure the personnel's radiation protection.

9.8.2 Baseline data and assessment methods

Employees' radiation exposure and the impacts of any emissions of radioactive substances in the case of extended operation were assessed on the basis of Loviisa power plant's actual emissions of radioactive substances and employees' radiation doses.

The calculated radiation dose of the residents in the surrounding area was assessed on the basis of the emissions of Loviisa power plant's normal operation. The calculated radiation doses are presented in the annual report for environmental radiation safety. The radioactive emissions into the air and waterways resulting from current operations, as well as the calculated radiation doses they cause to residents in the surrounding area, are presented and compared with the set emission limits and dose constraints.

The personnel's radiation doses and any radioactive emissions resulting from the handling and final disposal of radioactive waste, including waste generated elsewhere in Finland, are described in more detail in Chapter 9.10, as are their impacts.

In the case of decommissioning, the power plant will no longer be in operation, due to which emissions comparable to emissions during operation will not be generated. The impacts of decommissioning are presented on the basis of Loviisa power plant's decommissioning plan.

9.8.3 Present state

9.8.3.1 Employees' exposure to radiation

The radiation protection measures of Loviisa power plant are discussed in Chapter 7.3. The monitoring of the radiation exposure of Loviisa power plant's employees aims to ensure that the radiation exposure is kept as low as reasonably achievable, and that the dose limits specified for radiation workers in the Government Decree on Ionising Radiation (1034/2018) are not exceeded. The effective dose of a radiation worker may not be greater than 20 mSv a year. Loviisa power plant has furthermore set a lower individual dose constraint in accordance with YVL C.1 in its ALARA operational programme.

In addition to individual doses, Loviisa power plant monitors the employees' collective (aggregate) radiation dose. Loviisa power plant has set a dose constraint in accordance with YVL Guide C.2 for the collective radiation dose.

The people working in Loviisa power plant's radiation controlled area are radiation workers covered by the scope of individual radiation dose monitoring. The radiation exposure data are exported monthly to the dose registry maintained by STUK, and the results are presented in Loviisa power plant's annual report.

The factors impacting the radiation exposure of Loviisa power plant's employees are the radiation levels, the use of radiation shields and the duration of the radiation exposure. Employees' radiation doses arise primarily during annual outages. The length of the annual outages and work tasks relevant in terms of radiation protection have an impact on the magnitude of individual doses and the collective dose. The vast majority of the personnel's radiation doses at Loviisa power plant is attributable to work carried out in proximity to the primary system during annual outages. Greater annual variations are explained by more extensive annual outages, which involve more work carried out in the vicinity of active components and opened systems.

The radiation doses of Loviisa power plant's radiation workers are discussed in Chapter 7.3. Individual doses at Loviisa power plant have remained below 20 mSv throughout the 2000s: The largest annual dose of a Loviisa power plant employee in 2001–2020 was 6.3–19.5 mSv, and the average dose of all radiation workers during this period was 0.4–1.9 mSv. The collective radiation doses of Loviisa nuclear power plant's employees in 1977–2019 are shown in Figure 9-15. The impact that the longer annual outages, occurring during even years, have on the collective radiation dose are clearly distinguishable in the figure.

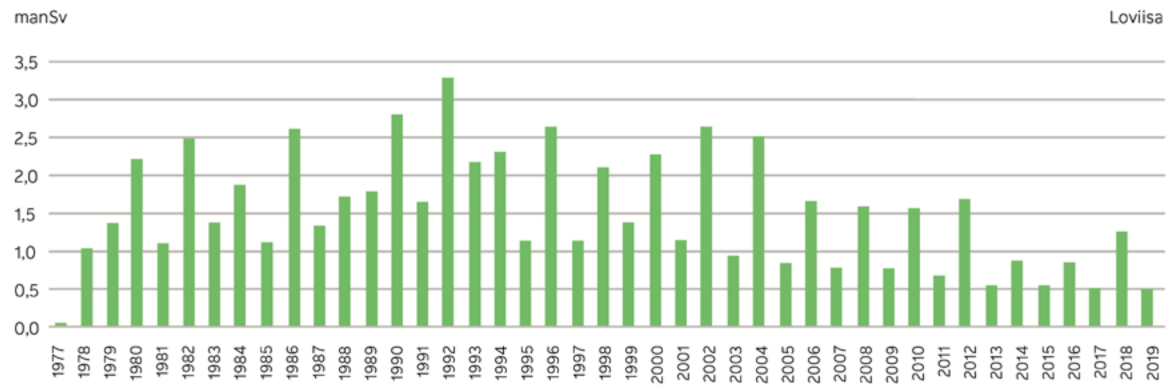

Figure 9-15. The collective (aggregate) radiation doses of Loviisa nuclear power plant's workers in 1977–2019. (STUK Guide 2021b)

9.8.3.2 Radioactive emissions

Loviisa nuclear power plant generates radioactive substances during its operation. Most of the radioactive substances build up and remain in the nuclear fuel. Nevertheless, some radioactive substances can be found in the cooling systems of the reactor and storage pools for spent fuel, as well as in the related purification and waste systems. Small amounts of radioactive substances are released into the air and waterways in a controlled manner. The emissions of radioactive substances and their limitation are discussed in Chapter 4.12.

The emissions of radioactive substances released into the environment are determined on the basis of air and water samples taken from the emission routes. The emission data are reported to STUK every three months and presented in the annual report for environmental radiation safety every year.

Loviisa power plant has set emission limits for the emissions of radioactive substances so that emissions occurring as a result of the plant's normal operation over any particular year do not exceed the annual dose limit for a member of the public in the surrounding area. Loviisa power plant has also set lower target values for the emissions of radioactive substances in the ALARA operational programme.

Emissions of radioactive substances into the air

The gaseous emissions of radioactive substances resulting from the operations of Loviisa power plant are collected, filtered if necessary and delayed before being conducted into the atmosphere via a ventilation pipe. The airflow passing through the vent stack is monitored with a duplicated activity measurement and sampling system.

Loviisa power plant's emissions of radioactive substances into the air in 2009–2019 are presented in Chapter 4.12.1, and the average emissions and emission limits for the years in Chapter 9.8.4. The emissions into the air during the period in question have remained significantly below the emission limits. No significant changes have taken place in the emissions of noble gases. The dominant substance in the emissions has been argon-41, which is generated as a result of the activation of the argon-40 nuclide, occurring naturally in the air between the reactor pressure vessel and the primary radiation shield. The small fuel leaks at the power plant units in 2009, 2010 and 2013 resulted in iodine emissions (I–131 e.) slightly higher than during other years. In terms of aerosol emissions in particulate form, the larger-than-usual emissions in 2013 resulted from both power plant units releasing short-lived arsenic-76 into the air due to additional shutdowns.

Emissions of radioactive substances into the waterways

The liquid emissions of radioactive substances generated in the operations of Loviisa power plant are treated by filtering and delay before they are released into the sea in controlled batches within the cooling water. The activity and emissions are monitored with the help of measurements and sampling. The sampling allows an emission's radioactive composition and activity to be identified. In addition, the emission route is monitored with continuous radiometry.

Loviisa nuclear power plant's emissions of radioactive substances into the waterways in 2009–2019 are presented in Chapter 4.12.2, and the average emissions and emission limits for the years in Chapter 9.8.4. The emissions of radioactive fission and activation products as well as tritium during the period in question have remained significantly below the set emission limits. In 2009, 2013 and 2017, Loviisa power plant carried out a scheduled discharge of low-level evaporation sludge into the sea, due to which the emissions of fission and activation products were larger than average. Tritium discharges into the waterways remained stable in 2009–2019. In respect of fission and activation products, emissions into the sea have reduced in recent years.

9.8.3.3 Radiation exposure of population in the surrounding area

The radiation exposure of people living in the area surrounding Loviisa power plant is assessed on the basis of actual annual emissions and meteorological measurements. The emissions are efficiently diluted within the atmosphere or sea, due to which only very small concentrations of radioactive substances accumulate in the environment. The emissions resulting from normal operation are so small that it is impossible to measure the radiation dose of members of the public attributable to them. This is why the radiation doses of members of the public are calculated. The methods employed in the dose calculations are described in Chapter 9.21.

According to the Nuclear Energy Decree (161/1988), the limit for an annual dose of a member of the public resulting from the normal operation of nuclear power plants is 0.1 mSv a year. This is equal to around one sixtieth of the average annual radiation dose of a person residing in Finland, 5.9 mSv (STUK 2021). The calculated radiation dose caused by the radioactive emissions of Loviisa power plant to a resident in the surrounding area in 2010–2019 ranged between 0.00014 mSv and 0.00029 mSv a year. The radiation dose caused has remained significantly less than one per cent of the set dose constraint.

9.8.3.4 Environmental radiation monitoring

Fortum monitors the environment of Loviisa power plant in accordance with the environmental radiation control programme. STUK also carries out its own independent monitoring in the environment of Loviisa power plant. Loviisa power plant's current environmental radiation control programme is described in Chapter 11.

The radioactive substances found in the surroundings of Loviisa power plant may include radioactivity present in nature (such as beryllium-7 and potassium-40), or they may originate from Loviisa power plant or elsewhere. Radioactive substances carried to the area from elsewhere, such as caesium-137, are derived from nuclear weapons tests and the Chernobyl nuclear power plant accident, for example.

Nuclides originating from Loviisa power plant are seldom detected, and the detected concentrations are very small.

They are usually detected from the air or fallout samples (fallout from the atmosphere to the soil). Nuclides originating from Loviisa power plant's emissions have not been detected in plants used for human consumption, milk or meat. The radioactivity levels detected in samples from the water environment have been low, and findings have mainly been made in the sinking matter and indicator organisms that absorb radioactivity but are not part of human nutrition. Radioactive substances originating from the power plant have not been detected in fish. The results of the measurements of external radiation have not shown abnormal results caused by Loviisa power plant.

9.8.3.5 Sensitivity

Table 9-18 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.8.4 Environmental impact of extended operation

Impact formation

During its operation, a nuclear power plant generates radioactive substances, the radiation of which may affect people's health. The quantity of radioactive substances released into the environment is constrained efficiently by filtering and delaying the emissions so that their radiation impact on the environment is very small compared to the impact of naturally occurring radioactive substances. The radiation doses of a plant's employees arise primarily during the annual outages of nuclear power plants, when the employees work in the vicinity of active components and opened systems.

Loviisa power plant has had a very low number of fuel leaks, which is an indication of the high quality and safe use of the fuel. This contributes in a major way to both the personnel's radiation doses, and to keeping the emissions of radioactive substances and the resulting radiation doses of members of the public as low as possible.

Loviisa power plant monitors advances in technology and carries out measures aiming to reduce contamination levels, radiation levels, emissions and radiation doses in accordance with the principle of continuous improvement. In addition, Fortum aims to actively develop operations in a direction which reduces the personnel's radiation doses and emissions into the environment. This would also apply to any future extended operation. Numerous improvements which have significantly reduced both the personnel's radiation doses (Figure 9-15) and emissions into the environment (Chapter 4.12) have already been carried out during the power plant's operation. The feasibility studies concerning development measures account for the ALARA and BAT principles in particular. Loviisa power plant's ALARA operational programme discusses the short and long-term objectives which aim to optimise the employees' radiation doses and to minimise environmental emissions, and thereby the radiation doses of residents in the surrounding area.

In the event that operation is extended, Fortum is unaware of any factors that would significantly increase the radiation dose of Loviisa power plant's employees from its current level. Therefore, based on current operations, the personnel's radiation doses during the normal operation of Loviisa power plant are expected to remain significantly below the set dose limits, as in the present situation (see Chapter 9.8.3.1).

Nor is Fortum aware of any factors that would significantly increase the emissions of Loviisa power plant's normal operation from their current levels in the event that operation were extended. Based on current operations, the emissions into the environment resulting from the normal operation of Loviisa power plant are indeed expected to remain very low and to continue to fall below the emission limits set for them. A summary of Loviisa power plant's average emissions of radioactive substances into the air and waterways during normal operation, as well as an estimate regarding extended operation, is shown in the tables below in Table 9-19 and Table 9-20.

Should the emissions remain at the current level, their impact on the radiation exposure of residents in the surrounding area and on the radiation load of the surrounding nature is also expected to remain very low, as in the current situation (see Chapters 9.8.3.1 and 9.8.3.4).

Despite the development measures, the magnitude of the change – in terms of both the personnel's radiation dose and the radiation impact radioactive emissions have on the environment – is expected to be at most *minor and negative,* when accounting for the additional years of operation.

The environmental impact of extended operation in terms of spent nuclear fuel, as well as low-level and intermediate-level waste, is described in Chapter 9.10.4.

9.8.5 Environmental impact of decommissioning

Impact formation

In decommissioning, the power plant will no longer be in operation, due to which emissions comparable to emissions during operation will not be generated. The dismantling activities will result in controlled radioactive emission into the air and waterways as well as in the radiation exposure of mainly personnel participating in the dismantling work and waste handling.

The Nuclear Energy Decree sets the limit for the annual dose to which a member of the public can be exposed to in connection with the decommissioning, according to plan, of a nuclear power plant or other nuclear facility with a nuclear reactor at 0.01 mSv (section 22 b 161/1988).

The emissions into the air and waterways generated during Loviisa power plant's decommissioning phase cannot be estimated at this stage of planning, given that all the dismantling and treatment methods to be used have yet to be specified and selected. As the planning of the decommissioning progresses, Loviisa power plant will determine the targets and emission limits for the decommissioning phase's emissions of radioactive substances. The decommissioning methods will be selected so that the set emission limits will not be reached, due to which the radiation impact can be expected to be very low.

The work to be carried out in an area defined a radiation controlled area during decommissioning will still be radiation work, subject to the same safety and radiation protection principles as complied with during the power plant's operation. The radiation doses caused to the personnel of Loviisa nuclear power plant in the case of decommissioning are expected to remain significantly below the set dose limits, as is the case in the current operation (see Chapter 9.8.3.1). Current estimates put the collective radiation dose to be accumulated during the preparation and dismantling phases at around 10 manSv (see Chapter 9.10.5.2).

The magnitude of the change in the impact of the decommissioning is expected to be at most *minor and negative.* In any case, the impact will reduce towards the end of the decommissioning and finally come to an end once the last plant parts which have been made independent have been decommissioned.

The handling and final disposal of spent nuclear fuel as well as low-level and intermediate-level waste are assessed in more detail in Chapter 9.10.5.

9.8.6 Radioactive waste generated elsewhere in Finland and its impact

The volume of radioactive waste generated elsewhere in Finland is low compared to the volume of Loviisa power plant's radioactive waste, and the impact that its handling and final disposal will have on the radiation doses of the personnel and residents in the surrounding area will be minor in relation

Table 9-18. Sensitivity of affected aspect: emissions of radioactive substances and radiation exposure.

Sensitivity of affected aspect: emissions of radioactive substances and radiation exposure	
The affected aspect's level of sensitivity is determined according to the radiation dose caused to a resident of the surrounding area from normal operation.	
Minor	In Finland, the limit for an annual dose of a member of the public resulting from the normal operation of nuclear power plants is 0.1 mSv a year (161/1988). The radiation dose caused by Loviisa power plant to residents in the surrounding area in recent years has been significantly less than one per cent of the dose constraint.

Table 9-19. Loviisa nuclear power plant's emission limits and actual annual emissions of radioactive substances into the air as an average in 2009–2019. An estimate with regard to extended operation is also shown.

Radioactive emissions	Current operation of the power plant		Extending operation
	Emission limit (TBq/year)	Actual (TBq/year) average in 2009-2019	
Noble gases (Kr-87 equivalent)	14,000	5.8	No significant change
Iodines (I-131 equivalent)	0.22	0.00001	No significant change
Tritium (H-3)	–*	0.2	No significant change
Aerosols	–*	0.00014	No significant change
Carbon-14 (C-14)	–*	0.4	No significant change

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

Table 9-20. Loviisa nuclear power plant's emission limits and actual annual emissions of radioactive substances into the waterways as an average in 2009–2019. An estimate with regard to extended operation is also shown.

Radioactive emissions	Current operation of the power plant		Extending operation
	Emission limit (TBq/year)	Actual (TBq/year) average in 2009-2019	
Tritium (H-3)	150	16	No significant change
Other fission and activation products	0.89	0.0006	No significant change

Table 9-21. Significance of impacts: emissions of radioactive substances and radiation exposure.

Significance of impacts: emissions of radioactive substances and radiation exposure			
Operational phase	Sensitivity	Magnitude	Significance
Extending operation	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the emissions of radioactive substances and the radiation exposure attributable to the operation would continue to be minor. The personnel's radiation doses resulting from normal operation would remain on par with what they currently are. The impact that radioactive emissions resulting from normal operation would have on the radiation load of the surrounding nature and the radiation exposure of residents in the surrounding area is expected to remain very low, as in the current situation. 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.
Decommissioning	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the personnel will be exposed to minor radiation, which will remain clearly below the set dose limits, during the dismantling phase of active parts. The decommissioning methods will be selected so that the set emission limits will not be reached, due to which the radiation impact can be expected to be very low. The impact will reduce towards the end of the decommissioning and finally come to an end once the last plant parts which have been made independent have been decommissioned.
Radioactive waste generated elsewhere in Finland	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** because the low and intermediate-level waste that would be received at the power plant could be, in terms of the radionuclides, of a different type than the waste generated by the power plant. The impact that the handling and final disposal would have on the radiation doses of the personnel and members of the public in the surrounding area would be minor compared to the waste originating from Loviisa power plant.

to waste originating from Loviisa power plant. The impacts of the handling and final disposal of radioactive waste generated elsewhere in Finland are described in Chapter 9.10.6.

9.8.7 Significance of impacts

Table 9-21 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.8.8 Mitigation of adverse impacts

The limitation of radioactive emissions into the air and waterways is described in more detail in Chapter 4.12, and the protection measures related to radiation in Chapter 7.3.

9.8.9 Uncertainties

The uncertainty in assessing the impact of decommissioning is increased by the fact that a detailed plan of the decommissioning work is yet to be prepared. The emissions into the air and waterways 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 yet to be specified and selected. The targets and emission limits for radioactive emissions during the decommissioning phase will be defined as the decommissioning plans progress.

9.9 USE OF NATURAL RESOURCES

9.9.1 Principal results of the assessment

Extending operation would not change the power plant area's current constraints for the use of natural resources.

In the case of extended operation, the use of natural uranium in the nuclear fuel will continue. Natural uranium is classified as a non-renewable resource, which is used, in essence, only by the nuclear power and defence industries. At an annual level, the volume of uranium concentrate required by Loviisa power plant in the case of the extended operation would be around 0.33% of uranium's annual production volume, and its total volume would be approximately 0.05% of the uranium reserves used with the current technology and at uranium's current price level. In addition to the aforementioned, when accounting for estimates concerning uranium reserves yet to be discovered, uranium reserves to be used at a higher price, and estimates on the growth of uranium's global demand, the impact that extended operation would have on the uranium reserves is expected to be negligible.

In the case of decommissioning, the significance of the impacts is minor and positive, given that the reuse of the quarry material generated in the quarrying of the L/ILW repository is considered to promote the circular economy, since its use can substitute for the procurement of virgin rock either in the closure of the L/ILW repository or in other construction.

Radioactive waste generated elsewhere in Finland would not have an impact on the use of natural resources.

9.9.2 Baseline data and assessment methods

The impacts of the use of natural resources have been assessed with regard to extended operation and decommissioning.

Regarding extended operation, the assessment covered the procurement of the nuclear fuel needed for the power plant's extended operation. The impact assessment generally describes the availability, supply chain, transports and use of nuclear fuel based on Loviisa power plant's current procurement practices in terms of nuclear fuel and the information concerning the impact of the fuel's supply chain published by the suppliers of nuclear fuel. The assessment also presents an estimate of the use of natural uranium, relying on estimates of the present state of uranium reserves and projections (OECD/NEA & IAEA 2020) as baseline data. The greenhouse gas emissions related to the procurement of nuclear fuel are reviewed separately in Chapter 9.12.

With regard to decommissioning, the impact assessment reviewed the total volume of the quarry material generated in the quarrying of the L/ILW repository in particular, and the current possibilities for its reuse. Among other things, the assessment accounted for the placement of the regional quarry and any surplus soil as well as the potential savings to be made in virgin rock by the reuse of the quarry material. The assessment relied on information about other quarrying projects of a similar size.

The possible recycling and reuse of the conventional dismantling material generated during decommissioning is described in Chapter 9.10.5.3.

9.9.3 Present state

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 total volume of the L/ILW repository located in the power plant area's bedrock is currently approximately 117,000 m³. The L/ILW repository was built in the 1990s, and expanded between 2010 and 2012. The quarry material generated in the quarrying of the L/ILW repository has been used outside the power plant area.

The nuclear fuel used in the power plant, produced from uranium ore through various chemical and mechanical stages, is procured from the supplier of nuclear fuel (see Chapter 4.5). The nuclear fuel cycle can be open or closed. 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. In a closed fuel cycle, the spent nuclear fuel is reprocessed. In reprocessing, uranium and plutonium are chemically separated from the spent fuel and reused in the production of new nuclear fuel. The high-level waste and other waste from the reprocessing are deposited 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.

The table 9-22 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.9.4 Environmental impact of extended operation

Impact formation

In the case of extended operation, the impacts of the use of natural resources result primarily from the procurement of the nuclear fuel throughout its supply chain.

In the case of extended operation, the impacts on the procurement of nuclear fuel are similar to the current operation. The environment is burdened by mining operations as well as by the production processes and transports of fuel. The majority of harmful impacts related to the nuclear fuel cycle are attributable to the mining operations.

The following describes the main characteristics of Loviisa power plant's nuclear fuel supply chain in the event of extended operation.

The fuel Loviisa power plant uses is fissionable nuclear fuel made from uranium ore through various chemical and mechanical stages. The power plant's annual fuel requirement totals approximately 24 tonnes of uranium dioxide. The production of this volume of fuel requires approximately 200 tonnes of uranium concentrate (U_3O_8).

9.9.4.1 Availability

The fuel used by the power plant can be procured either as complete entities, as fuel bundles or by buying the uranium and each stage of the fuel's supply chain separately. The

Table 9-22. Sensitivity of affected aspect: the use of natural resources.

Sensitivity of affected aspect: the use of natural resources	
The sensitivity of the affected aspect is determined on the basis of whether there are impediments for the use of natural resources in the project area.	
Moderate	The power plant restricts the direct use of the area's natural resources, but the rock engineering and quarrying closely associated with the power plant's operations can be carried out in the area by Fortum Power and Heat Oy. The power plant area has been in its current use since the 1970s, due to which there is no use of natural resources in the area. The nuclear fuel is procured from its suppliers, and the sensitivity of the suppliers' affected aspects is not assessed within the framework of this EIA. .

uranium markets are global, and they are dominated by a handful of major producing countries, including Kazakhstan, Canada and Australia. The other stages of the supply chain (conversion, enrichment and the production of fuel bundles) can be bought from Sweden, Germany, France, Russia and the United States, among other countries.

The annual requirement for uranium concentrate among the world's nuclear power plants totals roughly 63,000 tonnes, of which more than 95% is currently covered by the concentrate's production from natural uranium. The rest of the market's uranium need is met by emptying stocks and reprocessing spent nuclear fuel.

Given the ubiquity of uranium, the uranium reserves will last far into the future. The adequacy of the uranium reserves depends on the cost level of economically profitable uranium production. The more expensive the alternative forms of energy are, the more profitable it is to produce uranium expensively, and the larger the disposable reserves of uranium are. The known reserves of uranium total approximately 8,000,000 tonnes (OECD/NEA & IAEA 2020). In addition, estimates put the undiscovered reserves that can be mined by traditional methods at roughly 7,200,000 tonnes. Currently, the annual production volume of uranium is around 60,000 tonnes. The volume of uranium required for nuclear power production is expected to increase to 82,000 tonnes by 2030 and to roughly 90,000 tonnes by 2035. At these consumption levels, the uranium reserves will last for approximately 100–200 years. New methods for the exploitation of uranium reserves can be adopted in the future if the price of uranium increases. For example, seawater has been estimated to contain more than 4,000,000,000 tonnes of uranium, but its cost-effective exploitation is not possible with current methods.

The need for natural uranium can be reduced with the widespread adoption of reprocessing. The use of alternative fuels such as thorium is also being investigated, as are reactors employing uranium-238, which could replace the use of uranium isotope uranium-235 in the future. These measures allow the securing of the adequacy of the reserves for a considerably longer period of time than mentioned above.

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. According to the agreement, TVEL procures the enriched uranium required for the production of the fuel bundles from Russian subcontractors through the uranium producer ARMZ Uranium Holding Co. Currently, the uranium comes from the Krasnokamensk, Khiagda and Dalur mines in Russia. In addition to the mines, the zircon materials manufacturer ChMP (Chepetsky Mechanical Plant); the tie plate manufacturer NCCP (Novosibirsk Chemical Concentrates Plant); and MSZ (Mashinostroitelny Zavod), which is responsible for the production of the uranium oxide pellets and fuel bundles, are all TVEL's subcontractors which apply an environmental system pursuant to the certified ISO 14001 standard in their operations, requiring the companies to investigate all their environmental impacts and to continuously improve the level of environmental protection.

In 2001–2007, fuel was also procured from British Nuclear Fuels Ltd (BNFL) (now Westinghouse). The uranium used in both suppliers' fuel bundles has come from Russia. Due to the small markets, Westinghouse is the world's only supplier of VVER-440 fuel bundles in addition to TVEL. If the service life of Loviisa power plant is extended, the fuel procurement will be reviewed in accordance with Fortum's general procurement procedures. Currently, the alternative fuel supplier to the Russian TVEL is the Swedish-American Westinghouse.

9.9.4.2 Supply chain

The supply chain for the nuclear fuel is composed of the mining, enrichment and conversion of uranium, and the production of the fuel bundles. What follows provides a description of Loviisa's fuel at a general level.

Uranium mining and ore enrichment

Uranium is mined from underground shafts, open-pit mines and by means of underground leaching (with the uranium separated from the ore chemically). Uranium can also be separated as a by-product of other mining products such as gold, copper or phosphate. The uranium ore quarried from bedrock by traditional means is crushed and pulverised, after which the uranium is separated from the rock by a chemical dissolution method in a separate flotation plant. Following this, the uranium is precipitated, and the precipitate is separated, washed and dried. The result is enriched uranium (U_3O_8, or yellowcake), the uranium concentration of which is 60–80%.

Uranium mining operations account for a significant portion of the environmental impact of the production process of nuclear fuel. The reason for this is that, while the radioactive waste generated in the mining operations is of a low level in nature, its volume is relatively large. Uranium mining operations are characterised by the consideration of radiation impacts, but in other respects, they are part of the normal extractive industry. The most significant environmental impact of uranium's mining stage is related to radiation exposure and the waste generated by the quarrying and ore enrichment. Quarrying also often damages landscapes. The magnitude of the environmental impact of uranium mining also depends on the quarrying method.

The radiation doses arising during the uranium's quarrying and enrichment stages are primarily derived from three sources: the radiation of the uranium ore and dust when the ore is being quarried and handled; the radiation of the radon released from the uranium ore and the radon's decay products; and the radiation of the uranium mill tailings. The radiation emitted by the uranium itself is weak alpha radiation, which is halted by clothes or the skin alone. Indeed, the highest radiation doses are derived from uranium's radioactive decay products such as radium and radon.

Of uranium's decay products, radon is a gaseous substance released into the air wherever the soil contains uranium. Radon is known to contribute to lung cancer. Uranium mines release more radon than usual, because the uranium concentration in the mines is greater than its average concentration in the soil or bedrock (Vuori et al. 2002). It should nevertheless be noted that radon is not only a problem associated with uranium mines. Rather, it concerns all mining operations, because the soil always contains some uranium. The radiation exposure caused to workers by radon in open-pit mines is markedly lower than in underground shafts. Exposure to radiation in underground shafts can be considerably reduced by efficient ventilation. The detrimental effects of quarrying have been successfully reduced as quarrying techniques have developed, and operations have been automated. The control of workers' radiation exposure has improved in step with the development of working methods, and due to the extensive and efficient monitoring of radiation exposure (OECD/NEA 2014).

The environmental nuisance caused by uranium mining with regard to landscapes has also been successfully reduced by the increased adoption of in-situ recovery (ISR). In this method, the uranium is leached directly into a chemical solution drilled directly into the soil, and the solution is recovered with the help of pumping wells. The uranium is separated from the chemical solution, after which it is used for the production of enriched uranium, and the solution is reused in leaching.

The waste generated by uranium mining is composed of fine uranium dust, process waters, and radioactive soil and rock. The enrichment process also generates solid and liquid waste which, in addition to radioactive radium, also contains other harmful substances, including arsenic and heavy metals.

When temporarily storing the soil and rock left over from uranium mining on the surface of the ground, it must be ensured that any piles of soil or rock containing radioactive substances have no opportunity to disintegrate or emit dust. The piles are often covered with a layer of clay. If the quarrying takes place underground, the aim is to redeposit any solid waste in the mining shafts.

The sludge generated in the ore enrichment is placed in dammed storage and evaporating pools, in which the suspended solids settle at the bottom of the pool and the water separated from them can be conducted away. Radioactive substances and heavy metals are separated from the water with chemical precipitation, after which the water is reused as process water as far as possible. The evaporation sludge is collected in the form of sludge or a crystalline mass for treatment and final disposal. The environmental risks of the waste handling are mainly related to the breaking of the sludge pool dams, the carry-over of radioactive substances to groundwater, and the dust of the soil and rock.

Conversion and enrichment

The operation of a light water reactor is based on a chain reaction. The reactor physical properties required to maintain the chain reaction require the enrichment of the fuel's uranium to 3–5% in relation to the fissile isotope uranium-235. For the enrichment, the uranium concentrate (U_3O_8) is converted, by way of chemical conversion, into uranium hexafluoride (UF_6), which is a compound that gasifies directly from a solid state at a low temperature. The enrichment is based on the differences in the mass of the various uranium isotopes, which allows for separating isotope uranium-235 from the uranium's other isotopes with a centrifugal method.

Conversion and enrichment plants use the same chemicals as the conventional chemicals industry. The use of toxic chemicals such as fluorine compounds requires special and precautionary measures. The uranium in conversion and enrichment plants is isolated within the process equipment and does not have a radiation impact on employees or the environment. Wastewaters and waste gases are treated appropriately, due to which they have no significant impact on the environment in normal conditions.

Production of fuel bundles

For the production of fuel bundles, the uranium hexafluoride (UF) enriched in relation to the isotope uranium-235 is converted into uranium oxide powder (UO_2) by means of a chemical conversion process. In modern power plants, this conversion process takes place as a dry process, due to which the liquid emissions resulting from the process are lower than in a conversion based on the traditional wet process.

The uranium oxide powder is compressed into fuel pellets which are treated in an oven at a high temperature to become a ceramic material. The fuel pellets are then ground into their ultimate dimensions and placed inside cladding tubes made from a zirconium alloy. The tubes are pressurised with helium, which improves the fuel's heat transfer, and closed hermetically. Ready fuel rods are bundled into fuel bundles, consisting of 126 rods, which are stored for transport.

Each work phase takes place according to detailed procedures and strict quality control. The radiation impacts of the work phases are low, because enriched uranium contains hardly any of the decay products that are most harmful in terms of radiation – such as radium, radon and polonium. The production facilities' radiation levels and uranium dust concentration are monitored with continuous measurements.

9.9.4.3 Transport

The transports between different stages of the fuel chain are carried out as supervised maritime, rail and road transports, relying on special containers and normal transport equipment. The greatest transport capacity is required at the beginning of the fuel chain, given that, as the fuel's degree of processing grows, the amount of material to be moved decreases.

The transport packages and transport of radioactive substances are regulated by the International Atomic Energy Agency's (IAEA) regulations and the national regulations based on the IAEA's regulations. Uranium transports require an official permit, and they must be guarded and supervised to prevent their unauthorised seizure. Transports of spent fuel are subject to equivalent regulations.

Transports of enriched uranium and fresh fuel differ from the transports of natural uranium in that their transport must exclude the possibility of a situation in which a continuous chain reaction producing heat and radiation could be initiated. This is realised with the help of protections, and by dimensioning the size and shape of the transport packages so that a chain reaction would not be initiated even in the event of an accident. Transport packages must withstand strong collisions and fires, among other things.

It is nowadays typical for transports to be included in deliveries as a whole. Uranium concentrate is bought delivered to the conversion plant, and the converted uranium (UF6) delivered to the enrichment plant. The enriched uranium (UO_2) is either bought delivered to a plant which produces fuel bundles, or the transport of the enriched uranium is included in the fuel's production agreement, as is the ready fuel bundles' transport to the power plant. Transports do not impact the health of the transport staff or members of the public residing along the transport routes, because the transported materials are not highly radioactive.

The nuclear fuel intended for Loviisa is delivered to Finland via rail or by sea, and to the power plant by road. The annual fuel need of Loviisa's current power plant units is approximately 24 tonnes, i.e. equivalent to a few truck loads. The fresh fuel stored in dry storage at Loviisa power plant usually meets the needs of one or two years. The licence to possess nuclear fuel requires guarding, which prevents unauthorised persons from gaining access to the nuclear material.

9.9.4.4 Operation

The use of uranium as fuel is based on the splitting of the nucleus of the atom of the uranium isotope uranium-235, or fission. In a fission reaction, the heavy atom splits into two or more lighter atomic nuclei – called fission products – when it is hit by a free neutron. The reaction also releases some neutrons and a large amount of energy. The neutrons released in the reaction may cause new fissions, which enables the initiation of a chain reaction. Chemical elements which capture and consume the extra neutrons are used for the management of the chain reaction.

Other nuclear reactions besides fission also occur in the reactor. A majority of the fuel's uranium is made up of isotope uranium-238, which is not as fissionable as isotope uranium-235. A neutron moving with a suitable energy may be absorbed in the atomic nucleus uranium-238. When a neutron turns into a proton, the result is plutonium (Pu). In addition to plutonium, other transuranic elements – i.e. elements heavier than uranium – are also created in the reactor. Some of the transuranic elements, like plutonium-239, participate in the reactor's energy production.

Fuel bundles which have reached their planned service life – currently around a quarter of the fuel every year – are removed from the reactor during refuelling outages and 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. Due to the decay products and transuranic elements emerging in the fuel during operation, the radioactivity of spent fuel is so high that its handling and storage require special measures.

In addition to actual use, the stress to which the fuel bundles are subject during handling and transport, including the handling phases related to long-term storage and final disposal, is accounted for as early as during the planning of the fuel bundles.

9.9.4.5 Magnitude of change

In the case of extended operation, the volume of the procured nuclear fuel will remain at the same annual level (roughly 200 tonnes of uranium concentrate), while its total volume will increase. Estimates put the total volume at around 4,000 tonnes of uranium concentrate. Natural uranium is classified as a non-renewable natural resource, due to which its use reduces ore deposits. The volume of uranium concentrate required by Loviisa power plant in the case of the extended operation at an annual level would be around 0.33% of the uranium's annual production volume, and its total volume would be approximately 0.05% of the currently known uranium reserves. In addition to the aforementioned, when accounting for estimates concerning uranium reserves yet to be discovered, uranium reserves to be used at a higher price, and estimates on the growth of uranium's global demand, the impact that extended operation would have on the uranium reserves is expected to be negligible.

Extending operation would not change the power plant area's current constraints for the use of natural resources.

9.9.5 Environmental impact of decommissioning

Impact formation

Impacts are generated by the excavation work related to the expansion of the L/ILW repository. The quarry material generated as a result can be reused in the L/ILW repository's closure in approximately 30–40 years or in other construction work insofar as possible. Impacts will also result from the quarry material's interim storage, which would take place either in the power plant area or another area suitable for the purpose.

In the case of decommissioning, the L/ILW repository will be expanded by quarrying a total of 71,000 m^3 of additional space within the bedrock. This will generate a total of 100,000 m^3 of quarry material consisting of rapakivi granite. There are several alternatives for the use of the quarry material. It would primarily be used as a filling material for the L/ILW repository once the repository is closed (see Chapter 5.5) After the dismantling of the power plant buildings and structures, the quarry material could also be used in the power plant area for landscaping, for example. If not all the quarry material is used in the power plant area, it can also be used in earthworks outside the power plant area.

The quarry material generated in the quarrying of the L/ILW repository can be stored, as far as possible, within the power plant area or placed in interim storage in a suitable area beyond the plant area. The interim storage period lasts for approximately 30–40 years. The basic rule in terms of interim storage is that, after three years, the material is interpreted as waste, at which point an environmental permit should be sought for its interim storage, unless a specific intended use can be indicated for the material, such as the use of quarry material in the filling of the L/ILW repository. The interim storage of quarry material has indirect environmental impacts, including noise and dust originating from the unloading of the quarry loads, the formation of the storage piles and the quarry material's loading for further transport. The quarry material may furthermore contain nitrogen originating from explosives, which can gradually dissolve from the piles and be carried away by stormwaters. The transports of the quarry material also generate impacts (Chapter 9.4).

The quarry material can either be used as is or in a processed form in other construction work such as earthworks. The starting point is to reuse the already extracted rock as ecologically and efficiently as possible. By doing so, the reuse of the quarry material would also temporarily reduce the need to excavate any new natural aggregate. Due to the relatively small amount of quarrying, however, the reuse of the quarry material generated in the excavation of the L/ILW repository will not have any significant or long-term impact.

The reuse of the quarry material generated in the quarrying of the L/ILW repository is considered to promote the circular economy, given that its use can substitute for the procurement of virgin rock either in the closure of the L/ILW repository or in other construction work outside the power plant area. The magnitude of the change is expected to be minor and positive when accounting for the total volume of the rock generated.

Once the power plant's operation has ended, the possibilities for using the area's natural resources (in the forest industry, for example) will depend on the area's further use. Because of the existing L/ILW repository, no deep excavations extending dozens of metres down can be carried out in the area even in the future; rather, the use of the area of the L/ILW repository will continue to be subject to restrictions.

No new nuclear fuel will be procured during decommissioning, due to which the use of natural resources related to the procurement of fuel will no longer take place, but this will have no impact on the global production of uranium concentrate or the global uranium reserves.

9.9.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, interim storage or final disposal of radioactive waste generated elsewhere in Finland will not have an impact on the use of natural resources.

9.9.7 Significance of impacts

Table 9-23 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

Table 9-23. Significance of impacts: use of natural resources.

Significance of impacts: use of natural resources			
Operational phase	Sensitivity	Magnitude	Significance
Extending operation: power plant area	Moderate	No change	**No impact,** given that the extended operation would not change the power plant area's current constraints for the use of natural resources.
Extending operation: procurement of nuclear fuel	Cannot be determined	No change	**No impact,** because the significance of Loviisa power plant's procurement of uranium concentrate is negligible in terms of the global production of uranium concentrate and the global uranium reserves.
Decommissioning	Moderate	Minor positive	**The significance of the impacts is minor and positive,** given that the reuse of the quarry material generated in the quarrying of the L/ILW repository is considered to promote the circular economy, since its use can substitute for the procurement of virgin rock either in the closure of the L/ILW repository or in other construction.
Radioactive waste generated elsewhere in Finland	Moderate	No change	**No impact,** because the operations would not use natural resources.

9.9.8 Mitigation of adverse impacts

Procurement of nuclear fuel

The uranium used by Loviisa power plant is not expected to have an impact on the uranium reserves, but the production of nuclear fuel has an environmental impact. Fortum's procurement of nuclear fuel accounts for environmental impacts starting from the invitation-to-tender phase. The tenderers are required to include an account of their environmental system in their tender or to provide a description of how the environmental impact of their operations is taken into account. The appropriateness and adequacy of the operations in relation to legislation are assessed during the tenders' comparison phase. Fortum regularly audits the quality control systems of the key operators in its fuels supply chain, including the uranium supply chain. Among other things, the audits focus on the quality and effectiveness of suppliers' environmental and quality control systems.

In addition, Fortum regularly monitors the production of fuel bundles at the fuel plants, which are visited by a group of experts for the purpose of quality control two to four times every year. Fortum's opportunities to influence the procedures of different operators in the supply chain delivering nuclear fuel to the company are related to the obligations agreed in the fuel agreements. These operations are subject to their own environmental and other regulations in each country. In accordance with Fortum's environmental policy, the management of environmental matters emphasises the principles of continuous improvement and open interaction in cooperation with suppliers.

Reuse of quarry material

If the quarry material is placed in interim storage elsewhere or used in other construction projects, the transport distances should be optimised and future locations for the further use of the quarry material should be anticipated insofar as possible. The prevention of noise and dust should be considered in the interim storage.

9.9.9 Uncertainties

The assessment of the availability of natural uranium is based, in respect of production and use, on projections and estimates concerning the next few decades and on assumptions about the price of uranium. The assessment has not considered reactor types using another kind of fuel or the large-scale introduction of reprocessing in the long term. Part of the exploitation of the reserves requires new technology and/or a uranium price higher than the current one.

The reuse object or interim storage location of the rock generated by the quarrying of the L/ILW repository is not known, which increases uncertainty in the assessment's outcome. Even so, the assessment aims to cover the impacts in terms of this on a general level, based on an assessment of other quarrying projects of a similar size.

9.10 WASTE AND WASTE TREATMENT

9.10.1 Principal results of the assessment

In the case of extended operation, the increase in the total volume of spent nuclear fuel as well as low and intermediate-level waste will not increase the personnel's radiation doses in practice compared to current operation. The limit value for the radiation dose caused to a member of the public from the entire nuclear power plant's normal operation – including the various phases of the management of spent nuclear fuel, and low and intermediate-level waste – is 0.1 mSv, and the actual doses are only a fraction of this. The impact resulting from waste management measures in normal operation is very low.

The maximum impact of decommissioning is expected to be minor and negative. In normal operation, the interim storage and treatment of spent nuclear fuel within the power plant area do not cause abnormal radiation or emission impacts on the environment. Nor are the personnel's legal limit values exceeded. The radiation exposure of people and the environment resulting from the transport of spent nuclear fuel in a normal situation is very small, and the additional exposure is practically indistinguishable from the exposure caused by the environment's background radiation. The collective radiation dose accumulating during the decommissioning is expected to be around 10 manSv. Final disposal measures will account for slightly less than a fifth of this, i.e. slightly less than 2 manSv. The annual collective radiation dose will be roughly equal to that resulting from the plant's current operation. The radiation dose of even a single individual employee will not exceed the power plant's targeted dose constraint, set lower than the legal limit value. According to the long-term safety case, the L/ILW repository's existing parts meet the long-term safety requirements, and the planned expansion can be implemented so that the long-term safety requirements are met. When conventional waste is handled and stored in the power plant area appropriately, it does not have an environmental impact. Indirect environmental impacts result from the transport of conventional waste and from the processes of the operators responsible for its further treatment.

The handling and final disposal of radioactive waste generated elsewhere in Finland would be carried out so that its impact on the radiation doses of the personnel and residents in the surrounding area and on long-term safety, both during the plant's operation and after the closure of the final disposal halls, would be minor in relation to waste originating from Loviisa power plant, and so that the long-term safety requirements are met. The power plant's current waste management methods can be applied to most of the waste treatment. 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. At the level of the entire country, the reception of the waste is expected to have a moderate and positivepositive impact, because radioactive waste generated in different sources would be provided with a safe and cost-effective final disposal solution.

Table 9-24. Sensitivity of affected aspect: waste and waste treatment.

Sensitivity of affected aspect: waste and waste treatment	
The sensitivity level of the affected aspect is determined on the basis of the adequacy of the operational capacity related to the area's waste treatment.	
Minor	Functional waste treatment concepts are in place for the waste generated in the power plant area, and the waste management routes are known. The need for additional storage capacity is accounted for in the area's plans.

9.10.2 Baseline data and assessment methods

The impact assessment reviewed the volume, quality and treatment of the low and intermediate-level, and conventional waste generated during the power plant's extended operation and decommissioning. The impacts related to waste treatment were assessed on the basis of the characteristics and treatment techniques of the waste. The assessment accounted particularly for any radiation doses of the personnel caused by waste containing radioactivity, in addition to judging whether the treatment of the waste could have impacts beyond the power plant area.

The assessment also includes a description of the waste's potential reuse and the final disposal solutions. With regard to the final disposal of radioactive waste, the assessment reviewed long-terms impacts from the perspective of the long-term safety case, for example. The L/ILW repository's long-term safety case discusses the long-term safety impact of the low and intermediate-level waste generated during operation and decommissioning. The long-term safety impact of radioactive waste delivered from elsewhere will be ensured with separate investigations when necessary.

The handling and interim storage of spent nuclear fuel in the power plant area are described and their environmental impact are assessed on the basis of, among other things, the plant's current operation and Loviisa power plant's decommissioning plan. Transports of spent nuclear fuel from Loviisa power plant to Posiva's encapsulation and final disposal facility in Eurajoki were reviewed on the basis of Posiva's transport risk and implementation method report (Suolanen et al. 2004) and environmental impact assessment (Posiva Oy 2008). The main principles and long-term safety of the spent nuclear fuel's final disposal concept were reviewed at a general level based on Posiva's publications (Posiva Oy 2008 and 2012).

Among other things, the environmental impacts of radioactive waste generated elsewhere in Finland and received at Loviisa power plant were reviewed on the basis of the results obtained in the EIA procedure concerning the decommissioning of VTT's FiR1 research reactor (VTT 2014) and other reports on the topic. Their impacts were assessed as part of the impact of waste treatment at Loviisa power plant.

9.10.3 Present state

The waste generated in the power plant's current operations and its treatment are described in Chapters 4.7 and 4.8. There are no other industrial operators in the immediate vicinity of the power plant whose operations generate or who handle waste.

Table 9-24 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.10.4 Environmental impact of extended operation

Impact formation

The impacts are attributable to the handling and storage of spent nuclear fuel, low and intermediate-level waste, and conventional waste.

9.10.4.1 Spent nuclear fuel

An average of 168 fuel bundles are removed from Loviisa power plant's reactors as spent fuel every year. 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 by approximately 3,700 bundles over a period of 20 years. The maximum amount of spent nuclear fuel placed in interim storage is 12,800 fuel bundles, which is equivalent to around 1,600 tonnes of uranium.

Following its removal from the reactor, a spent fuel bundle is cooled for 1–3 years in the reactor building's refuelling pool, during which time the bundle's radioactivity and heat production reduces significantly. After this, the bundle is moved to a pool of water in the interim storage for spent nuclear fuel. The fuel's radioactivity and heat production continue to decrease during its storage in the water pool. After an interim storage period of about 50 years, the radioactivity of the spent nuclear fuel removed from the reactor has dropped to a thousandth of the original.

In the case of extended operation, the storage capacity for spent nuclear fuel in the power plant area would have to be increased. This would be implemented either by placing the fuel more densely within the water pools of the existing storages or by expanding one of the existing interim storages by a maximum of two new pools of water. The alternatives do not differ in terms of a fuel bundle's radioactivity or heat production. Rather, the end result would be the same. The planning of the interim storage accounts for the effect that the growth of the total amount of spent nuclear fuel would have on the heat production. For example, the cooling capacity can be increased by increasing the flow of the cooling water to the heat exchangers or by increasing the size of the heat exchangers.

The effect that the growth in the total number of bundles of nuclear fuel would have on the personnel's radiation doses would be negligible compared to current operation, and both methods for increasing storage capacity would have the same effect on radiation doses.

The subcritical state of the nuclear fuel is ensured during every stage of the handling and storage of spent nuclear fuel, so that an uncontrolled fission chain reaction cannot take place. This is ensured with regard to the transfer casks, storage spaces and handling equipment, for example. The impact that the handling and interim storage of spent nuclear fuel have on the environment in normal operation is very low compared to the power plant's emissions, and the legal limit values are not exceeded. The limit value for the annual dose of a member of the public caused by the entire nuclear power plant's normal operation, including the handling and interim storage of spent nuclear fuel, is 0.1 mSv.

9.10.4.2 Low and intermediate-level waste

While extended operation would not change the amount of low and intermediate-level waste accumulated annually, their total volumes would increase over the 20-year period (Chapter 4.7). The current accumulation rate of low-level waste is 20–30 m³ per year, and the volume expected to accumulate by the end of the current operating licences is approximately 2,700 m³. Given that the annual accumulation will remain unchanged, the total volume of low-level waste generated during the 20 years of additional operation would be roughly 600 m³. This would put the total volume of low-level waste at around 3,300 m³.

The current accumulation rate of intermediate-level waste is 15–30 m³ per year (when solidified and packed, 60–120 m³ per year), and the volume expected to accumulate by the end of the current operating licences is approximately 4,900 m³. Given that the annual accumulation will remain unchanged, the total volume of intermediate-level waste (packed) generated during the 20 years of additional operation would be roughly 2,400 m³. This would put the total volume of intermediate-level waste at around 7,300 m³.

There are existing handling methods, as well as storage and final disposal locations, for low and intermediate-level waste. In the case of extended operation, the waste management methods would remain largely unchanged. The final disposal concept for maintenance waste may be changed slightly by using concrete boxes as further support for metal barrels, for example. The change would constitute part of ageing management, and it would ensure occupational and radiation safety during the additional years of operation. Further studies on the change of concept are underway. The L/ILW repository located within the power plant area has three spaces within the bedrock for the final disposal of low-level maintenance waste and one for solidified intermediate-level waste. The capacity is also sufficient for the final disposal of the low and intermediate-level waste generated during the extended operation.

The measures related to waste management are part of the power plant's normal operation and will cause only a small part of the personnel's collective radiation dose. The limit value for the annual dose of a member of the public caused by the entire nuclear power plant's normal operation, including the various phases of the waste management of low and intermediate-level waste, is 0.1 mSv.

Regardless of the amount of waste stored within the power plant area, the handling of low and intermediate-level waste in normal operation does not result in emissions of radioactive substances into the environment. It will be ensured that waste packages are intact and in good condition during final disposal, at which point it will also be checked that there is no contamination on their surface that could become loose. This means that no radioactive substances are released outside the waste packages under normal operations, and that no waters accumulating in the final disposal halls can be contaminated by radioactive substances. The principle of final disposal is to keep the radioactive substances contained by the waste separate from organic nature so that the environment's safety is not compromised at any stage. Long-term safety is discussed in more detail in Chapter 7 and Chapter 9.10.5.2.

9.10.4.3 Waste to be cleared from regulatory control and conventional waste

Different types of maintenance waste – including insulation materials, old work clothes, parts of machinery and equipment as well as used tools and packaging materials – are generated within the power plant's radiation controlled area. The activity of maintenance waste is analysed with several consecutive measurements. Provided that the activity of a waste batch is low enough, it can be cleared from regulatory control pursuant to section 27 c of the Nuclear Energy Act. The constraint for the annual dose of members of the public or employees handling waste caused by materials cleared from regulatory control is 0.01 mSv. In addition, the radiation exposure attributable to waste cleared from regulatory control must also be kept as low as reasonably achievable in every respect. The further treatment of waste cleared from regulatory control can be identical with that of conventional industrial waste. The annual volume of waste to be cleared from regulatory control generated in current operations is approximately 100 tonnes. The annual volume varies greatly in accordance with repair work and component replacements. The annual volume of waste to be cleared from regulatory control is expected to remain the same as it currently is.

The power plant generates conventional waste in a manner similar to any other industrial activity. Conventional waste includes paper, plastic and bio-waste, as well as scrap metal, which are generated at a rate 400–1,000 tonnes a year. In addition, the power plant's operations generate some 20–100 tonnes of hazardous waste a year. These include WEEE (waste electrical and electronic equipment), waste oils and chemicals, batteries, etc.

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. The handling of conventional waste would also remain similar to its current level. Some 85% of the waste generated is used as energy or materials. The rest, or roughly 15%, of the waste is transported to landfills or disposed of by other means. The volumes of waste generated are kept as low as possible, and the shares of reused waste high. This is monitored with the help of waste accounting, for example. Separately sorted waste is forwarded for treatment, reuse or final disposal as required by waste legislation or the environmental permit decisions. Hazardous waste is stored appropriately and delivered to plants which treat hazardous waste.

The treatment of conventional waste carried out within the plant area does not have an environmental impact. The impact is primarily attributable to the transport of waste as well as the processes of the operators responsible for the further treatment of the waste.

9.10.4.4 Summary of the magnitude of the change

The limit value for the annual dose of a member of the public caused by the entire nuclear power plant's normal operation – including the handling and interim storage of spent nuclear fuel and the various phases of the waste management of low and intermediate-level waste – is 0.1 mSv. The personnel's radiation doses resulting from the handling of spent nuclear fuel or low and intermediate-level waste are very low and remain below the limit values set for a nuclear power plant's normal operation. The total volumes of waste would increase as a result of the additional years of operation, but methods for their handling are already in place. At most, the magnitude of the change is expected to be *minor and negative.*

9.10.5 Environmental impact of decommissioning

Impact formation

The impacts are attributable to the handling, storage and final disposal of spent nuclear fuel, low and intermediate-level waste, and conventional waste.

9.10.5.1 Spent nuclear fuel

Treatment

During the first dismantling phase of decommissioning, all spent nuclear fuel at the power plant will be stored in the interim storages for spent fuel, located separate from the power plant units to be dismantled and the L/ILW repository. The spent fuel is under a layer of water several metres thick, which efficiently dampens the ionising radiation emitted by the spent fuel. Most of the time, the storage for spent fuel also remains unmanned. The impact on the power plant's own personnel is nearly non-existent, and the legal limit values are not exceeded.

If the power plant's decommissioning begins at the end of the current operating licence, the transports of spent fuel for final disposal would begin according to the current schedules and plans after the power plant's remaining buildings and operations have shifted to the phase of independent operation. The decommissioning of the plant parts to be made independent (second dismantling phase) begins after all of the spent nuclear fuel has been transported to Posiva's final disposal. From the dismantling phase onward, the power plant will no longer contain spent nuclear fuel.

The amount of spent nuclear fuel accumulated in the storages by the end of Loviisa power plant's current operating licence will total approximately 7,700 bundles, which is equal to roughly 960 tonnes of uranium. The spent nuclear fuel is packaged into transfer casks while it is under water, due to which the prevalent radiation levels (a maximum of 0.03 mSv per hour) do not increase during packaging. Nor does the packaging have any radiation or emission impacts on the environment which would depart from the power plant's normal operation. The fuel's handling and transfers from the storage pools to the transfer casks will correspond with the power plant's current fuel handling methods. The fuel bundles to be placed in the transfer casks will be selected according to their residual heat production, dose rate and reactivity. The aim of this is to ensure that both the final disposal capsules' and the transfer cask's heat production and criticality safety meet the required level, and that the dose rate outside the cask remains within the confines of the set limits.

Transport

The transports of Loviisa's spent nuclear fuel to Olkiluoto for encapsulation and final disposal take place either by road or by sea. In the case of decommissioning starting after the current operating licence has expired, there would be 6–8 road transports of spent nuclear fuel a year (one transfer cask at a time) or 2 transports by sea a year (3–4 transfer casks at a time).

The transport of spent nuclear fuel is strictly regulated by national and international regulations and agreements. In Finland, transports of spent nuclear fuel require a permit from STUK. STUK inspects the transport plan, the structure of the transfer cask, the qualifications of the transport personnel, the safety and security arrangements, and the preparedness for accidents.

A transport of spent nuclear fuel will be supervised, meaning it will be accompanied by the necessary escort personnel such as the police and STUK's supervisor. Aspects impacting road safety will be ensured with the help of the escort's supervision.

Various routes for the transport of spent nuclear fuel by road from Loviisa to Olkiluoto exist. These will be reviewed in more detail well in advance of the transports of the spent nuclear fuel.

Spent nuclear fuel can also be transported to Olkiluoto by sea. In Loviisa, the departure would take place from the Port of Valko, located approximately 7 kilometres from Loviisa nuclear power plant area. Two alternative routes in the Gulf of Finland have been investigated. The alternative to the route passing through the Archipelago Sea is a route circling the Åland Islands. The port of destination would be either Rauma or Olkiluoto. Various combinations of these alternatives yield a number of routes to be reviewed. Due to feeder traffic, the route of the maritime transport option will also be composed of a combination of transport modes (road-sea-road). (Posiva Oy 2008)

The transfer cask for spent nuclear fuel dampens the radiation emitting from the fuel extremely efficiently. In accordance with the safety regulations, the dose rate of the radiation emitting from the transfer cask may not exceed the value of 0.1 mSv per hour at a distance of two metres. A transport risk review (Suolanen et al. 2004, Posiva Oy 2008) has been drawn up for the transports of spent nuclear fuel from Loviisa nuclear power plant to the final disposal facility at Olkiluoto. The review relied on the actual dose level of radiation, 0.03 mSv per hour, prevailing at a distance of one metre from the external surface of a transfer cask based on measurement results. The measurement concerned spent nuclear fuel which had been cooling for 3–4 years, meaning that the dose rate and the doses further calculated on its basis were conservative in terms of spent nuclear fuel that has been cooling for a long time. No further than at a 30-metre distance from the cask, the dose rate caused by the spent nuclear fuel through the wall of the transfer cask to the environment was at the same level as naturally occurring radiation. The radiation dose of the most exposed member of the public, assumed to spend a total of two hours at a ten-metre distance from a cask, attributable to normal transports over a year was 0.0009 mSv. (Suolanen et al. 2004, Posiva Oy 2008)

The maximum collective dose of the population (the calculated total dose of a specific population group) caused by normal transports (30 tU per year) on the reviewed routes was 0.00027 manSv per year, while for the transport personnel, it was 0.0089 manSv per year, and for the cask handlers 0.0028 manSv per year. The workers are exposed to a greater radiation dose from the transports than members of the public, because the transport personnel and the cask handlers are closer to the casks during transport operations. The population's radiation dose attributable to normal transports by sea is even lower, given that residences are located further away from shipping lanes, and the population density by the transport routes is smaller than in road transports. (Suolanen et al. 2004, Posiva Oy 2008)

The calculation results show that the radiation dose of members of the public in connection with road transports (less than 0.001 mSv per year) is markedly lower than the average annual radiation dose of people residing in Finland (5.9 mSv). The radiation exposure of people and the environment resulting from the transport of spent nuclear fuel in a normal situation is very small, and the additional exposure is practically indistinguishable from the exposure caused by the environment's background radiation.

Encapsulation, final disposal and long-term safety

At Olkiluoto, the spent nuclear fuel is delivered to Posiva Oy's encapsulation plant, where it is safely enclosed within the final disposal capsules. The encapsulation plant is connected to the underground final disposal facility with a capsule lift with which the capsules are transported down to the final disposal level, at a depth of around 430 metres, and the underground receiving station. From there, they are transferred to the final disposal tunnels by way of a transfer and installation vehicle.

The long-term safety of the final disposal of spent nuclear fuel is based on a multi-barrier system, illustrated in Figure 9-16. The radioactive substances are inside several release barriers which support each other but are as independent from one another as possible, so that the failure of a single release barrier will not compromise the effectiveness of the isolation. The technical release barriers consist of the state of the fuel, the final disposal capsule, the buffer bentonite, and the filling of the tunnels. The bedrock functions as the natural release barrier. In the final disposal solution, the spent nuclear fuel is packed in watertight durable final disposal capsules, the interior of which is cast iron and the exterior of which is copper. The capsules are deposited at a depth of approximately 430 metres within the bedrock, where they are separate from people and in which they remain sealed without maintenance for as long as their contents could cause material harm to organic nature.

In addition to nuclear and radiation safety criteria, the basis for designing long-term safety consists of various assessments of changes taking place in nature. Among other things, the long-term safety case includes an analysis of how the final disposal solution endures earthquakes, future ice ages for up to a million years, and the stress caused by the ice sheet. The long-term safety case also addresses uncertainties related to the behaviour of the final disposal solution as well as the assessment of various potential events and developments. The likelihood of the events is accounted for when assessing risks.

Posiva has been engaged in long-term work to assess the long-term safety of the final disposal of spent fuel for several decades now. Posiva's long-term safety case obtains most of its baseline data from the description of the final disposal location, which is based on all the studies conducted since the 1980s in which the area and bedrock of Olkiluoto have been investigated from the perspective of the final disposal of nuclear waste. The construction of an underground

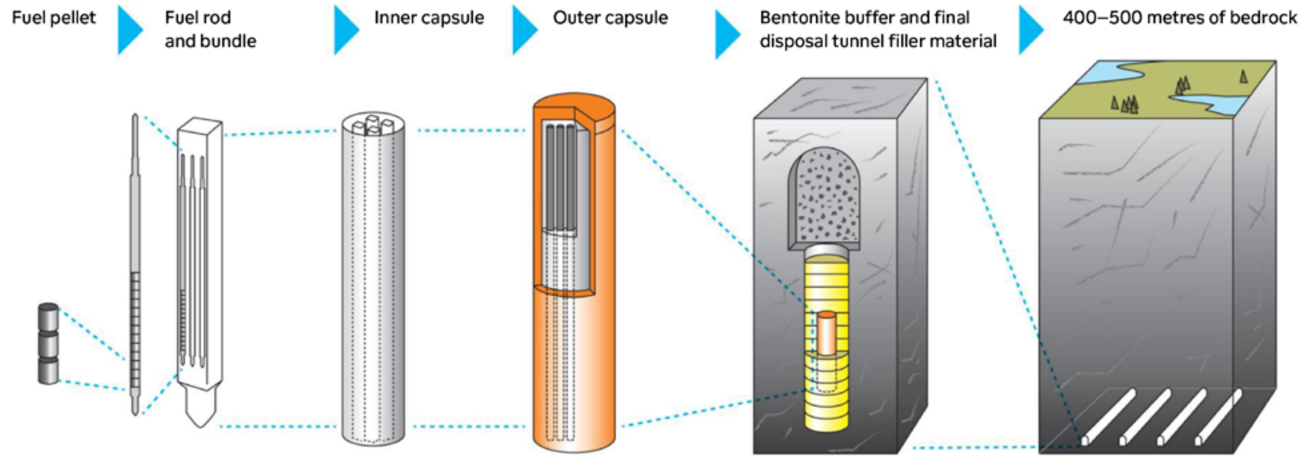

Figure 9-16. The safety of the final disposal of spent fuel is based on the multi-barrier principle, in which several release barriers securing each other ensure long-term safety. Photo: Posiva Oy

research facility, which has made underground studies an increasingly important source of information, began in 2004. In addition, studies conducted above ground have provided a comprehensive picture of the final disposal location's characteristics and processes. The location description includes descriptions of the final disposal location's geology, hydrology, hydrogeology, hydrogeochemistry and rock mechanics, and estimates of their future development.

According to the long-term safety case drawn up for Posiva's application for a construction permit (Posiva Oy 2012), the annual radiation doses resulting from developments considered probable would, even in the case of the most exposed individuals, over the following ten thousand years, remain significantly below the limit provided in the Nuclear Energy Decree, and even the doses of other people would remain small enough to be inconsequential. After this, the emissions of radioactive substances resulting from developments considered probable are expected to remain less than a thousandth of the maximum values set by STUK, even at their maximum. In addition, based on an assessment of typical radiation doses, the radiation exposure of the final disposal location's biota similar to the current biota would remain significantly smaller than the reference value proposed in international projects. The resulting radiation doses and the release rates of radioactive substances have been assessed by accounting for any random deviations from the final disposal system's operating capability requirements, and for the uncertainties of the calculation models and baseline data used in the assessment. (STUK 2015)

Posiva examines the long-term safety of the final disposal of nuclear fuel in its application for an operating licence. Among other things, the reports of Posiva's safety case describe the design bases, the final disposal system's initial stage, the status of the low and intermediate-level waste to be deposited in the final disposal facility, the analysis concerning the operating capability of the technical release barriers, the formation of scenarios, the release and transport of radionuclides, the calculation models and their baseline data as well as complementary reviews. These form the basis for the presentation of a summary of the principal results and conclusions, an estimate of the fulfilment of official regulations and an assessment of the reliability of the long-term safety of the final disposal of spent fuel and the safety assessment.

9.10.5.2 Low and intermediate-level waste

Waste management measures

For the purpose of decommissioning, the **L/ILW repository will be expanded** by a total of 71,000 m^3 of new space. The expansion of the L/ILW repository will not generate radioactive waste.

In the **decommissioning phase**, the nuclear power plant's operation has ended, and no more low and intermediate-level operational waste is generated. On the other hand, the dismantling measures (dismantling phase 1 and dismantling phase 2) of the decommissioning are expected to generate radioactive waste as follows:

- activated waste: 3,300 m^3
- contaminated waste: 19,000 m^3
- maintenance waste and other waste to be packed in barrels: 700 m^3
- solidified liquid waste: 2,260 m^3.

In addition to radioactive waste, crushed concrete can be placed in the L/ILW repository as filling. The crushed concrete may consist of either very low-level or conventional concrete originating from the conventional dismantling of buildings. If very low-level concrete is used as a filling material, the volume used will amount to less than 50,000 m^3.

Special attention will be paid to the personnel's radiation protection when planning the dismantling measures and other decommissioning phases. The waste generated during the decommissioning will be handled, based on its properties, in accordance with the process designed for its own class of waste. When necessary, the waste will be packaged in waste packages so that no radioactive substances will be detached from it, after which it will be transported to the L/ILW repository's final disposal halls for decommissioning waste.

The final disposal of the low and intermediate-level waste in the L/ILW repository is primarily similar to the final disposal of waste generated during the power plant's operation. Regardless of this, the wastes to be deposited in final disposal are different: for example, the sizes of the waste packages will be bigger, and some of the waste (large equipment and blocks of concrete) will be deposited unpacked.

Current estimates put the collective radiation dose to be accumulated during the preparation and dismantling phases at around 10 manSv. Final disposal measures will account for slightly less than a fifth of this, i.e. slightly less than 2 manSv. The estimate includes the radiation doses of all Fortum employees and contractors working in the power plant area. When dividing the collective radiation dose by the duration of the preparation phase and dismantling phase (12.5 years), the annual dose is at the same level as during the plant's operation. The decommissioning work will be planned and carried out in such a way that not even a single individual employee's radiation dose exceeds the targeted dose limit set for the decommissioning.

The Nuclear Energy Decree sets the limit for the annual dose to which a member of the public can be exposed to in connection with the decommissioning, according to plan, of a nuclear power plant or other nuclear facility with a nuclear reactor at 0.01 mSv (section 22 b 161/1988). The decommissioning methods will be selected so that the set emission limits will not be reached, due to which the radiation impact can be expected to be very low.

The dismantling work of decommissioning, the packaging of waste and the transports of waste within the power plant area to the L/ILW repository will not result in a radiation dose to people outside the power plant area. All low and intermediate-level waste is handled and deposited in final disposal within the power plant area, due to which it will not be carried outside the area. The handling of low and intermediate-level waste does not result in emissions of radioactive substances into the environment in normal operations.

The operation of the plant parts to be made independent will generate 260 m^3 of solidified liquid waste and 20 m^3 of maintenance waste, and they will be handled with methods similar to the current ones. The volumes of waste generated in the decommissioning of the plant parts to be made independent (dismantling phase 2), their handling methods and impacts are included in the descriptions above.

The starting point in the management of the radioactive waste generated in the operation and decommissioning of the nuclear power plant is that the waste is isolated from human habitats. Once all the radioactive waste has been deposited in the L/ILW repository for final disposal, the L/ILW repository is closed. At this point, the waste halls and tunnels are filled with quarry material and crushed concrete, and closed by casting reinforced steel seals at the mouths of the tunnel, shafts and waste halls. Among other things, the fillings and seals are intended to prevent access to the final disposal halls and to restrict the flow of groundwater through them. The disposal of nuclear waste will be designed in a way that does not call for continuous supervision to ensure long-term safety.

Long-term safety

The long-term safety of nuclear waste has been assessed with the aid of a separate long-term safety case described in Chapter 7. Loviisa power plant's long-term safety case (Nummi 2019) discusses the long-term safety impacts of both operational waste and decommissioning waste.

The long-term safety case models the future development of the final disposal system with various scenarios that cover the uncertainties related to the operation of the release barriers. In accordance with the requirements of YVL Guide D.5, the scenarios are divided into base, variant and disturbance scenarios. By analysing several scenarios, the aim is to address uncertainties in future developments as extensively as possible. The formation of the scenarios is based on the mathematical modelling of the release barriers' operational capability and related phenomena. The long-term safety case's scenarios described in Table 9-25 have been formed on the basis of the modelling.

The future developments described by all scenarios assess the release of radionuclides from the waste and their transport within the final disposal halls and bedrock and ultimately, the surface environment. The radiation exposures of the most exposed individuals are modelled with consideration for food chains, drinking water, the breathing of radioactive substances and external radiation. Probability-based calculation methods were a key tool in the assessment of the impact of the uncertainties.

The results of the long-term safety case yielded estimates of the doses of the most exposed individuals, including probability distributions, in different scenarios. The long-term safety case also includes an estimate of the radiation doses of larger groups of people and the emissions of radioactive substances in relation to emission limits. The radiation impacts fall below the set limit values. The radiation dose of the most exposed individuals will remain below 0.1 mSv a year, and the average annual dose of other people will remain small enough to be considered negligible. Based on the results of the long-term safety case, the final disposal of both Loviisa power plant's operational waste and decommissioning waste within Loviisa's final disposal facility can be carried out safely.

The long-term safety case described above examined waste generated during the power plant's current operating licence by 2030 and during decommissioning. If the power plant's service life is extended, and when the accumulation rate of the waste remains roughly the same, the total accumulation of waste and the accumulated radioactivity will increase. Therefore, the total volume and radioactivity of the waste to be deposited in final disposal will also increase. The environmental impacts following the closure of the final disposal will increase nearly proportionately, but the increase in the volume and activity of waste caused by the possible extension will not result in changes to the key conclusions of the long-term safety case.

Table 9-25. Descriptions of the scenarios, their classification as a base scenario, variant scenarios and the disturbance scenario

Descriptions of the scenarios (name of scenario in bold)
In the **base scenario,** the release barriers are expected to operate as planned. The concrete seals with which the halls are closed restrict the flow of groundwater for tens of thousands of years. The concrete release barriers and concrete vessels are efficient in restricting the transport of radionuclides. The reactor pressure vessels and steam generators used as waste packages will remain intact for tens of thousands of years.
The variant scenario of the **accelerated weathering of concrete** assumes that the concrete seals do no restrict the flow of groundwater. The scenario also assumes cracks in the concrete release barriers and a loss of the reactor pressure vessels' tightness faster than in the base scenario.
The variant scenario of **initial fault of welds** assumes a leakage left in the reactor pressure vessels and steam generators when closing them, which would allow radioactive substances to begin to be released from within them immediately after closing.
The **major earthquake** disturbance scenario examines the potential sudden mechanical breakdown of the concrete seals, concrete release barriers and concrete vessels, which would increase the flow of groundwater through the final disposal halls and the concrete release barriers, thereby accelerating the release of radioactive substances. While earthquakes of this kind usually occur in connection with retreating glaciers, they cannot be excluded during other times either, although their frequency is in the region of once in a million years.

9.10.5.3 Waste to be cleared from regulatory control and conventional waste

The power plant will continue to produce electricity during the quarrying of the L/ILW repository, due to which conventional waste will be generated in the same manner as it is currently generated, and the expansion of the L/ILW repository will not bring a significant change to this. The handling of the quarry material generated in the quarrying of the L/ILW repository and its impact are described in more detail in Chapter 9.9. (Use of natural resources).

Due to the dismantling measures, the volume of conventional waste generated during decommissioning will increase significantly compared to current operations. Maintenance waste, most of which will be cleared from regulatory control, will be generated continuously in connection with the dismantling to be carried out during dismantling phases 1 and 2. The estimated volume of maintenance waste to be cleared from regulatory control generated during the dismantling phase 1 is 2,400 m^3. No estimate on the volume of maintenance waste to be generated during dismantling phase 2 exists yet. Small amounts of dismantling waste that can be cleared from regulatory control are also likely to be generated in connection with the dismantling of radioactive parts. All waste materials which involve a suspicion of radioactive contamination are subject to the necessary investigations prior to any clearance from regulatory control.

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 measurements, and once the buildings fall below the clearance limits, they can be cleared from regulatory control and do not require special arrangements for protection against radiation. Following their clearance from regulatory control, the aim is to find a reuse for the buildings in accordance with the brownfield principle or dismantle them in accordance with the greenfield principle. If the decommissioning is carried out according to the greenfield principle, a majority of all conventional waste will be generated during the dismantling of the buildings. The further use of the power plant area will therefore have a great impact on the volume of the conventional waste generated. If existing buildings cleared from regulatory control are not dismantled, the waste handling, waste transports and any possible substances dissolving from the materials or causing dust in terms of the retained buildings can be avoided. If all buildings related to the power plant's operations were to be dismantled, the volume of dismantling waste generated would be significantly higher. If the greenfield option, in which all the buildings are dismantled, is selected, the maximum amount of concrete to be generated by the dismantling of the buildings is expected to be around 355,000 tonnes. The maximum amount of recyclable metal (steel, stainless steel and copper) to be generated is expected to be approximately 41,000 tonnes. Current estimates put the maximum volume of hazardous waste to be generated at roughly 42,000 tonnes. Other conventional dismantling material may also be generated. According to preliminary estimates, 90% of the dismantled conventional material can be reused.

For example, the conventional concrete waste generated in the dismantling could be reused in the area's further use by crushing it and using it for earthworks. Earthworks must account for the provisions of the Government Decree on the Recovery of Certain Wastes in Earth Construction (843/2017) to ensure that harmful amounts of pollutants are not dissolved from the material into the soil. If the concrete waste generated cannot be reused in the area, the material must be transported for reuse at other construction sites. Such sites include various road and field structures for which crushed concrete is technically well suited, while substituting for the use of virgin rock and crushed gravel. If the examined concrete waste exceeds the limit values set for the solubility and total concentrations of harmful substances specified in the Government Decree on the Recovery of Certain Wastes in Earth Construction, the concrete waste is delivered to a waste handler permitted to receive the waste in question. In this case, the concrete waste would probably be placed in a landfill. However, compared to other industrial facilities built during the same period, a majority of the concrete waste is likely to be fit for reuse. In addition to conventional concrete waste, the dismantling measures will generate a maximum of 50,000 m^3 of concrete waste with a very low level of activity. While this concrete waste cannot be cleared from regulatory control, it could be used, to the extent possible, as filling material alongside the quarry material during the L/ILW repository's closing phase. 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.

The metal waste generated in connection with dismantling will be directed to metal recycling. In practice, 100% of conventional metal waste can be recycled for the production of new metal. Other conventional waste generated during dismantling is delivered to materials recycling insofar as possible. Such materials include plastic and gypsum waste, window glass and asphalt. The recycling of the materials for the production of new products reduces the use of virgin raw materials. Some of the dismantled materials will be used as energy in a facility permitted to incinerate the waste in question. Materials that can be used as energy include wood waste (excluding impregnated wood).

Soil materials will have to be excavated in the context of the dismantling. If the soil materials are contaminated as referred to in the Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007), they will either have to be handled in the area or transported to a waste handler permitted to receive the soil material in question. The degree to which the soil is contaminated will be assessed in accordance with a separate plan in the context of the dismantling.

Typical hazardous substances in the construction materials, machinery and equipment of this period include:

- asbestos
- materials containing PAH compounds (such as water insulation)
- materials containing PCB (including hydraulic fluids, lubricants, the oils of heat exchangers)
- materials containing heavy metals
- CCA and chlorophenol (impregnated wood)
- waste electrical and electronic equipment (WEEE waste)
- condenser and hydraulics oils
- other oily waste.

The handling, storage and transport of hazardous waste generated during the dismantling must be carried out in accordance with regulations. Hazardous waste can be recycled as materials, used as energy and disposed of by incineration or final disposal. Part of the hazardous waste can be processed to serve as raw materials for the industrial sector.

A decommissioning waste management plan according to which the waste will be handled and placed in interim storage within the power plant area so that it will not result in an environmental impact will be drawn up for conventional waste. Indirect environmental impacts will be generated by the transport of waste and from the processes of the operators responsible for the further treatment of the waste.

9.10.5.4 Summary of the magnitude of the change

Limit values are not exceeded in the handling of low and intermediate-level waste and spent nuclear fuel within the power plant area under normal operations, when accounting for existing and planned handling and operating methods. The radiation exposure of people and the environment resulting from the transport of spent nuclear fuel in a normal situation is also very small, due to which the additional exposure is practically indistinguishable from the exposure caused by the environment's background radiation. All in all, the magnitude of the change in the environmental impact when accounting for the handling of low and intermediate-level waste and transports of spent nuclear fuel is expected to be *minor and negative* at most.

When conventional waste is handled and stored in the power plant area appropriately, it does not have an environmental impact. Indirect environmental impacts will be generated by the transport of waste and from the processes of the operators responsible for the further treatment of the waste. The magnitude of the change is expected to be *minor and negative*.

9.10.6 Radioactive waste generated elsewhere in Finland and its impact

Since Loviisa power plant already has both 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 recommendations of the National Nuclear Waste Management Cooperation Group established by the Ministry of Economic Affairs and Employment (MEAE 2019) that they would be available as part of the overall social solution.

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 radioactive waste generated by Loviisa power plant itself will be in the order of 100,000 m^3 at most, the waste generated elsewhere in Finland will be small by comparison (roughly 2%).

The waste generated elsewhere in Finland is primarily packed in a manner fit for final disposal in the location where it is generated, but it is also possible for Loviisa power plant's waste treatment systems (such as the solidification of liquid waste) to be used for the treatment of this waste. In principle, the handling and final disposal of radioactive waste generated elsewhere in Finland complies with Loviisa power plant's established practices, procedures and instructions.

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. The quality and volume of the waste to be received is accounted for in the expansion and long-term safety case of the L/ILW repository. The personnel's radiation doses attributable to radioactive waste generated elsewhere in Finland are expected to remain very low.

Radioactive waste generated elsewhere in Finland can result in a maximum of 10 transports a year. The transports will be carried out with a vehicle fit for the purpose. The transports of radioactive substances are subject to the Act on the Transport of Dangerous Goods (719/1994) and the statutes issued pursuant to it. Among other things, these provide for

- the transport packages
- the expertise of the person performing the transport
- safety procedures
- the marking of the vehicle
- the protective equipment and supervision.

According to these provisions, the detailed requirements for the transport's execution depend on the radionuclides to be transported and their radioactivity, for example.

Transports of radioactive substances are regulated by the Act on the Transport of Dangerous Goods (719/1994) and the Radiation Act (859/2018), among other regulations. More than 13 million tonnes of dangerous goods are transported by road alone every year (Strömmer 2019). In 2017, the total haulage (the product of the mass of the material to be transported and the transport distance) of dangerous goods by road was 1,773 million tonne-kilometres, and flammable liquids and corrosive substances form the majority of the transport of dangerous goods (Strömmer 2019). The transports of radioactive substances constitute a small portion of the transports of dangerous goods. According to The Strategy for Transport of Dangerous Goods published by the Ministry of Transport and Communications, the volume of radioactive substances transported in a year amounts to approximately 20,000 packages (Ministry of Transport and Communications 2012). The police and the Ministry of Transport and Communications (Traficom), with whom STUK cooperates, hold primary responsibility for the general supervision of the transport of dangerous goods. STUK is the competent authority with regard to the approval of the classification, packages and special arrangements for a radioactive substance (STUK 2012).

In Finland, the radioactive waste generated outside Loviisa power plant possibly transported to Loviisa power plant or the L/ILW repository is primarily in solid form, and does not burn or cannot explode easily, for example. Transport regulations regulate the radiation shielding of vehicles so that external radiation will not cause harm in the vicinity of a transport. Furthermore, when comparing the number of transports of radioactive waste generated elsewhere in Finland destined for Loviisa power plant (a maximum of 10 transports a year) to the aforementioned volumes of dangerous goods transported on Finnish roads, one can conclude that the addition will be negligible.

The waste generated elsewhere is either deposited in the L/ILW repository for final disposal immediately after it has arrived in Loviisa or will possibly be placed in interim storage within the premises of the power plant or the L/ILW repository prior to final disposal. Interim storage may come into question when it is appropriate to deposit the waste in Loviisa power plant's final disposal halls for decommissioning waste. Due to the small volume of the waste, the radiation impact of these measures amounts to only a fraction of the already quite small radiation impact of operational waste. The final disposal will be implemented so that the total emissions of radioactive substances and the resulting radiation doses of the population in the surrounding area remain below the limit values pursuant to the Nuclear Energy Decree, both during the plant's operation and the closure of the final disposal facility.

The dismantling waste of VTT's FiR 1 research reactor differs from Loviisa power plant's own decommissioning waste particularly in terms of the aluminium and graphite it contains, which may carry relevance mainly in the final disposal conditions of the waste. The basic safety significance of aluminium involves the corrosion risk it constitutes for the final disposal hall's other possible metal packaging and the related development of gas. On the other hand, the special characteristics of graphite are the C-14 radionuclide it contains as well as the radionuclide's chemical behaviour and state in the final disposal conditions. These questions are taken into account in the detailed planning for final disposal, ensuring the long-term safety of the final disposal.

The long-term safety impact of the decommissioning waste of the FiR 1 research reactor and VTT's research lab (Otakaari 3) is reviewed in a separate safety analysis. According to the analysis, the radiation impact of the waste in question is significantly lower than that of Loviisa power plant's own waste. While the final disposal of other radioactive waste is assessed on a case-by-case basis, the radiation dose impact of such waste can also be concluded to be significantly lower than that of Loviisa power plant's own waste.

The final disposal in the L/ILW repository of all other waste generated elsewhere in Finland is planned and implemented in such a way that its impact on long-term safety is minor compared to waste originating from Loviisa power plant and that the long-term safety requirements are met. The long-term safety impact of radioactive waste generated elsewhere in Finland will be ensured with separate investigations when necessary.

All in all, the reception, handling and final disposal of radioactive waste generated elsewhere in Finland is expected to have only a minor impact in the Loviisa power plant area, given that the volume of the waste is very small compared to the volume of Loviisa power plant's own waste (at maximum 2% of the volume). The magnitude of the change is expected to be at most *minor and negative* within the Loviisa power plant area.

Since Loviisa power plant is well-equipped for the management of radioactive waste, the reception of radioactive waste at Loviisa power plant supports the safe waste management of radioactive waste generated elsewhere in Finland. This corresponds with the recommendations set by the National Nuclear Waste Management Cooperation Group established by the Ministry of Economic Affairs and Employment (MEAE 2019). At a national level, the reception of the waste is expected to have a moderate and positive impact, because radioactive waste generated in different sources is provided with a safe and cost-effective final disposal solution.

9.10.7 Significance of impacts

Table 9-26 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

Table 9-26. Significance of impacts: waste and waste treatment.

Significance of impacts: waste and waste treatment			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extending operation	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the volume of spent nuclear fuel as well as the low and intermediate-level waste to be handled due to the additional years of operation would increase, and that the radiation to which the personnel is exposed as a result of the waste management measures would continue. Even so, the increase in the total volume of waste would not increase the personnel's radiation doses significantly compared to the current operations. The limit value for the annual dose of a member of the public caused by the entire nuclear power plant's normal operation – including the various phases of the waste management of spent nuclear fuel as well as low and intermediate-level waste – is 0.1 mSv. The impact generated by the waste management measures in normal operations is very low, and the legal limit values are not exceeded.
Decommissioning	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** because the dismantling work and waste handling will expose the personnel to minor radiation. The personnel's collective radiation dose accumulating during the decommissioning is expected to be around 10 manSv. Final disposal measures will account for slightly less than a fifth of this, i.e. slightly less than 2 manSv. The annual collective radiation dose will be roughly equal to that resulting from the plant's current operation. The radiation dose of even a single individual employee will not exceed the power plant's targeted dose constraint, set lower than the legal limit value. The decommissioning methods will be selected so that the annual dose constraint of 0.01 mSv applicable to a member of the public pursuant to the Nuclear Energy Decree is not exceeded. This means that the radiation impacts will be very low. The radiation exposure of people and the environment resulting from the transport of spent nuclear fuel is very small, and the additional exposure is practically indistinguishable from the exposure caused by the environment's background radiation. According to the long-term safety case, the existing parts and expansion of the L/ILW repository meet the requirements for long-term safety. Once the L/ILW repository has been closed, the radiation dose of the most exposed individuals will remain below 0.1 mSv a year.
Radioactive waste generated elsewhere in Finland: Loviisa	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the volume of radioactive waste generated elsewhere in Finland is low compared to the volume of Loviisa power plant's radioactive waste, and the impact that its handling and final disposal will have on the radiation doses of the personnel and residents in the surrounding area will be minor in relation to waste originating from Loviisa power plant.
Muualla Suomessa muodostuneet radioaktiiviset jätteet: koko Suomi	**Moderate**	**Moderate positive**	**The significance of the impacts is moderate and positive,** because radioactive waste generated in various sources would be provided with a safe and cost-effective final disposal solution on a nationwide scale. 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.

9.10.8 Mitigation of adverse impacts

With regard to radioactive waste, adverse impacts can be mitigated in the same manner as in current operations by minimising the waste volume, appropriate radiation protection measures, and correct handling and final disposal methods, for example. In addition, the long-term safety case and modelling are also intended to facilitate the assessment of the safety of final disposal in the future, and to serve as a basis for planning the handling and packaging methods of future waste in a manner favourable to long-term safety, for example. The handling and final disposal of radioactive waste will be implemented in accordance with the provisions of the Nuclear Energy Act (990/1987) and the statutes issued pursuant to it.

All conventional waste is handled in accordance with valid legislation and as planned. This ensures that the waste materials do not cause harm or pose a risk to the environment or people. With regard to conventional waste, the waste materials are delivered to waste handlers permitted to handle the waste in question. This means that the waste management operators are responsible for ensuring that the adverse impacts are as small as possible.

9.10.9 Uncertainties

The impact assessment involves uncertainties in terms of decommissioning. Loviisa power plant's decommissioning plans are partly preliminary and waste volumes, for example, will be specified only at a later stage.

The reception of radioactive waste generated elsewhere in Finland also involves uncertainties, and their impacts will be assessed in more detail in the detailed planning to be carried out subsequently on a case-by-base basis.

The long-term safety assessment reviews a very long time interval, due to which it naturally involves uncertainties. The long-term safety case and modelling will be specified during various stages of the final disposal facility's lifecycle, up to and including its closure. An assessment of the uncertainties and impacts of a very long time interval also constitutes an integral part of this work.

9.11 ENERGY MARKETS AND SECURITY OF SUPPLY

9.11.1 Principal results of the assessment

The extended operation of Loviisa nuclear power plant supports the security of supply of Finland's energy system and reduces the need to import electricity as its consumption grows in the future. Nuclear power plants also enable the export of electricity which replaces fossil-based electricity production elsewhere. The significance of the impact of extending operation would be major and positive.

The power plant's decommissioning would result in a need to procure electricity free of carbon dioxide emissions for Finland to achieve its carbon neutrality objective. This would lead to the construction of new electricity production capacity in Finland and the increased importation of electricity.

The possibilities for exporting electricity from Finland would also reduce. The significance of the impacts would be major and negative.

Radioactive waste generated elsewhere would not have an impact on the energy markets or the security of supply.

9.11.2 Baseline data and assessment methods

The impacts on the energy markets and security of supply were assessed on the basis of statistics on the electricity markets of Finland and other Nordic countries, as well as projections and reports, taking into account Finland's objective of carbon neutrality by 2035. The baseline data are presented in more detail in the following figures.

9.11.3 Present state

The electricity production of Loviisa power plant in 2020 was 7.8 TWh (Fortum Power and Heat Oy 2021). Loviisa power plant produces electricity for the Nordic wholesale electricity market, which covers Finland, Sweden, Norway and Denmark. In 2020, the net production of electricity in the Nordic electricity market totalled 402 TWh, while electricity consumption amounted to 378 TWh (Nord Pool 2021). The Nordic market also carries out electricity trades with other market areas.

Finland's electricity production in 2020 was 65.9 TWh, while the total consumption of electricity was 80.9 TWh. Finland's electricity exchange with other Nordic countries amounted to 18.7 TWh of net import. A further 2.8 TWh of electricity was imported to Finland from Russia, in addition to which the net export of electricity to Estonia was 6.6 TWh. (Finnish Energy 2021)

Figure 9-17 shows electricity production per energy source and the net import of electricity in 2020. In peak consumption situations, Finland depends on imports – for example, the

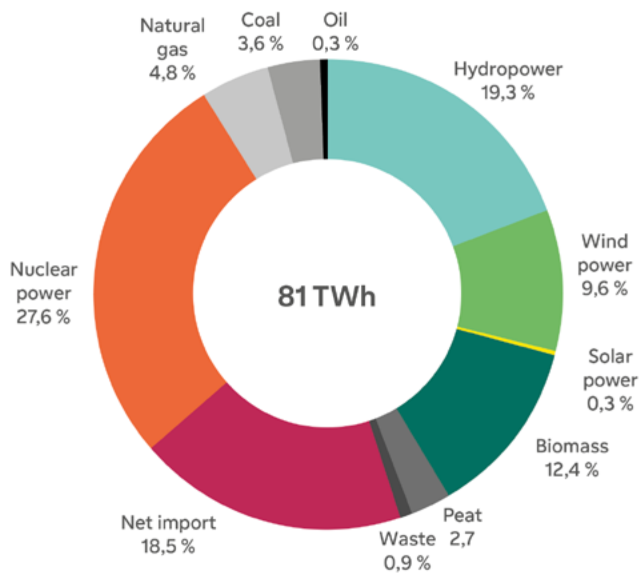

Figure 9-17. Electricity production by energy source and net import of electricity in 2020. (Finnish Energy 2021)

Table 9-27. Sensitivity of the affected aspect: energy markets and security of supply.

Sensitivity of the affected aspect: energy markets and security of supply	
The sensitivity level of the affected aspect is determined according to the current situation of Finland's energy markets and security of supply, which are influenced by, among other things, the electricity production capacity, electricity consumption as well as the import and export of electricity.	
Moderate	Finland's electricity production in 2020 was 65.9 TWh, while the total consumption of electricity was 80.9 TWh. In peak consumption situations, Finland depends on imports, with the greatest estimated need for imports in the winter of 2020/2021 having been roughly 4,300 MW on a cold day.

greatest estimated need for imports during a cold winter day in 2020/2021 was roughly 4,300 MW. The importation capacity from neighbouring countries to Finland via transmission connections totals around 5,100 MW. (Energy Authority 2021)

Table 9-27 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.11.4 Environmental impact of extended operation

Impact formation

In the case of extended operation, electricity production in Loviisa will continue for approximately 20 years, during which Loviisa nuclear power plant's electricity production would remain on its current level.

The current Government Programme in Finland aims to achieve carbon neutrality by 2035 and carbon negativity soon after that (Government 2021). Electricity can replace the use of fossil fuels and raw materials which lead to carbon dioxide emissions in the industrial sector, transport and heating. At the same time, the good efficiency of electronic processes improves energy efficiency. In addition to electricity's direct end use, electricity can be used for the production of synthetic fuels and the industrial sector's raw materials with what is referred to as Power-to-X solutions, by producing hydrogen from water with the help of electrolysis. Electricity consumption is therefore expected to grow significantly in the future, in Finland and in the other Nordic countries. According to the low-carbon roadmaps published by the MEAE, Finland's climate objectives could translate into a 100% growth in the industrial sector's electricity consumption and a more than 50% growth in Finland's electricity consumption by 2050 MEAE 2020a, Figure 9-18).

Nordic electricity consumption is also expected to grow significantly. In the scenarios drawn up by European transmission system operators, electricity consumption in the Nordic countries would be in the range of 436–472 TWh in 2030 and in the range of 468–558 TWh in 2040 (ENTSO-E & ENTSOG 2020).

In respect of the security of supply in Finland's electricity production, nuclear power plays a key role in terms of the available electricity production, regardless of weather and the fuel storages of nuclear power plants. This importance is set to grow as coal power plants are decommissioned due to the use of coal for energy becoming prohibited as of May 2029, and as the energy use of peat and peat stocks decreases in line with climate targets.

The opportunities to increase hydropower in Finland are small; nor can Finland increase the availability of woodfuel for power plant use to any significant degree from the current level. While the production of wind and solar power is growing, they are constrained by their dependence on weather and the small production of solar power during winter. As the consumption of electricity increases, both existing and new nuclear power plants will support the security of supply in Finland's energy system and reduce the need to import electricity. At the same time, nuclear power plants enable the export of electricity, which can replace fossil-based electricity production and reduce the attendant carbon dioxide emissions, especially in the Baltic countries and Poland. Given that emission reduction targets increase the costs of fossil-based electricity production through emissions trading, Finland's increasing nuclear and wind power capacity, combined with the flexible Nordic hydropower capacity, will provide the conditions needed for both Finland's increasing electricity consumption and the export of electricity.

Based on the above, the magnitude of the change in the extended operation of Loviisa power plant can be expected to be *considerable and positive.*

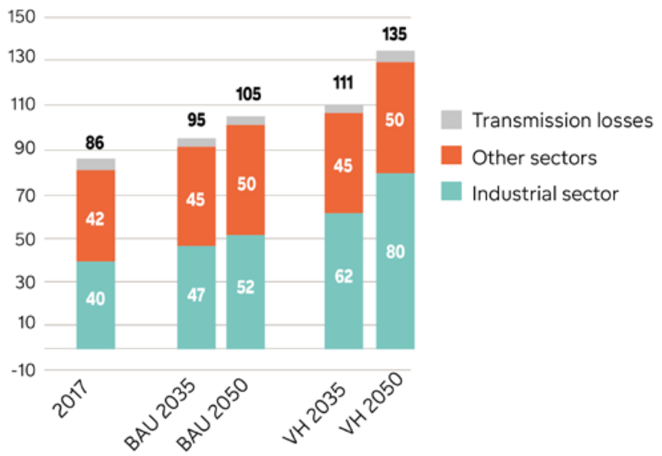

Figure 9-18. The electricity demand of the industrial and other sectors in the scenarios of the background review of the energy industry's roadmap. Photo: Ministry of Economic Affairs and Employment 2020a.

9.11.5 Environmental impact of decommissioning

Impact formation

The impacts of decommissioning arise when the electricity produced by nuclear energy needs to be replaced by increasing the production or import of electricity.

Loviisa power plant's decommissioning would result in a need to procure electricity free of carbon dioxide emissions for Finland to achieve its carbon neutrality objective. This would lead to additional costs and environmental impact, the construction of new capacity in Finland and the increased importation of electricity. The import of electricity would increase. Alongside the Nordic and Baltic countries, this would probably include Russia, which has yet to limit the carbon dioxide emissions of electricity production.

The use of fossil fuels could also increase in Finland, which would demand additional investments in the recovery of carbon dioxide. The possibilities for exporting electricity from Finland would also reduce, which would reduce export earnings and impede the reduction of fossil-based electricity production, especially in the Baltic countries and Poland. The reduction of nuclear power at the level of the EU as a whole as well would result in additional costs were the EU to achieve its emission reduction targets.

Advantageously for Finland's power grid, Loviisa power plant is located in Uusimaa, southern Finland, which is a deficiency area in terms of its electricity balance. The use of electricity in the regions of southern Finland (Southwest Finland, Uusimaa, Kanta-Häme, Päijät-Häme, Kymenlaakso, South Karelia and South Savo) was 37.3 TWh in 2019, while the regions produced 23.4 TWh of electricity, of which Loviisa power plant accounted for 8.2 TWh. The area's net export to Estonia amounted to 3.5 TWh, whereas the majority, or 7.6 TWh, of electricity imported from Russia was delivered to the area (Finnish Energy 2020).

The decommissioning of Loviisa power plant would mean a significant additional deficiency in the electricity balance of southern Finland, which would probably require the construction of new transmission lines to this area from elsewhere in Finland. The region of Uusimaa also still has quite a lot of combined heat and power production that relies on fossil fuels. The future replacement of this production with other district heat production will increase the need for power transmission to the area (Fingrid 2021).

Based on the above, the magnitude of the change is expected to be considerable and negative when the nuclear power plant's electricity production comes to an end.

9.11.6 Radioactive waste generated elsewhere in Finland and its impact

Radioactive waste generated elsewhere in Finland would not have an impact on the energy markets or the security of supply.

9.11.7 Significance of impacts

Table 9-28 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

Table 9-28. Significance of impact: energy markets and security of supply.

Operational phase	Sensitivity	Magnitude	Significance
Extending operation	**Moderate**	**Major positive**	**The significance of the impacts is considerable and positive,** because as the use of electricity increases, 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. Nuclear power plants also enable the export of electricity which replaces fossil-based electricity production.
Decommissioning	**Moderate**	**Major negative**	**The significance of the impact is major and negative,** Loviisa power plant's decommissioning would result in a need to procure electricity free of carbon dioxide emissions for Finland to achieve its carbon neutrality objective. This would lead to the construction of new capacity in Finland and the increased import of electricity. The production method and carbon dioxide emissions of imported electricity may vary according to origin. The possibilities for exporting electricity from Finland would also reduce.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No impact**	**No impact,** because the operations are not related to the energy markets.

9.11.8 Mitigation of adverse impacts

The mitigation of possible adverse impacts on the energy markets and security of supply would result in a need for additional investments by various market operators in the electricity system.

9.11.9 Uncertainties

The impact assessment is an indicative assessment, given that it is based on projections of the electricity market's future development, among other things. Projections always involve a degree of uncertainty. The uncertainties are related to assessments of the replacement of electricity produced by nuclear power with other forms of electricity production in the future. The preparation of more precise reviews of Finland's energy markets and security of supply is the responsibility of the Finnish government (2020b).

9.12 GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE

9.12.1 Principal results of the assessment

The nuclear power plant's electricity production does not generate greenhouse gas emissions. The nuclear power plant's emission-free electricity production supports Finland's objective to be carbon neutral by 2035, in line with the Programme of Prime Minister Sanna Marin's Government. This means that the production of electricity and heat in Finland must be nearly emission-free by the end of the 2030s, taking into account the perspectives of maintenance and delivery reliability. The greenhouse gas emissions during the lifecycle of electricity produced by means of nuclear power are at the same level as those of electricity produced with wind power. In extended operation, the emissions of the emergency diesel generators and traffic would remain the same as their current annual levels, and their impact on the annual level would be negligible. The significance of the impacts is expected to be moderate and positive in the case of extended operation.

The decommissioning of Loviisa power plant would lead to a need to increase other electricity production capacity to a corresponding degree. Should the substituting form of electricity production be wind power, for example, the greenhouse gas emissions resulting from the electricity production would not change when accounting for the emissions generated by the production operations and the specific emissions during the lifecycle of the form of electricity production. The greenhouse gas emissions to be generated in the decommissioning (by traffic and the testing of the diesel generators, among other things) are negligible. Overall, the significance of the impacts of decommissioning is expected to be moderate and negative.

Radioactive waste generated elsewhere would not have an impact on greenhouse gas emissions.

9.12.2 Baseline data and assessment methods

The emissions generated by the project are presented as carbon dioxide equivalents (CO_{2e}): the greenhouse gas emissions created in the different stages of the project were made commensurate to describe the global warming potential (GWP).

With regard to the extension of the power plant's operation, the assessment reviewed the direct greenhouse gas emissions of the activities, generated mainly by the CO_{2e} emissions from the use of fuel by the power plant's backup power generators and the consumption of fuel by transports during the power plant's additional years of operation. The emissions calculation employed the following baseline data and assumptions:

- The greenhouse gas emissions attributable to the power plant's backup power generators were calculated on the basis of data on the consumption of light fuel oil. The unit-specific emissions data for light fuel oil were obtained from the database of the Gabi lifecycle assessment software (Gabi database 2021).
- In terms of heavy vehicle traffic, the assessment relied on the assumption that the vehicles used in the transports were big distribution trucks (gross vehicle mass 15 tonnes, load-carrying capacity 9 tonnes) or earthmoving trucks (gross vehicle mass 32 tonnes, load-carrying capacity 19 tonnes), to which emission factors defined in the VTT LIPASTO database were applied (VTT Ltd. 2017). With regard to heavy vehicle traffic, the background data on the transports consisted of average transport distances in Finland (OSF 2020).
- The emission factors applied to passenger traffic were the unit emission factors in the VTT LIPASTO database (passenger cars on average in Finland in 2016).
- In terms of passenger traffic, it was assumed that the personnel's average daily commute by passenger car was approximately 20 km in one direction. The calculation did not account for the personnel's possible use of public transport or the electrification of the passenger car fleet.

In terms of extended operation, reviews and comparisons also included the greenhouse gas emissions of different forms of energy production over their lifecycles, based on published studies (Bruckner et al. 2014; WNA 2016).

In the case of decommissioning, the reviews also included direct greenhouse gas emissions during decommissioning, which are generated by the CO2e emissions of traffic and the testing of the diesel generators. The emission calculations employed the baseline data and assumptions presented above. In reality, the fuel consumption related to the testing of the diesel generators during decommissioning will be less than it is during the power plant's operation. In the case of decommissioning, the review also included the impact that the end of the power plant's operation would have from the perspective of Finland's national carbon neutrality objective by investigating, in an indicative sense, the possibility of replacing the electricity produced by nuclear power with other forms of electricity production.

Preparations for the possible impacts of climate change are described in Chapter 7 and Chapter 9.22.2.3. Furthermore, the cooling water modelling (Chapter 9.16 and Appendix 4) accounts for the increase in heat attributable to climate change by relying on the exceptionally warm summer of 2011 as observational data. The selection of the modelling year aimed to consider the impact of climate change which will increase the mean annual temperature, and as a result of which conditions warmer than average may occur at sea.

9.12.3 Present state

The greenhouse gas emissions of the town of Loviisa in 2018 totalled some 118,000 tonnes in carbon dioxide equivalents (CO_2e). The most notable sources of emissions in Loviisa are road traffic (27%), agriculture (16%) and other heating (10% of total emissions). Emissions have been on a declining trend since 2005, and have reduced by 23%. The figures are based on a calculation of municipality-specific greenhouse gas emissions produced by the Finnish Environment Institute (SYKE 2020). The 2018 emissions of the town of Loviisa account for some 0.8% of Uusimaa's greenhouse gas emissions and approximately 0.2% of the greenhouse gas emissions of Finland as a whole (OSF 2021).

In 2018, Loviisa signed the Covenant of Mayors for Climate & Energy, which is a voluntary energy and climate covenant of mayors. The signatory cities and towns undertake to support the EU's reduction target of 40% in terms of greenhouse gas emissions by 2030, and to adapt to a joint approach for mitigating and adjusting to climate change. The town of Loviisa also monitors its own greenhouse gas emissions with a CO_2 calculation. (Town of Loviisa 2021c, Benviroc Oy 2018) The Helsinki-Uusimaa Regional Council has drawn up its own municipal Climate Neutral Helsinki-Uusimaa 2035 roadmap, which is based on national and international climate goals (Helsinki-Uusimaa Regional Council 2020). The roadmap supports the region's municipalities and other operators in the implementation of climate work. The climate work has been structured around six different focal areas.

Finland's greenhouse gas emissions totalled 52.8 million tonnes CO_2e in 2019. Emissions reduced by 6% compared to the previous year. The emissions have declined by 26% from the reference year 1990 and by 38% since 2003, when the emissions were at their highest during the 1990–2019 time series (OSF 2021). In accordance with the Programme of Prime Minister Sanna Marin's Government, Finland aims to be carbon neutral by 2035 (Government 2021). Of the targets laid out in the Government Programme, the target related to energy production states Finland's ambition to be the world's first fossil-free society. This means that the production of electricity and heat in Finland must be nearly emissions-free by the end of the 2030s, accounting for the perspectives of maintenance and delivery reliability. According to the programme, the means for achieving this include a positive attitude towards extending the permits and licences of existing nuclear power plants, provided that STUK is in favour of it. (Government 2021)

The new medium-term climate plan extending until 2035 will be ready by the summer of 2021. It aims to outline how Finland can achieve the carbon neutrality objective pursuant to the Government Programme. The new climate and energy strategy covers all Finland's sources (the emissions trading sector, effort-sharing sector, land use sector) and sinks (land use sector) of greenhouse gas emissions. The strategy functions as a connective carbon neutrality 2035 action plan. (Ministry of Economic Affairs and Employment 2020c)

According to the Intergovernmental Panel on Climate Change (IPCC 2018), human activities had warmed the world's climate by approximately 1 °C by 2017 compared to pre-industrial times. So far, the temperature has increased by about 0.2 °C each decade. An increase of only 1.5 °C in the mean temperature could have significant impacts for life on Earth. The IPCC's report reviews these impacts by comparing them to an increase of 2 °C in the mean temperature. Should the two-degree scenario materialise, the number of ice-free summers in the North Pole would increase tenfold, for example, and the number of people suffering from a lack of water globally would double. According to the IPCC, for global warming to be limited to 1.5 °C, carbon dioxide emissions must begin to decline steeply without delay. In the Paris Agreement, the world's countries committed to the target of keeping the increase in the world's mean temperature to less than 2 °C and to pursue measures which could limit the warming to less than 1.5 °C.

Table 9-29 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

Table 9-29. Sensitivity of the affected aspect: greenhouse gas emissions and climate change.

Sensitivity of the affected aspect: greenhouse gas emissions and climate change
The sensitivity level of the affected aspect cannot be determined, because the impacts of climate change at a local level are indirect, affecting the natural environment and its phenomena in different ways. Climate change is a global problem, and combating it is a joint mission of all states. As part of the European Union, Finland has committed to the Paris Agreement and set the national target for reducing emissions as being carbon neutral by 2035. This requires several different measures to be carried out by various industries. The production of electricity and heat in Finland must be nearly emission-free by the end of the 2030s, taking into account the perspectives of maintenance and delivery reliability.

9.12.4 Environmental impact of extended operation

Impact formation

The operation of the nuclear power plant does not generate direct greenhouse gas emissions. Indirect greenhouse gas emissions are generated by the emissions of the backup power generators and the fuel consumption of traffic. Emissions are also generated during the lifecycle of the nuclear fuel.

Operation's greenhouse gas emissions

The operation of the nuclear power plant does not generate direct greenhouse gas emissions. Indirect emissions are generated by the emissions of the backup power generators and the fuel consumption of traffic.

The greenhouse gas emissions generated by the power plant's backup power generators (the diesel plant and the diesel-powered emergency power plant) have been calculated on the basis of the consumption of light fuel oil. The average amount of light fuel oil used is 260 tonnes a year (the maximum amount stored is 595 tonnes). The specific emissions of light fuel oil are approximately 0.088 kg CO_2e per MJ of energy produced. This means that its use generates greenhouse gas emissions of 991 t CO_2e at an annual level, when the use remains at an average level. Cumulatively, the total amount of greenhouse gas emissions is 19,825 t CO_2e when operation continues for 20 years, and the annual emissions do not change (Table 9-30).

The plant receives daily commuter traffic and goods transports, which generate greenhouse gas emissions. The average daily traffic to the power plant is approximately 500 vehicles, of which approximately 40 are heavy 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. Annual outages last for 2–8 weeks, on average for 35 days. The power plant's daily commuter traffic and goods transports generate a total of 2,183 t CO_2e of greenhouse gas emissions a year. When accounting for the increased traffic during the annual outage, the emissions caused by all traffic amount to a maximum of 2,444 t CO_2e a year. Daily traffic accounts for 89% of this, and the traffic during the annual outage for a maximum of 11%. Passenger car traffic accounts for 46%, and heavy vehicle traffic for 54% of the total emissions of all traffic. Cumulatively, the total amount of greenhouse gas emissions generated by traffic over a period of 20 years is 48,874 t CO_2e, provided that the annual emissions do not change (Table 9-31).

Table 9-30. Greenhouse gas emissions attributable to the use of light fuel oil in the case of the power plant's extended operation.

	Average use a year	The produced energy	Emission factor	Emissions per year	Cumulative emissions (c. 20 years)
Light fuel oil	260 t	11,232 000 MJ	0.088 kg CO_2e/MJ	991 t CO_2e	19,825 t CO_2e

Table 9-31. Greenhouse gas emissions attributable to the plant's commuter traffic and goods transports.

	Number of vehicles/day	Emission factor	Distance, km (one direction)	Emissions kg CO_2e /day	Emissions t CO_2e /year	Cumulative emissions t CO_2e /20 years
Daily traffic						
Passenger cars	460	152 g CO_2e/km	20	2,797	1,021	20,417
Heavy vehicles	40	67 g CO_2e/tkm	66	3,184	1,162	23,242
Total	**500**			**5,981**	**2,183**	**43,659**
Maximum increase during annual outage						
Passenger cars	440	152 g CO_2e /km	20	2,675	94	1,873
Heavy vehicles	60	67 g CO_2e /tkm	66	4,776	167	3,343
Total	**500**			**7,451**	**261**	**5,216**
All traffic (daily traffic and impact of annual outage)						
Emissions, total					**2,444**	**48,874**

In the case of extended operation, the magnitude of the annual direct greenhouse gas emissions, when accounting for both the use of the backup power generators and the power plant's traffic, is equal to its level in current operation, i.e. approximately 3,355 t CO_2e/v. This amount is roughly 3% of the total emissions of the town of Loviisa (118,000 t CO_2e). The impact of the total amount of greenhouse gas emissions is negligible at the annual level compared to the emissions of the town of Loviisa or Finland. The climate change impact will remain at its current annual level, but will continue for approximately 20 years.

Emissions during the lifecycles of different fuels

The use of the reactor in nuclear-powered electricity production does not generate direct greenhouse gas emissions. In this respect, nuclear power is equal to hydro-, wind and solar power, which do not generate greenhouse gas emissions. However, when reviewing the greenhouse gas emissions of different forms of energy production, one must assess their emissions throughout the lifecycle, meaning that in the case of nuclear power, the procurement of nuclear fuel, for example, is also included. The amount of energy and fossil fuels consumed during different phases of a lifecycle has an impact on the total emissions of different forms of energy production.

Several lifecycle studies compare the greenhouse gas emissions of different forms of energy production. A study published by the IPCC (Bruckner et al. 2014) compares the specific emissions during the lifecycles of different forms of energy production. A lifecycle's specific emissions include direct emissions, the emissions from infrastructure building, biogenic CO_2 emissions and methane emissions. According to the IPCC's estimate, the lifecycle's greenhouse gas emissions in electricity produced by nuclear power are around 12 g CO_2e/kWh (Bruckner et al. 2014, Figure 9-19). Country-specifically conducted assessments range between 3–16 g CO_2e/kWh (WNA 2016).

The emissions of electricity produced with coal or natural gas are tenfold as high – 820 g CO_2e/kWh for coal and 490 g CO_2e/kWh for natural gas. The CO_2 emissions during the lifecycle of electricity produced with nuclear power are mostly generated in the fuel's supply chain and as a result of the power plant's construction. Especially the fossil fuels used as input for production in the nuclear fuel's supply chain (the extraction of uranium, the refining of the fuel, transports, etc.) have an impact on the formation of the emissions. In the case of fossil fuels, the CO_2 emissions during the lifecycle of the electricity production are mostly generated during the electricity's production phase. (Bruckner et al. 2014, WNA 2016) Even though the incineration of wood-based fuels or other biomass generates large amounts of greenhouse gas emissions, bio-energy is interpreted as emission-free in Finland's greenhouse gas inventory, because a tree has sequestered a corresponding amount of carbon from the atmosphere during its growth to what is released in its incineration.

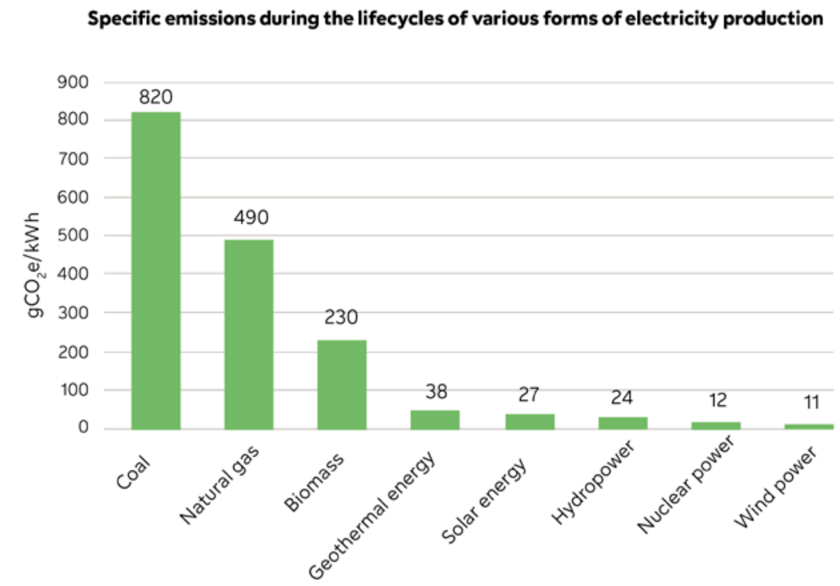

Figure 9-19. Comparison of the specific emissions during the lifecycles of different forms of energy production. (Bruckner et al. 2014)

When comparing the emissions during the lifecycles of different forms of energy production, the greenhouse gas emissions during the lifecycle of electricity produced by nuclear power (12 g CO_2e/kWh) are at the same level as those of electricity produced by wind power (11 g CO_2e/kWh). The use of nuclear power in electricity production supports Finland's goal, the Programme of Prime Minister Sanna Marin's Government, of being carbon neutral by 2035, which would require heat and power production in Finland to be nearly emission-free by the end of the 2030s, taking into account the perspectives of maintenance and delivery reliability. According to the programme, the extended permits and licences of existing nuclear power plants will be regarded positively, provided that STUK is in favour of it. (Government 2021)

9.12.5 Environmental impact of decommissioning

Impact formation

Greenhouse gas emissions are generated during various phases of decommissioning by the fuel consumption of commuter traffic and transports as well as by the testing of the diesel generators. The replacement of nuclear-powered electricity production with other low-emission forms of electricity production must also be taken into account.

Operation's greenhouse gas emissions

The estimated traffic volumes during various phases of decommissioning and the greenhouse gas emissions they generate are presented in the table 9-32. Cumulatively, a total of 131,976 t CO_2e of greenhouse gas emissions is generated during all phases of decommissioning (roughly 40 years). Of this, 5% is generated during the expansion of the L/ILW repository (roughly three years), 29% during the first dismantling phase (roughly seven years), 54% during the operation of the plant parts to be made independent (roughly 35 years), 12% during the second dismantling phase (roughly three years), and 1% during the L/ILW repository's closing phase. At an annual level, the greenhouse gas emissions of the decommissioning are, on average, approximately 3,300 t CO_2e.

In addition, small amounts of greenhouse gas emissions are generated during decommissioning by the testing of the diesel generators, which are needed primarily to ensure the cooling of the storage for spent nuclear fuel. The amounts are significantly lower than in the power plant's current operation.

In the case of decommissioning, the greenhouse gas emissions are roughly 3,300 t CO_2e on average, which is in the region of the emissions of the current operation (approximately 3,355 t CO_2e per year). This amount is roughly 3% of the current total emissions of the town of Loviisa (118,000 t CO_2e). The impact of the total amount of greenhouse gas emissions is negligible at the annual level when compared to the emissions of the town of Loviisa or Finland alone.

The traffic volumes resulting from the dismantling of all buildings in accordance with the greenfield principle have not been assessed. Should the greenfield principle be followed, the volume of both passenger traffic and heavy vehicles would be higher than is presented here due to the increased dismantling work.

Replacement of electricity production

The decommissioning of Loviisa power plant would lead to a need to increase other electricity production capacity or the importation of electricity to a corresponding degree if the demand for electricity remains unchanged. Based on Finland's carbon neutrality objective, the substituting of production in Finland should be emission-free. Alternatively, the carbon dioxide emissions should be recovered. Any increasing fossil-based electricity production in Finland or other EU member states would have to be compensated for with emissions reductions at the level of the entire system due to the common emission cap set by the EU's emissions trading scheme.

In Finland, the most likely new electricity production would consist of wind power, given that Finland would not be able to increase the availability of woodfuel for electricity production to any significant degree from the current level. Due to the weather dependency of wind power, its use would also involve the construction of large amounts of storage capacity for electricity on the basis of battery technology and other technologies under development. The flexibility of the production of existing hydropower plants and biopower plants, and the flexibilities in electricity consumption, should also be put to use to an increasing degree to compensate for the fluctuation in the production of wind power.

Should the substituting electricity production rely on fossil fuels, it would also involve the recovery and storage of the carbon dioxide emissions (Finnish Coal Info 2021). Given that the energy use of coal in Finland will be prohibited from the spring of 2029, the principal power plant fuel after this would be natural gas (Gasum Oy 2019).

The use of hydrogen as a power plant fuel could also be technically possible, in which case the burning would not generate carbon dioxide emissions. However, at least for now, hydrogen is considerably more expensive than other fuels, given that it must be produced either from natural gas or by electrically powered electrolysis from water. The production of hydrogen from natural gas generates carbon dioxide which would have to be stored or reused.

Loviisa power plant's current units could also be replaced by new nuclear power plant units. However, due to the duration of the nuclear power's permit and construction process, any potential nuclear power plant units based on the current technology could not be implemented by the end of the current operating licences of Loviisa's units. The modular nuclear power plants based on new technology, the unit size of which is smaller, are not yet commercially available.

9.12.6 Radioactive waste generated elsewhere in Finland and its impact

Small amounts of greenhouse gas emissions are generated by the transports of radioactive waste generated elsewhere in Finland (approximately 10 transports a year). The maximum amount of these emissions at an annual level is approximately 0.8 t CO_2e.

Table 9-32. Greenhouse gas emissions attributable to passenger traffic and logistics during various phases of the plant's decommissioning.

	Number of vehicles/day	Emission factor	Distance, km (one direction)	Emissions t CO_2e /day	Emissions t CO_2e /year	Cumulative emissions during phase, t CO_2e
Expansion of L/ILW repository (duration c. 3 years)						
Passenger cars	480	152 g CO_2e/km	20	2.9	1,065	3,196
Heavy vehicles	50	67 g CO_2e/tkm	36	2,.7	999	2,996
Total	**530**			**5.7**	**2,064**	**6,192**
First dismantling phase (duration c. 7 years)						
Passenger cars	800	152 g CO_2e /km	20	4.9	1,775	12,428
Heavy vehicles	100	40 g CO_2e /tkm	66	10.0	3,662	25,632
Total	**900**			**14.9**	**5,437**	**38,059**
Operation of the plant parts to be made independent (duration c. 35 years)						
Passenger cars	250	152 g CO_2e/km	20	1.5	555	19,418
Heavy vehicles	40	40 g CO_2e/tkm	66	4.0	1,465	51,264
Total	**290**			**5.5**	**2,019**	**70,682**
Second dismantling phase (duration c. 3 years)						
Passenger cars	800	152 g CO_2e/km	20	4.9	1,775	5,326
Heavy vehicles	100	40 g CO_2e/tkm	66	10.0	3,662	10,985
Total	**900**			**14.9**	**5,437**	**16,311**
Closure of L/ILW repository (duration c. 3 years)						
Passenger cars	20	152 g CO_2e/km	20	0.1	44	133
Heavy vehicles	10	40 g CO_2e/tkm	36	0.5	200	599
Total	**30**			**0.7**	**244**	**732**
All phases, total						
Emissions, total						**131,976**
Total emissions per year						**3,299**

9.12.7 Significance of impacts

The sensitivity level of the affected aspect and the magnitude of the change cannot be determined precisely in terms of climate change, because climate change is a global phenomenon involving a variety of direct and indirect impacts. The impact assessment nevertheless accounts for the global warming potential of the total amount of greenhouse gas emissions generated. The indicative total significance of the impacts has been assessed by a group of experts.

Table 9-33. Significance of impact: greenhouse gas emissions and climate change.

Significance of impact: greenhouse gas emissions and climate change			
Operational phase	Sensitivity	Magnitude	Significance
Extending operation	*Cannot be determined*	*Cannot be determined*	**The significance of the impacts is moderate and positive,** because the nuclear power plant's electricity production does not generate greenhouse gas emissions, and because its emission-free electricity production supports Finland's objective of being carbon neutral by 2035, in line with the Programme of Prime Minister Sanna Marin's Government. This means that the production of electricity and heat in Finland must be nearly emission-free by the end of the 2030s, taking into account the perspectives of maintenance and delivery reliability. The greenhouse gas emissions during the lifecycle of electricity produced by means of nuclear power are at the same level as those of electricity produced with wind power. The greenhouse gas emissions generated by the power plant's operations (as a result of the emergency diesel generators and traffic, for example) are negligible.
Decommissioning	*Cannot be determined*	*Cannot be determined*	**The significance of the impacts is moderate and negative,** given that the decommissioning of Loviisa power plant would lead to a need to increase other emission-free electricity production capacity by a corresponding degree. Should the substituting form of electricity production be wind power, for example, the greenhouse gas emissions resulting from the electricity production would not change when accounting for the emissions generated by the production operations and the specific emissions during the lifecycle of the form of electricity production. The greenhouse gas emissions to be generated in the decommissioning (by traffic and the testing of the diesel generators, among other things) are negligible.
Radioactive waste generated elsewhere in Finland	*Cannot be determined*	*Cannot be determined*	**No impact,** given that the greenhouse gas emissions, primarily generated by traffic, are negligible.

Table 9-33 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.12.8 Mitigation of adverse impacts

Alternatives to the reduction of direct greenhouse gas emissions include the improvement of the generators' energy efficiency and the replacement of fossil fuels with bio-based fuels. The impact of traffic emissions can be reduced in terms of passenger traffic by offering incentives for the use of public transport, for example. The reduction of greenhouse gas emissions generated during a fuel's lifecycle especially involve the replacement of the fossil fuels used as an input for production in the supply chain of nuclear fuel with other fuels.

9.12.9 Uncertainties

The assessment's uncertainties are related to the calculation limitations and assumptions made in the emission calculations concerning traffic and to the assessments concerning the replacement of nuclear-powered electricity production with other forms of electricity production in the future.

The magnitude of the change caused by the decommissioning cannot be assessed in its entirety yet, because a substituting electricity production method cannot be ascertained. Should the substituting form of electricity production be wind power, for example, the greenhouse gas emissions resulting from the electricity production would not change when accounting for the emissions generated by the production operations and the specific emissions during the lifecycle of the form of electricity production.

9.13 REGIONAL ECONOMY

9.13.1 Principal results of the assessment

Loviisa power plant's impact on the regional economy is locally and regionally major, and also visible at the level of the entire country. The power plant's operations will continue in the current manner for the next 20 years, resulting in the accumulation of significant direct impacts on the regional economy during the additional years of operation. These impacts will simultaneously maintain the current level of the economy, especially at the local and regional level. In addition, the amount of turnover generated for other industries in the Loviisa sub-regional area in the form of a multiplier effect amounts to more than EUR 500 million. Added value accounts for more than EUR 280 million of this turnover, and the amount of labour that the various industries will need as a result will equal more than 5,000 person-years. Nevertheless, the employment impact of extended operation will be largely covered by existing jobs, and the annual euro-denominated effects will be similar to their current size. The significance of the impacts is expected to be very high and positive within the Loviisa sub-regional area. The impacts also extend to Eastern Uusimaa and Kymenlaakso, as well as the rest of Finland.

Once the power plant is no longer in operation, its significant impacts on the regional economy will come to an end. However, regional economy impacts affecting different operators and industries will be generated during decommissioning. New demand forming in the sub-regional area of Loviisa during the decommissioning will amount to more than EUR 300 million in the form of a multiplier effect, more than EUR 170 million in added value and more than 3,800 person-years as a need for labour. The significance of the impacts is expected to be high and positive, but the impacts on the regional economy will come to an end when the decommissioning ends. The impacts also extend to Eastern Uusimaa and Kymenlaakso, as well as the rest of Finland.

The radioactive waste generated elsewhere in Finland will not have measurable regional economic impacts, given that the operations are of such a small scale.

9.13.2 Baseline data and assessment methods

The baseline data for the assessment consisted of the prepared plans as well as the latest economic indicators provided in regional and national accounts.

The impacts that the extended operation and decommissioning of the power plant will have on the regional economy were assessed with the help of the resource flow model developed by Ramboll Finland Oy and the Natural Resources Institute Finland by commission of the Finnish Innovation Fund Sitra. The model was developed on the basis of an input-output method, and it indicates how resource flows in money and materials are directed to the region's production, intermediate consumption between industries (public and private), and as exports from the region.

In the modelling, the review focused on a description of the reviewed areas' present state in terms of socioeconomics and the regional economy, and based on this, on identifying the interactive relationships between different industries and assessing the economic impacts. The modelling accounted for the local (the town of Loviisa), regional (the former region of Eastern Uusimaa and the region of Kymenlaakso) and national levels (the entire country). The data in the resource flow model were updated with the latest statistics available on the state of the regional economy and economic life before the impact assessment (including jobs and turnover by sector).

The assessment covered the multiplier effects that the project's production and consumption will have on employment, total yield, value added and tax income. The assessment of the impacts on the regional economy thereby considers the production impacts that are indirectly linked to the operations, as well as changes in consumption caused by the changed compensation of employees and its associated impacts. The results of the modelling do not include Fortum Power and Heat Oy's Loviisa nuclear power plant's own net sales, value added, investments, production labour needs or the taxes paid on the operations during the operation of Loviisa power plant. However, the results do include Fortum's employees related to the investment in extending the service life of Loviisa nuclear power plant and the plant's decommissioning, as well as the income and local taxes withheld from their wages. The potential extension of the service life creates a need for new investments higher than the current average investments. While these investments do not increase the need for production labour in the power plant's operating organisation, they do require labour for planning and implementation operations. These impacts are included in the results of the modelling.

The power plant's direct impacts on the regional economy are discussed separately in Chapter 9.13.3.

9.13.3 Present state

Loviisa nuclear power plant has great importance for the vitality of the region of Loviisa. The nuclear power plant's current operations maintain and increase economic activity at the local, regional and national levels. The present state can be reviewed through Statistics Finland's regional accounts and statistics on enterprises, which demonstrate the energy industry's (TOL 35) significance at various regional levels, among other things. The energy industry's significance is shown in Table 9-34. In the sub-regional area of Loviisa (the town of Loviisa + the municipality of Lapinjärvi), the energy industry is extremely important for the area's vitality and cash flows, and further accentuated compared to its importance in other geographical areas (Table 9-34).

Table 9-34. The energy industry's (TOL 35) share of the total in terms of the direct impacts at various regional levels.

	Loviisa (sub-regional area)	Kymenlaakso (region)	Uusimaa (region)	Finland as a whole
Investments (EUR)	70.6 %	0.4%	5.0%	6.1%
Turnover (EUR)	32.8%	2.2%	2.1%	2.2%
Value added (EUR)	40.4%	2.0%	2.2%	2.0%
Employee compensations (EUR)	18.4%	0.7%	0.9%	0.8%
Employment (persons)	10.5%	0.4%	0.6%	0.5%
Establishments (number of)	0.4%	0.6%	0.3%	0.4%

Up to 70.6% of all new investments in the Loviisa sub-regional area occur in the energy industry which, in essence, largely translates into Loviisa nuclear power plant. This percentage is extremely significant, given that at the national level, the energy industry's investments make up only 6.1% of all annual investments. Indeed, the nuclear power plant's role as the driver of the economy in the sub-regional area of Loviisa cannot be overstated. The energy industry's importance at the local level is also visible in other indicators of the regional economy (turnover, value added, employee compensations, employment).

The regional economic indicators also clearly show that the activity in question is capital intensive, given that the energy industry's share of all the region's impacts, when measured by euro-denominated variables, is around 18–70%, whereas when measured solely in jobs, it is only slightly above 10%. Yet the employment impact (10% of all employed persons in the sub-regional area) is significantly above the average in Finland or the regional level in Kymenlaakso and Uusimaa, where the energy industry accounts for only 0.4–0.6% of all employed persons, depending on the regional level reviewed.

According to Statistics Finland's indicators, there were approximately 4,900 jobs in Loviisa in 2017 (Statistics Finland 2019a; Table 9-35). An increasing share of the labour force in Loviisa works in the service industry, although this share is significantly smaller than the average in Uusimaa and Finland as a whole. One of the most important employers in the processing industry in Loviisa is Fortum's Loviisa power plant, which generates electricity (approximately 500 jobs). The number of business establishments in Loviisa in 2017 was 1,410 (Statistics Finland 2019b). The share of the processing industry in Loviisa is higher than the average in Finland. Loviisa's enterprise structure is focused on small and medium-sized enterprises. In 2016, there were 99 industrial establishments in Loviisa, the turnover of which was EUR 121 million (Kokkonen 2018). Loviisa's income tax rate in 2020 was 20.25% (Association of Finnish Municipalities 2020).

Table 9-36 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4). The sensitivity of the regional economy impacts was deemed very high at the local level (the sub-regional area of Loviisa), moderate at the regional level (Eastern Uusimaa + Kymenlaakso) and minor at the national level.

9.13.4 Impact of extended operation

Impact formation

Loviisa nuclear power plant's multiplier effects on the regional economy are composed of the purchases required by the operations over a period of 20 years, the maintenance investments related to extended operation and the consumption at various regional levels arising from the employee compensations paid within their value chains. The results of the modelling do not include Loviisa nuclear power plant's own net sales, value added, investments, production labour needs or the taxes paid on the operations during the operation of Loviisa power plant.

Table 9-35. Indicators for the town of Loviisa 2017 (Statistics Finland 2019a).

	Per cent %
Primary production	5.8
Processing	32
Services	59.9
Unemployment rate	11.2
Employment rate	71.2
Commuting	41.6

The impact that extended operation would have on the regional economy is major at the local, regional and national levels. The turnover to be generated for other industries in Finland in the form of multiplier effects as a result of the maintenance investments to be made during the operation and the purchases required by the operations amounts to approximately EUR 3.6 billion, and the employment impact would equal roughly 26,700 person-years. However, given that these impacts would concern largely the same operators which they concern now, during current operation, this means that the employment impact, for example, would translate to the existing jobs continuing to exist only until 2050. The impacts on the regional economy generated in the form of multiplier effects add up amongst themselves in different regions (Table 9-37). The results do not include Fortum Power and Heat Oy's Loviisa nuclear power plant's own net sales, value added, investments, production labour needs or the taxes paid on the operations. These direct impacts of the power plant would remain the same as their current levels in their magnitude (Chapter 9.13.3). The period reviewed concerned the extension of operation by roughly 20 years following the expiration of the current licences.

The magnitude of the impacts was assessed at a local (the sub-regional area of Loviisa), regional (Eastern Uusimaa + Kymenlaakso) and national levels (the entire country). The magnitude of the calculated multiplier effects is shown in relation to the most recent (one-year) indicators of the regional accounts. This has allowed a description of the significance for the regional economy's key indicators, which are turnover, added value, employment, investments and taxes. Table 9-38 shows the average magnitude of the impact of extended operation by region at the annual level and over the entire review period.

Based on the results, one can see that the regional economy impacts resulting from extended operation are fairly significant, particularly at the local level, where approximately 1.4–5.3% of all regional economy impacts in the Loviisa

Table 9-36. Sensitivity of affected aspect: regional economy.

Sensitivity of affected aspect: regional economy	
The sensitivity of the affected aspect was assessed with the aid of the region's economic structure, unemployment, public economy and population development, among other factors.	
Minor	**National level** The region has a diverse economic structure, low unemployment, growing population development as well as diverse public and private sector services, and the number of new enterprises in the region is growing.
Moderate	**Regional level (Eastern Uusimaa + Kymenlaakso)** The region has a balanced economic structure, a solid local economy, a balanced population structure, a steady employment situation and a sufficient range of services.
Very high	**Local level (the sub-regional area of Loviisa)** The region has a very narrow economic structure, high unemployment, a rapidly declining population, and a limited range of services or no services at all.

Table 9-37. The regional economy multiplier effects that extended operation would have on other industries at local, regional and national levels. The regional data add up, meaning that Eastern Uusimaa and Kymenlaakso do not include the figures of Loviisa to avoid double counting.

	Loviisa	Eastern Uusimaa and Kymenlaakso	The rest of Finland	Finland as a whole, total
Duration	20 years	20 years	20 years	20 years
Net sales	EUR 524 million	EUR 864 million	EUR 2,224 million	EUR 3,612 million
Value added	EUR 289 million	EUR 442 million	EUR 1,061 million	EUR 1,792 million
Employment	5,111 person-years	9,624 person-years	11,978 person-years	26,714 person-years
New investments	EUR 87 million	EUR 104 million	EUR 307 million	EUR 499 million
Taxes	EUR 264 million	EUR 332 million	EUR 439 million	EUR 1,036 million

Table 9-38. The magnitude of the regional economy multiplier effects in extended operation. The magnitude of the calculated multiplier effects is shown in relation to the most recent (one-year) indicators of the regional accounts.

	Loviisa	Eastern Uusimaa and Kymenlaakso	Finland as a whole
Cumulative impact over entire review period			
Duration	20 years	20 years	20 years
Net sales	55%	6%	0.8%
Value added	52%	8%	0.9%
Employment	92%	14%	1.0%
New investments	29%	7%	0.9%
Taxes	107%	13%	1.9%
Average impact per year			
Net sales	2.8%	0.28%	0.04%
Value added	2.6%	0.39%	0.04%
Employment	4.6%	0.69%	0.05%
New investments	1.4%	0.37%	0.04%
Taxes	5.3%	0.66%	0.1%

sub-regional area are generated in the form of multiplier effects. The results do not include the energy industry's direct economic impacts which, according to the latest statistics on the regional economy, have been in the order of 10–70%. They are described in more detail in Chapter 9.13.3 and in Table 9-34.

As a result of the extended operation of Loviisa nuclear power plant, existing demand would also continue for 20 years longer, which would have an impact on other industries and operators in both Eastern Uusimaa and Kymenlaakso as well as elsewhere in Finland. A cumulative assessment puts these impacts at around EUR 864 million in Eastern Uusimaa and Kymenlaakso, and around EUR 3,600 million across the entire country.

9.13.5. Impact of decommissioning

Impact formation

Loviisa nuclear power plant's impacts on the regional economy arise from the new demand generated in various industries during the decommissioning, and from the consumption at various regional levels generated by the employee compensations paid within the value chains. The new demand will concern particularly the recycling and dismantling of materials.

Should the operation of Loviisa nuclear power plant not be continued after the current operating licences, the demand described in the previous chapters will be removed from the regional economy. The decommissioning will generate economic activity in industries departing from the power plant's current operation, given that the operation will have ended, and the nuclear power plant will have progressed to the next phase of its lifecycle. The cumulative impacts of the decommissioning by region are shown in Table 9-39. The results in the different regions are cumulative. The period reviewed covered 30 years, which would take place either in 2030–2060 or 2050–2080, depending on whether the power plant's operation is extended or not. Nevertheless, the impacts are similar in both cases, and their realisation in the regional economy will only take place over a different period.

Cumulatively, the decommissioning will generate a need for labour equal to some 17,500 person-years, which will be divided – based on the existing plans and the socioeconomic structures of the different regions – as follows: approximately 22% in the Loviisa sub-regional area, approximately 35% in Eastern Uusimaa and Kymenlaakso, and approximately 43% elsewhere in Finland. The other impacts on the regional economy will also spread across the different regions, which is explained in more detail in Table 9-39.

The magnitude of the impacts was assessed at a local (the sub-regional area of Loviisa), regional (Eastern Uusimaa + Kymenlaakso) and national levels (the entire country). The magnitude of the calculated multiplier effects is shown in relation to the most recent (one-year) indicators of the regional accounts. This has allowed a description of the significance for the regional economy's key indicators, which are turnover, added value, employment, investments and taxes. Table 9-40 shows the average magnitude of the impact of decommissioning by region at the annual level and over the entire review period.

The results show that the decommissioning will generate economic impacts which consist of new demand and which do not currently exist. At the annual level, these economic impacts will account for roughly 0.5–2.3% of all regional impacts in the sub-regional area of Loviisa, based on the data in the latest regional accounts. The equivalent approximate percentages in terms of Eastern Uusimaa and Kymenlaakso, as well as other regions in Finland, are 0.11–0.31 and 0.02–0.04 respectively. However, the economic impacts of the current operation will disappear from the regional economies at the same time. The impacts during operation and the impact of the decommissioning will nevertheless concern largely different industries and operators, meaning that the impacts will be positive for some of the operators and negative for others. The net impact was not modelled in the context of assessing the impacts on the regional economy. Rather, the assessment concerned the impacts on other enterprises and industries resulting from the operations carried out during Loviisa power plant's different lifecycle phases, including the sub-regional area of Loviisa at the local level as well as Eastern Uusimaa and Kymenlaakso at the regional level, and the rest of Finland at the national level.

9.13.6 Radioactive waste generated elsewhere in Finland and its impact

The theoretical impacts on the regional economy within the value chain arise from the reception, handling, interim storage and final disposal of individual batches of waste. According to current estimates, the individual batches would correspond to approximately one full load a year. This means that the reception of radioactive waste generated elsewhere in Finland is such a small-scale activity that it would not have measurable economic impacts. The activity would be carried out by making use of already existing resources and other investments made for the nuclear power plant's operations. This being the case, nor would the reception of radioactive waste generated elsewhere in Finland result in separately payable employee compensations or new consumption demand in different regions.

Table 9-39. The regional economic impacts of the decommissioning at the local, regional and national levels. The regional data add up, meaning that Eastern Uusimaa and Kymenlaakso do not include the figures of Loviisa to avoid double counting.

	Loviisa	Eastern Uusimaa and Kymenlaak	The rest of Finland	Finland as a whole, total
Duration	30 years	30 years	30 years	30 years
Net sales	EUR 311 million	EUR 502 million	EUR 1,444 million	EUR 2,257 million
Value added	EUR 176 million	EUR 273 million	EUR 702 million	EUR 1,151 million
Employment	3,815 person-years	6,055 person-years	7,664 person-years	17,534 person-years
New investments	EUR 45 million	EUR 69 million	EUR 194 million	EUR 308 million
Taxes	EUR 151 million	EUR 205 million	EUR 292 million	EUR 648 million

Table 9-40. The magnitude of the impacts that the decommissioning will have on the regional economy. The magnitude of the calculated multiplier effects is shown in relation to the most recent (one-year) indicators of the regional accounts.

	Loviisa	Eastern Uusimaa and Kymenlaakso	The rest of Finland
Cumulative impact over entire review period			
Duration	30 vuotta	30 vuotta	30 vuotta
Net sales	33%	3%	0.5%
Value added	32%	5%	0.6%
Employment	69%	9%	0.7%
New investments	15%	4%	0.5%
Taxes	61%	8%	1.2%
Average impact per year			
Net sales	1.1%	0.11%	0.02%
Value added	1.1%	0.16%	0.02%
Employment	2.3%	0.31%	0.02%
New investments	0.5%	0.14%	0.02%
Taxes	2.0%	0.26%	0.04%

9.13.7 Significance of impacts

Figures 9-20, 9-21 and 9-22 illustrate the impact that extended operation and decommissioning will have on the regional economy, and their temporal realisation, at the local level (the sub-regional area of Loviisa) through turnover, added value and employment. The period between 2000 and 2018 is based on the realised amount of turnover, value added and need for labour reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on turnover, value added and the need for labour was assumed to be equal to that during 2018, the latest year for which statistics on regional accounts were compiled. The impact of the decommissioning on turnover, value added and the need for labour is based on the results of the modelling, in which the impacts during the nuclear power plant's operation, including their multiplier effects, have been removed from the amount and the impact of the decommissioning, including its multiplier effects, has been added to the results. Following the end of operation, the region's turnover will ultimately be at a new level, which is approximately 32% lower than in 2018. Correspondingly, the value added would be at a level around 38% lower and employment at a level around 12% lower [than in 2018].

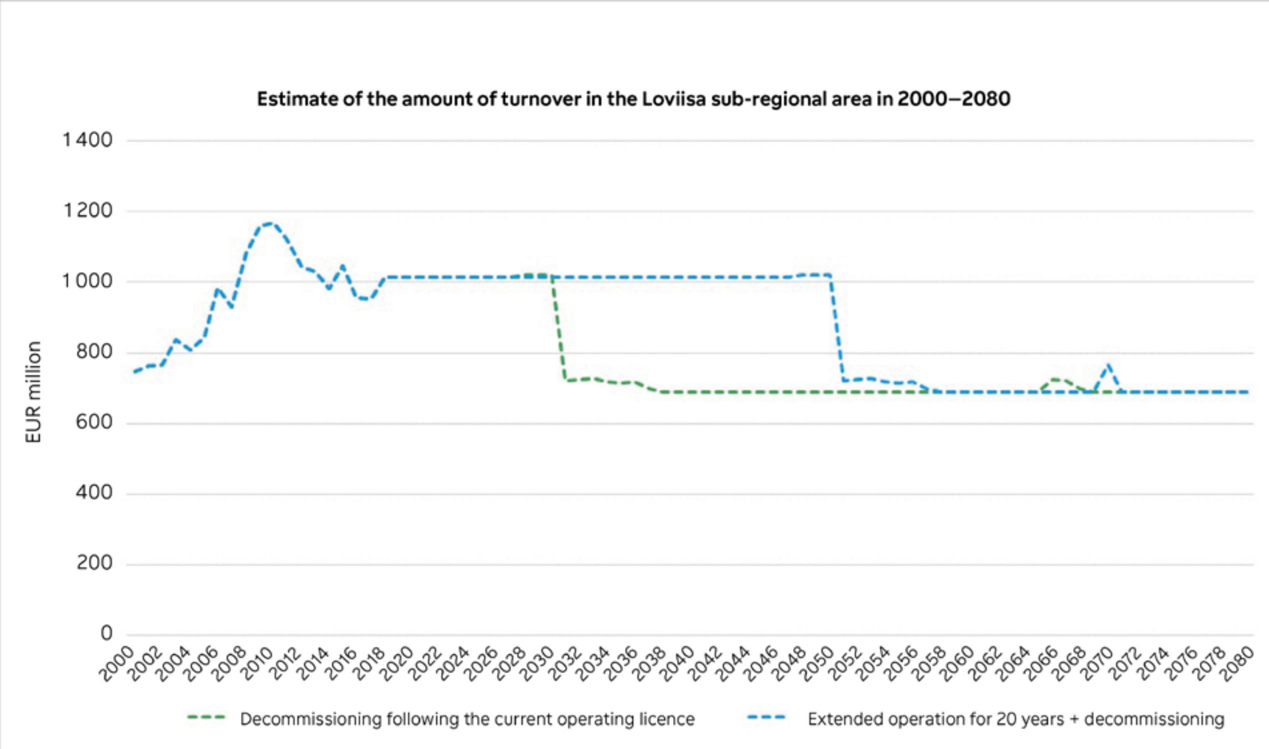

Figure 9-20. Estimate on the amount of turnover in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on turnover was assumed to be equal to that during 2018, the latest year for which statistics on regional accounts were compiled. In respect of the multiplier effects, the impact of the decommissioning is based on the results of the modelling, and in respect of the direct impact, it is based on the data concerning regional accounts reported by Statistics Finland. The nuclear power plant's impacts during operation, including their multiplier effects, have been removed from the regional amount in the graph, while the impact of decommissioning, including its multiplier effects, has been added to the results.

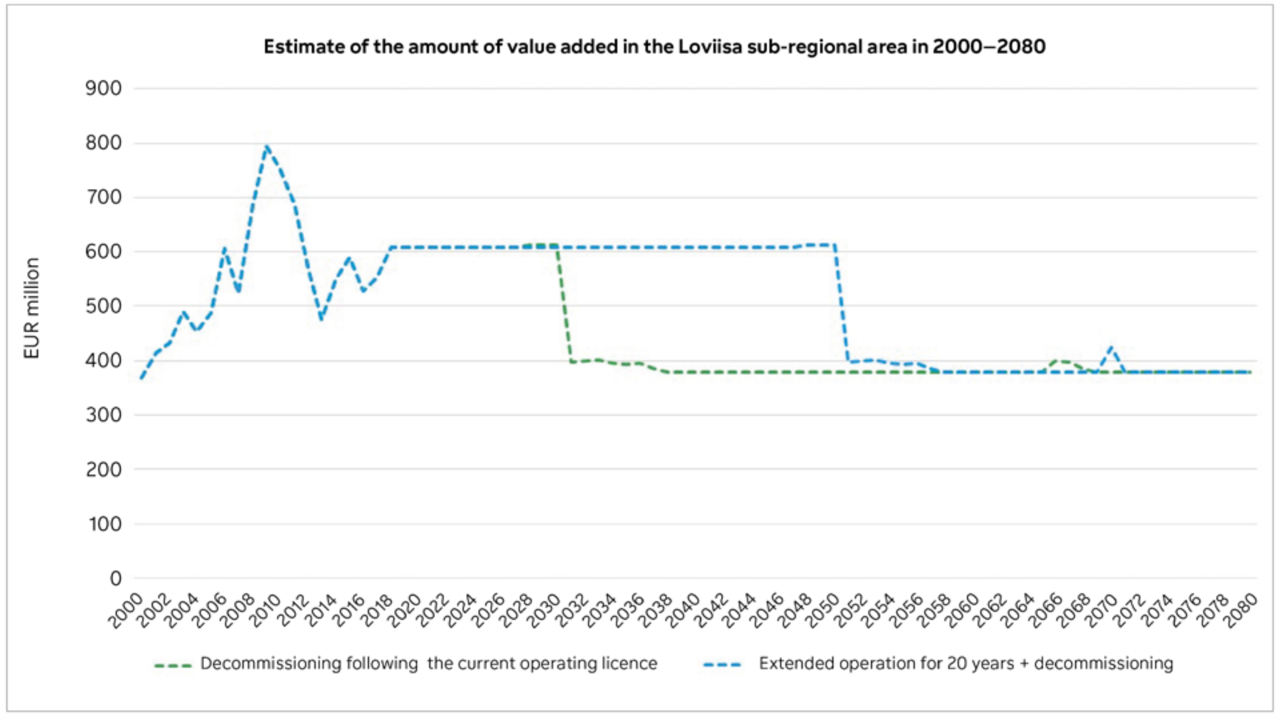

Figure 9-21. Estimate on the amount of value added in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on the value added was assumed to be equal to that during 2018, the latest year for which statistics on regional accounts were compiled. In respect of the multiplier effects, the impact of the decommissioning is based on the results of the modelling, and in respect of the direct impact, it is based on the data concerning regional accounts reported by Statistics Finland. The nuclear power plant's impacts during operation, including their multiplier effects, have been removed from the regional amount in the graph, while the impact of decommissioning, including its multiplier effects, has been added to the results.

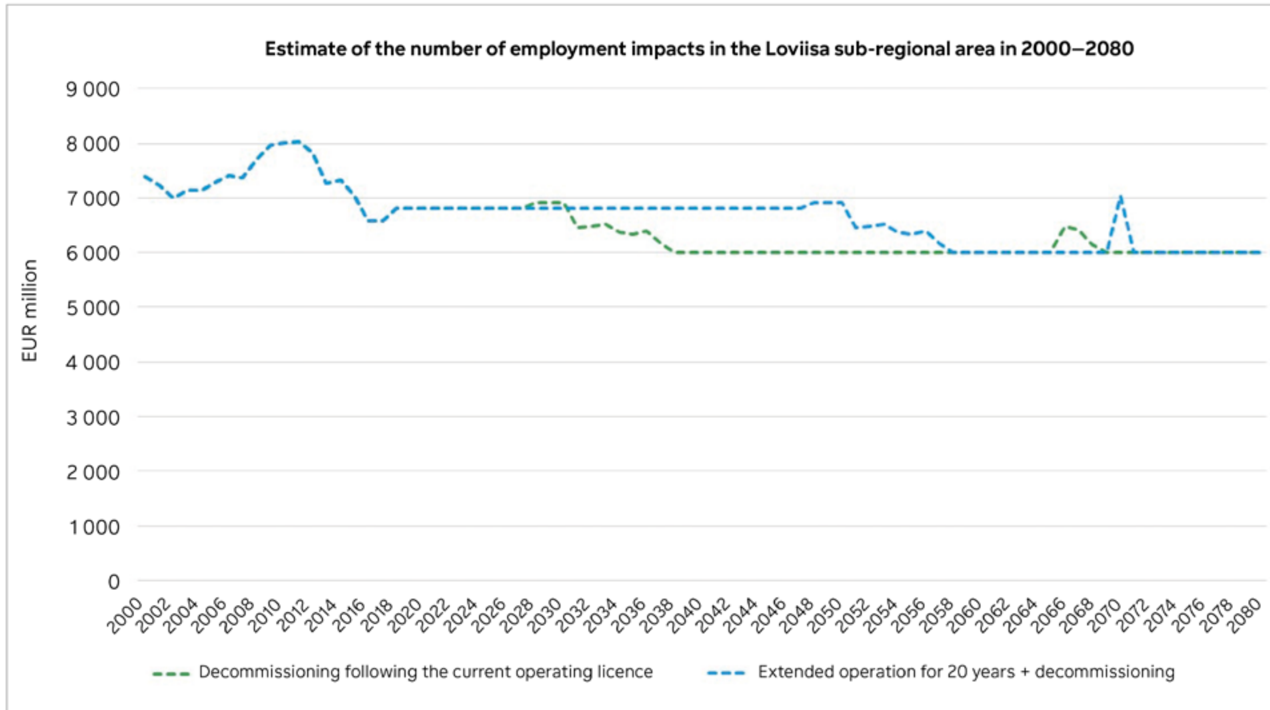

Figure 9-22. Estimate on the amount of labour needed in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on the need for labour was assumed to be equal to that during 2018, the latest year for which statistics on regional accounts were compiled. In respect of the multiplier effects, the impact of the decommissioning is based on the results of the modelling, and in respect of the direct impact, it is based on the data concerning regional accounts reported by Statistics Finland. The nuclear power plant's impacts during operation, including their multiplier effects, have been removed from the regional amount in the graph, while the impact of decommissioning, including its multiplier effects, has been added to the results.

Table 9-41. Significance of impacts: regional economy (Loviisa sub-regional area).

Significance of impacts: regional economy (Loviisa sub-regional area)			
Operational phase	Sensitivity	Magnitude	Significance
Extended operation	Very high	Major positive	**The significance of the impacts is major and positive,** given that 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. The turnover that would also be generated for other industries in the form of multiplier effects would amount to more than EUR 500 million, while the value added would amount to more than EUR 280 million, and the need for labour to more than 5,000 person-years.
Decommissioning	Very high	Considerable positive	**The significance of the impacts is considerable and positive,** because even though the impact on the regional economy generated during the operation will come to an end as operation ends, regional economy impacts will be generated for various operators and industries during decommissioning. Once the power plant is no longer in operation, its impacts on the regional economy will come to an end. New demand forming during the decommissioning will amount to more than EUR 300 million, while the value added will amount to more than EUR 170 million, and the need for labour to more than 3,800 person-years. The impacts on the regional economy will come to an end once the decommissioning ends.
Radioactive waste generated elsewhere in Finland	Very high	No impact	**No impact,** given that the activity is of such a small scale that it would not have measurable impacts on the regional economy.

Table 9-42. Significance of impacts: regional economy (Eastern Uusimaa and Kymenlaakso).

Significance of impacts: regional economy (Eastern Uusimaa and Kymenlaakso)			
Operational phase	Sensitivity	Magnitude	Significance
Extended operation	Moderate	Moderate positive	**The significance of the impacts is moderate and positive,** given that 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. The turnover that would be generated for other industries in the form of multiplier effects would amount to more than EUR 1,300 million, while the value added would amount to EUR 731 million, and the need for labour to more than 14,700 person-years.
Decommissioning	Moderate	Minor positive	**The significance of the impacts is minor and positive,** because even though the impact on the regional economy generated during the operation will come to an end as operation ends, regional economy impacts will be generated for various operators and industries during decommissioning. Once the power plant is no longer in operation, its impacts on the regional economy will come to an end. New demand forming during the decommissioning will amount to more than EUR 800 million in multiplier effects, while the value added will amount to more than EUR 440 million, and the need for labour to more than 9,800 person-years. The impacts on the regional economy will come to an end once the decommissioning ends.
Radioactive waste generated elsewhere in Finland	Moderate	No change	**No impact,** given that the activity is of such a small scale that it would not have measurable impacts on the regional economy.

Table 9-43. Significance of impacts: regional economy (the entire country).

Significance of impacts: regional economy (the entire country)			
Operational phase	Sensitivity	Magnitude	Significance
Extended operation	Minor	Minor positive	**The significance of the impacts is minor and positive,** given that 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 to the nuclear power plant, the amount of turnover generated for other industries in the form of multiplier effects would amount to more EUR 3,600 million. Added value would account for more than EUR 1,700 million of the new turnover, and the amount of labour that the various industries would need as a result would be equal to approximately 26,700 person-years.
Decommissioning	Minor	Minor positive	**VThe significance of the impacts is minor and positive,** because even though the impact on the regional economy generated during the operation will come to an end as operation ends, regional economy impacts will be generated for various operators and industries during decommissioning. Once the power plant is no longer in operation, its impacts on the regional economy will come to an end. New demand forming during the decommissioning will amount to more than EUR 2,200 million in multiplier effects, while the value added will amount to more than EUR 1,150 million, and the need for labour to more than 17,500 person-years. The impacts on the regional economy will come to an end once the decommissioning ends.
Radioactive waste generated elsewhere in Finland	Minor	No change	**No impact,** given that the activity is of such a small scale that it would not have measurable impacts on the regional economy.

Tables 9-41, 9-42 and 9-43 present an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4). The aspect reviewed consisted of the local, regional and national impacts in the sub-regional area of Loviisa, Eastern Uusimaa and Kymenlaakso, and the rest of Finland, respectively.

9.13.8 Mitigation of adverse impacts

The regional economy will be subject to adverse impacts when the operation of Loviisa power plant comes to an end, and the economic activity around the power plant will end at the same time. This impact can be pushed back by extending operation, but rather than mitigating the impacts, this would only postpone them. Once the plant reaches the end of its lifecycle, significant economic impacts will also form during the decommissioning, but these impacts will largely concern industries different from those subject to the multiplier effects during operation. From the perspective of the regional economy, the activities during decommissioning will nevertheless mitigate the adverse impacts, and the transition to a new economic balance resulting from the end of the activities of Fortum's nuclear power plant will last longer.

The adverse impacts on the regional economy and economic life during decommissioning will largely consist of problems related to the supply and demand of labour (matching) and from the perspective of the region's employers, the potential increase in the cost of labour as demand grows. The potential adverse impacts can be mitigated by the extensive procurement of purchased services from different operators and insofar as possible, from other regions as well. This would help avoid any sudden changes in the matching of supply and demand.

The negative impacts on the regional economy after decommissioning could be mitigated by putting the power plant area to some other further industrial use. This would be supported by decommissioning in accordance with the brownfield principle, in which case the infrastructure serving further use would be left in place.

9.13.9 Uncertainties

The modelling assesses the realisation of a situation in line with current plans. This means that the realisation of the impacts on the regional economy depends on whether the decommissioning will be carried out according to the current plans, and on whether the operations in the future will accord with projections. The multiplier effects will be generated through purchased products and services, the price level of which will have an impact on the multiplier effects generated.

9.14 SOIL AND BEDROCK

9.14.1 Principal results of the assessment

In the case of extended operation, the impacts would be limited to the earthmoving related to new buildings. Extended operation would not result in impacts different from the present state on the soil and bedrock.

During decommissioning, impacts will be generated by the excavation carried out for the expansion of the L/ILW repository. The expansion will be carried out in a manner similar to the current L/ILW repository, in that any significant fragmented rock occurring in the bedrock will not intersect with the final disposal halls. The volume of the L/ILW repository's expansion is smaller than the repository's current size. Compared to the area's present state, the significance of the impact on the bedrock is expected to be minor.

The volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the safety case, and would therefore not have a significant impact on the soil and bedrock.

9.14.2 Baseline data and assessment methods

The impact assessment was carried out in the form of an expert assessment based on previous research and survey data pertaining to the soil and bedrock of the Hästholmen area. Data on the the area's bedrock, presented in the groundwater model of Hästholmen, have also been used. More than 30 test holes were drilled in Hästholmen and the area surrounding it during the research related to the final disposal location. Approximately 20 of these holes extend to the depth of the final disposal halls, and the deepest to a depth of 600–1,000 metres. Most of the holes are in the vicinity of the final disposal halls.

9.14.3 Present state

The island of Hästholmen is located in the coastal zone of Loviisa, and the area profile is generally flat and low. The area is characterised by numerous islands, bays extending deeply into the mainland and long peninsulas with a distinct tendency to lead from northwest to southeast. The bays reflect the fragmented rock zones in the bedrock, the shape of which has been accentuated by the wear caused by the ice sheet during the ice age.

The highest parts of Hästholmen are 16 metres above sea level. The seabed around the island is generally at a depth of 5–10 metres, but deeps of 15 metres can also be found locally. The island's bedrock is to a large extent exposed or covered only by a thin layer of soil. It has been found that to the south and the east of the island, the bedrock sinks locally as deep as 60–70 metres under the strata (Anttila 1988). With the exception of these depressions, the bedrock can be typically found within 20 metres below sea level in the water areas near Hästholmen.

The soil in the Hästholmen area primarily consists of stony and rocky moraine. The thickness of the moraine layer on the island is usually a few metres at most. Construction in the power plant area has required extensive earthmoving activities, which is why the original surface of the ground is covered by various land masses in many areas. The layers of soil on the seabed consist mainly of moraine or rough soil types, gravel and sand, with clay and silt sand layered on top in places. The thickest layers of soil can be found in a deep on the eastern side of Hästholmen, where the total thickness of strata is approximately 60 metres.

The bedrock in Hästholmen is rapakivi granite, typical of the Loviisa area, which can be found in several variants. The most common variant on Hästholmen is pyterlite. The main minerals are potassium feldspar, plagioclase, quartz, biotite and hornblende. Fluorite is a typical accessory mineral. It is mostly unweathered and massive, and its strength properties are good. The disintegration into small rocks typical of rapakivi has been found to occur mainly deeper in the zones containing fragmented rock (Anttila 1988).

Hästholmen's patches of bare rock are dominated by two nearly vertical main cracking directions, northeast to southwest and northwest to southeast. The third main cracking direction veers slightly to the east/northeast. The cracking type is therefore nearly cubic overall. In addition, rock studies have indicated zones containing fragmented rock with a higher density of cracking than elsewhere in the rock. The zones of fragmented rock bear water a lot better than the solid rock between them (Anttila et al. 1999). Rock structures key to the flow of groundwater are described in Chapter 9.15. The L/ILW repository, excavated at a depth of approximately 110 metres in the bedrock of the island of Hästholmen, has been designed so that the significant zones of fragmented rock do not intersect with the final disposal facility. The weathering of rock, especially when associated with fragmentation, always weakens the strength properties of rock mass to some extent. However, the secondary minerals formed as a result of weathering increase the capacity of the rock to retain substances carried with groundwater, such as radionuclides.

The rock mechanics monitoring programme carried out in the L/ILW repository since 1997 surveys the rock's local deformations and stress changes with the help of temperature, extensometer, fissurometer, load and convergence measurements. Based on the observations, rock movements and changes in the state of stress have been minor and largely attributable to changes in temperature. While the impacts of the quarrying work have been detected in the measurement results, they have not had any significant effect on the bedrock in the vicinity of the repository. The results of the monitoring programme have also been complemented with simulations of rock mechanical behaviour. The simulations indicate that the current monitoring network focusing on rock mechanics is sufficient for observing movements occurring in the area of the repository. The monitoring programme was reviewed in the L/ILW repository's periodic safety review drawn up in 2020, in which it was deemed sufficiently extensive and comprehensive.

Table 9-44 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

Table 9-44. Sensitivity of affected aspect: soil and bedrock.

Sensitivity of affected aspect: soil and bedrock	
The assessment criteria for the sensitivity include the affected aspect's geological values as well as the area's present state and natural state.	
Vähäinen	The aspect's sensitivity is minor, because the soil and bedrock in the power plant area have no special value in terms of their geological properties, and because the aspect's soil and bedrock have already been manipulated.

9.14.4 Environmental impact of extended operation

Impact formation

Extended operation would not require an expansion of the previously excavated spaces within the bedrock. Any impacts would be mainly attributable to the earthmoving related to any new buildings.

The L/ILW repository intended for low and intermediate-level waste is already largely built, housing maintenance waste and solidified waste from the power plant's period of operation. The capacity of the previously excavated spaces is also sufficient for the final disposal of the low and intermediate-level waste generated during extended operation, and extended operation would not require an expansion of the repository.

In the case of extended operation, the impacts on the soil and bedrock are related to the construction in the area (including new storage and hall buildings). The new buildings would be located in areas already built or would replace old buildings, meaning that there would be no need to claim new areas for buildings on the island of Hästholmen. The impacts of construction would concern the surface layers of the earth, and their impacts would be comparable to those of conventional earthmoving. Extended operation would not result in impacts different from the present state on the soil and bedrock.

Transport accidents related to chemicals, fuel oil and lubricants could cause contamination of the soil. Incidents and accidents are discussed in Chapter 9.22. The annual storage and usage volumes of chemicals and oils would remain unchanged. The potential risks with regard to the soil would therefore also remain unchanged.

9.14.5 Environmental impact of decommissioning

Impact formation

The most significant impact will arise from the expansion of the L/ILW repository. The expansion will be carried out in a manner similar to the current L/ILW repository, in that any significant fragmented rock occurring in the bedrock will not intersect with the final disposal halls. The volume of the expansion is smaller than the repository's current size.

The most significant impact on the bedrock is caused by the expansion of the L/ILW repository to be located at a depth of more than 100 metres from the surface, and the related excavation. 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.

The design of the L/ILW repository's expansion will account for the zones of fragmented rock in the area's bedrock, the location of which has been modelled on the basis of bedrock drilling conducted in the area. If necessary, the research data will be supplemented with additional drilling. The expansion will be carried out in a manner similar to the current L/ILW repository, in that any significant fragmented rock occurring in the bedrock will not intersect with the final disposal halls.

The plan is to use the quarry material generated in the expansion of the L/ILW repository primarily as a filling material in the closure of the L/ILW repository. Other potential uses of the quarry material are discussed in more detail in Chapter 5.8.6. In addition to the fillings consisting of crushed rock or concrete used for the closure of the L/ILW repository, 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.

The magnitude of the change concerning the area's soil and bedrock is expected to be minor and negative.

9.14.6 Radioactive waste generated elsewhere in Finland and its impact

The maximum volume of radioactive waste generated elsewhere in Finland will be 2% of the total volume of waste generated at the power plant and placed in the L/ILW repository. The volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the long-term safety case, and would therefore not have a significant impact on the soil and bedrock.

Table 9-45. Significance of impact: soil and bedrock.

Significance of impact: soil and bedrock			
Operational phase	Sensitivity	Magnitude	Significance
Extended operation	Minor	No change	**No impact,** given that extended operation would not result in impacts different from the present state on the soil and bedrock. Any impacts would be confined to the earthmoving related to any new buildings.
Decommissioning	Minor	Minor negative	**The significance of the impacts is minor and negative,** because rock quarrying will be carried out for the expansion of the L/ILW repository. The volume of the L/ILW repository's expansion is smaller than the repository's current size.
Radioactive waste generated elsewhere in Finland	Minor	No change	**No impact,** because the volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the long-term safety case.

9.14.7 Significance of impacts

Table 9-45 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.14.8 Mitigation of adverse impacts

The planning of the excavation and use of the bedrock spaces aims to minimise the volume of rock quarried for the expansion of the L/ILW repository, thereby allowing for the rock volume that is to be quarried to be used for the final disposal of waste as efficiently as possible. Instructions for the L/ILW repository's maintenance, ageing management and monitoring are given in the power plant's instructions. These measures include a number of measurements related to rock mechanics.

9.14.9 Uncertainties

The research data on the area's soil and bedrock do not include uncertainties which would be significant in terms of the impact assessment. Data on the area's bedrock and structural geology will be supplemented with further research if necessary as the project's further planning progresses.

The dimensioning of the L/ILW repository's expansion already accounts for any remaining uncertainties in the volume of waste to be deposited in final disposal.

9.15 GROUNDWATER

9.15.1 Principal results of the assessment

Extended operation would not result in impacts differing from the present impact in terms of the quality or volume of groundwater, but the impact would continue for roughly 20 years beyond the expiration of the current operating licences, at most until around 2050. Based on the measurement results of the past few years, the current volume of the L/ILW repository's seepage water is approximately 40 litres per minute.

During decommissioning, the expansion of the L/ILW repository will temporarily increase the volume of seepage water, but the volume will decrease over time. The impact of the L/ILW repository's expansion is expected to be smaller than the impact of the excavation of the original space, given that the expansion will not change the present state of the groundwater conditions as strongly as the excavation and construction of the original space. The impact that the excavation will have on the quality of groundwater is expected to be minor and limited to the immediate vicinity of the space to be quarried. There are no groundwater areas, water catchments or private wells of domestic water in the vicinity of the power plant which could be impacted by the excavation. To prevent migration occurring via the flow of groundwater, the location of the L/ILW repository has been designed, on the basis of the area's bedrock and groundwater studies, as well as modelling, so that the significant zones of fragmented rock within the bedrock do not intersect with the final disposal facilities. The long-term safety of the final disposal is based on technical release barriers and the surrounding bedrock, which serves as a natural release barrier. Following its closure, the L/ILW repository will be gradually filled with groundwater filtering into the facility, meaning that both the level of the groundwater and the boundary between the fresh and saline water will gradually return to their original state.

The volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the safety case, and would therefore not have a significant impact on the soil and bedrock.

9.15.2 Baseline data and assessment methods

The impact assessment was carried out in the form of an expert assessment, based on earlier studies and investigations of the power plant area and the monitoring results. The key baseline data comprised the results of the groundwater chemistry and hydrological monitoring related to the L/ILW repository's periodic safety review and Hästholmen's groundwater model.

Above ground, the hydrological monitoring has covered measurements of the sea level, precipitation and the groundwater level as well as the level of the boundary between fresh and saline groundwater. Measurements conducted in the final disposal facility have covered groundwater pressure and electrical conductivity as well as the volume of seepage water. The monitoring programme was reviewed in the L/ILW repository's periodic safety review drawn up in 2020, in which it was deemed sufficiently extensive and comprehensive.

Hästholmen's groundwater model has been developed in phases. The groundwater conditions have been studied since the 1980s, and a second version of the groundwater model which was originally presented in the 1996 safety review, prepared for the purpose of the application for an operating licence, was drawn up for the 2006 and 2008 safety review. The second version of the model was updated in 2011 with new data on the quality of the bedrock. A third version of the Hästholmen groundwater model was drawn up for the 2018 safety review, and it also includes the planned expansions of the L/ILW repository. All three versions of the groundwater model have been calibrated and validated based on the results of the groundwater measurements. The model will also be updated as necessary in future safety cases, accounting for the most recent data on the bedrock and groundwater conditions.

9.15.3 Present state

In the Hästholmen area, groundwater is primarily found in the layers of loose soil that cover the rock in deeper rock depressions in which the strata are thicker. Gaps in the bedrock contain groundwater. The quality of the seepage waters originating from the bedrock and carried to the L/ILW repository is monitored, and the waters are managed by pumping. The level of groundwater in the Hästholmen area is usually only a few metres below the surface of the ground, and the sea and groundwater levels meet in the littoral zone. The groundwater in the surface level of the groundwater layer is fresh, becoming saline further down.

There are no categorised groundwater areas in the vicinity of Hästholmen. The nearest groundwater area is the Valko groundwater area approximately seven kilometres to the northeast on the mainland. It has been categorised as a groundwater area important for water supply (class 1). There are no private domestic water wells in the vicinity of Hästholmen. The nearest residential buildings are located on the mainland side, some 800 metres northeast of the power plant. These buildings are residential buildings that belong to the power plant's accommodation area and are not permanently inhabited. Domestic water to the area is conducted from the water treatment plant located in Hästholmen, the raw water of which is taken from the Lappomträsket lake. The nearby areas surrounding the power plant are owned by Fortum, and there are no domestic or service water wells in these areas.

Based on the hydrological monitoring, the fluctuations in the level of groundwater significantly interact with the fluctuations of the sea level, which is typical 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. The drop in the level of groundwater that occurred in the observation holes, particularly those in the vicinity of the spaces within the bedrock, was also fairly steep, owing to the water seeping into and pumped out of the spaces. The seepage waters have been measured since 1996, when the volume of the excavated bedrock spaces was approximately 110,000 m^3 (Figure 9-23). When the monitoring began, the volume of the seepage water was around 300 litres per minute. There has been a clearly detectable declining trend in the total volume of seepage over the long term. Initially, the volume declined

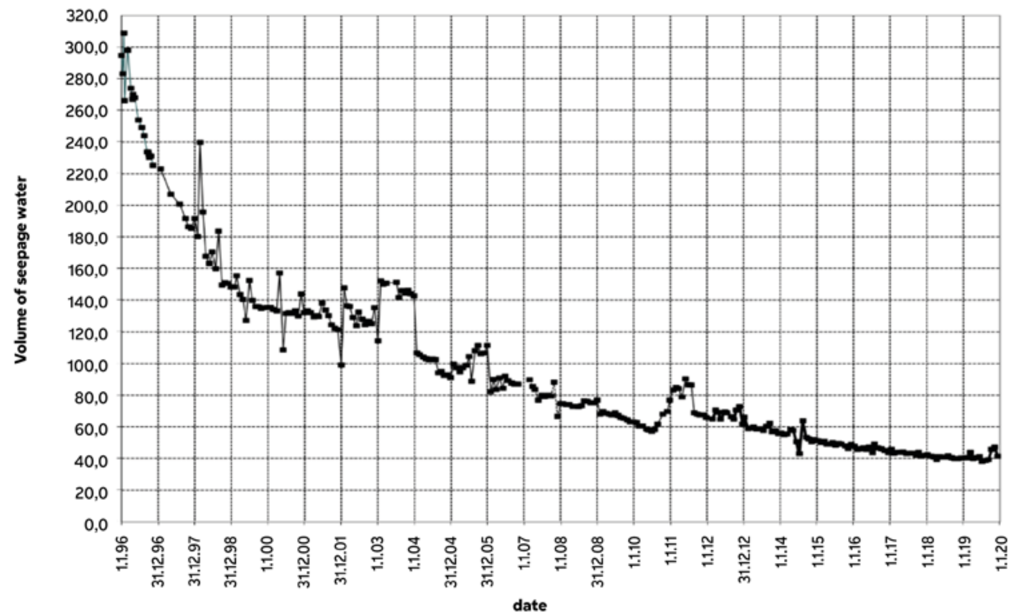

Figure 9-23. The final disposal facility's volume of seepage water (source: Fortum Power and Heat Oy).

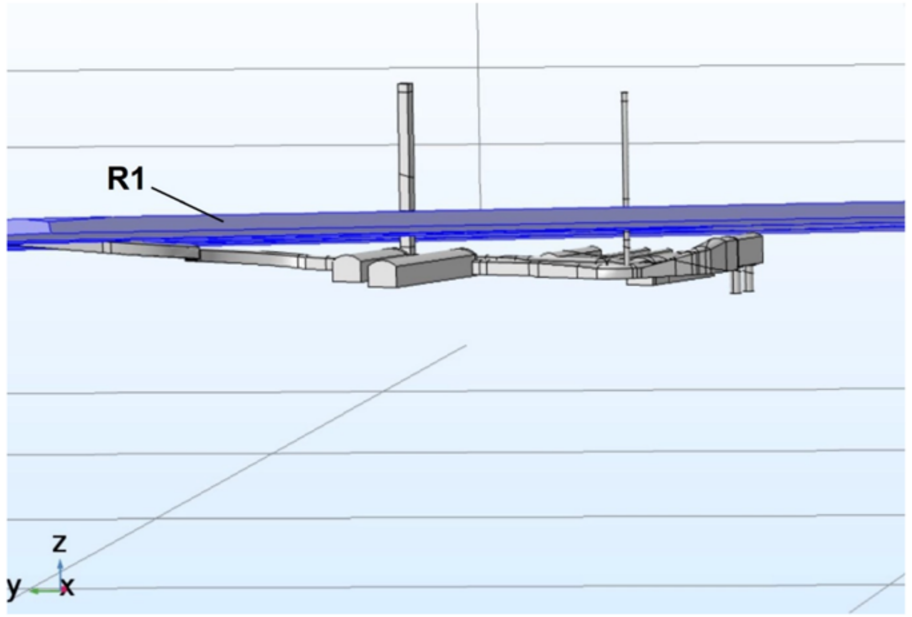

Figure 9-24. The location of the bedrock's zone of fragmented rock R1 (the horizontal zone above the final disposal facility which intersects with the shafts and the access tunnel) according to Hästholmen's groundwater model drawn up for the 2018 long-term safety case.

steeply, but the decline has since levelled off. In October 2010, before the excavations began, the volume of seepage water was approximately 60 litres per minute. Due to the excavating, the volume grew to a maximum of approximately 90 litres per minute. Once the excavating was over, the volume of seepage water declined rapidly again, to 66 litres per minute by the end of 2011. By the end of 2012, the volume of seepage water had dropped to 60 litres per minute, which is equal to the level preceding the excavations. Approximately half of the entire L/ILW repository's seepage waters originate from the access tunnel, and the rest from the final disposal depth. In 2019, the average volume of seepage water was 40 litres per minute.

In terms of the flow of groundwater, the bedrock's flat-dipping zones of fragmented rock R1 and R2, between which the final disposal halls have been placed, are key structures that bear water well. R1 continues further beneath the sea surrounding the island. Of these zones of fragmented rock, R1 intersects with the access tunnel, as well as the lift and ventilation shafts, and is therefore a key structure in terms of the possible migration of radionuclides. The area also has other, smaller zones of fragmented rock within the bedrock, some of which intersect with the final disposal facility. They are of lesser significance in terms of the migration of radionuclides, because their water-bearing capacity is weaker, and they are limited to a small area. The modelled location of the fragmented rock zone R1 is shown in Figure 9-24.

The level of the boundary between fresh and saline water has been monitored with measurements carried out between 1991 and 2015. When the studies began in 1991, the monitoring covered seven test holes drilled in the bedrock. Once the construction of the L/ILW repository got underway in 1994, the boundary levels of the fresh and saline water increased considerably. After the construction phase ended, the boundary level of the fresh and saline water returned close to the level preceding the construction at most of the monitoring points. Impacts of the excavation were detected in only some of the holes (Figure 9-25). The monitoring of the boundary level of fresh and saline water was discontinued in 2015, because the results cannot, due to challenges related to their interpretation, be used as baseline data for the modelling of groundwater flows, for example.

Based on the monitoring of the quality of Hästholmen's groundwater, the groundwater has, compared to the seawater, been depleted of sodium, magnesium and sulphate. However, in respect of calcium and ammonium ion, the groundwater has grown significantly richer than the seawater. The iron content at the groundwater stations has varied slightly during the monitoring period. Concrete functions as the L/ILW repository's principal release barrier, which is why the chemical stress caused to the concrete structures by groundwater was assessed in connection with the results. While the conditions are not – based on the pH values, when looking at parameters with relevance for concrete's long-term durability – aggressive to concrete, the nature of the groundwater is classified as weakly aggressive to concrete in terms of its magnesium and sulphate.

Changes in the isotope results have been minor over the past 20 years. The low tritium contents are an indication of the young water's low degree of mixing. Carbon-14 dating has put the age of the groundwater at 6,000–14,000 years, and given that it is more saline than the current seawater, it has been construed as consisting at least partly of water from the Littorina Sea.

As expected, the construction of the L/ILW repository has changed the conditions of the groundwater chemistry, and even fairly major changes were observable between 1993 and 1997. The variation in the TDS value at different groundwater stations is shown in Figure 9-26. The TDS value describes the total concentration of dissolved solids in the water. The lowest TDS value was measured in 1996 at a groundwater station located at -109 m. In recent years, the results of the analysis of the groundwater chemistry have been very even.

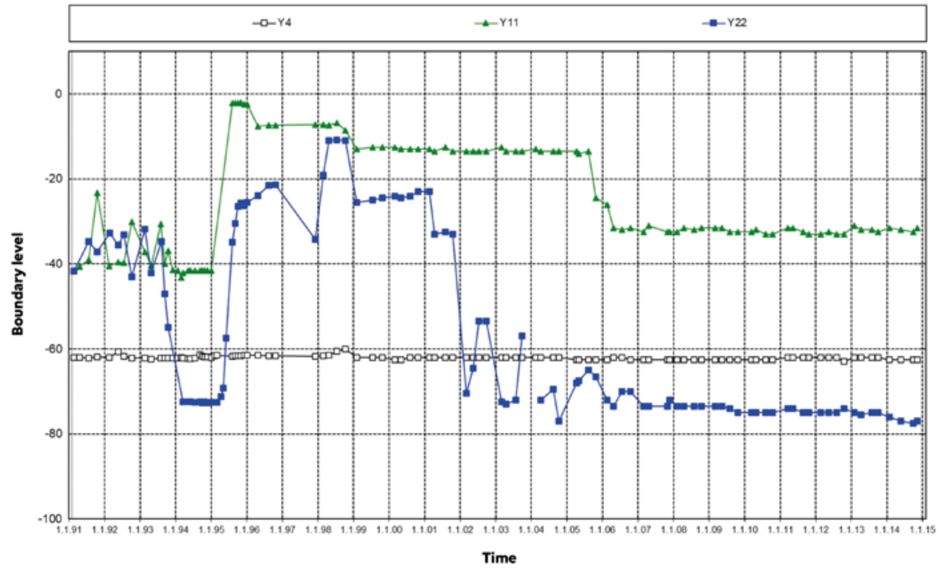

Figure 9-25. Measurement results of the boundary level of fresh and saline water in holes Y4, Y11 and Y22.

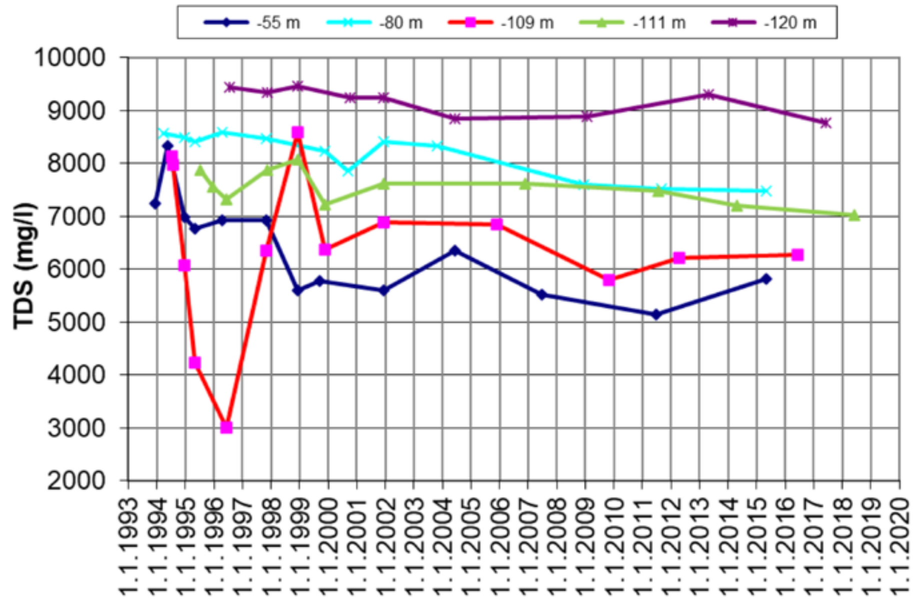

Figure 9-26. The total concentration of dissolved solids (TDS) in the groundwater at groundwater stations located at different depths.

Table 9-46. Sensitivity of affected aspect: groundwaters.

Sensitivity of affected aspect: groundwaters	
The aspect's sensitivity with regard to groundwater is impacted by the groundwater areas, water catchments and private wells of domestic water located within the impact area. The closer the groundwater areas, water catchments and wells are to the power plant area, the greater the affected aspect's sensitivity.	
Minor	There are no groundwater areas, water catchments or private wells of domestic water in the vicinity of the power plant area. The power plant area's groundwater cannot be used as domestic water in terms of either its quality or quantity.

Table 9-46 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.15.4 Environmental impact of extended operation

Impact formation

Extended operation would not require an expansion of the previously excavated spaces within the bedrock. Impacts on groundwater are formed by the seepage waters in the bedrock spaces and their pumping. Impacts on the quality of groundwater could potentially arise from a chemical leak occurring in exceptional situations.

The L/ILW repository was built in the 1990s, and expanded between 2010 and 2012. The final disposal halls have been designed so that any significant water-bearing zones of fragmented rock occurring in the bedrock do not intersect with the final disposal halls. Extended operation would not cause an impact differing from the present state on the volume of groundwater. Based on the hydrological monitoring, development in the volume of seepage water has been steady. According to the measurement results in recent years, the volume of seepage water has been around 40 litres per minute. The seepage waters are pumped into the sea in Hudöfjärden.

Transport accidents related to chemicals, fuel oil and lubricants could result in groundwater contamination. Incidents and accidents are discussed in Chapter 9.22.

The annual storage and usage volumes of chemicals and oils would remain unchanged. The potential risks with regard to the quality of groundwater would therefore also remain unchanged. No areas are categorised as groundwater areas, water catchments or private domestic water wells in the vicinity of the power plant area. The island of Hästholmen is a separate body of groundwater in relation to the mainland, due to which any effects with an impact on the quality of the groundwater would be limited to the power plant area.

9.15.5 Environmental impact of decommissioning

Impact formation

The excavation of the bedrock spaces will increase the volume of seepage waters. Impacts on the quality of groundwater may arise from the migration of any traces of the explosives used in the quarrying and nitrogen compounds.

The hydrological monitoring related to the impacts of the L/ILW repository's excavation and the subsequent quarrying has indicated that while the volume of seepage waters has increased temporarily as a result of the construction work, it has begun to decline fairly rapidly once the work has been completed (see 9.15.3). Based on the results, the expansion of the L/ILW repository can therefore be expected to temporarily increase the volume of seepage water, but the volume will decrease over time. The impact of the L/ILW repository's expansion is expected to be smaller than the impact of the excavation of the original space, given that the expansion will not change the present state of the groundwater conditions as strongly as the excavation and construction of the original space.

The impact that the excavation will have on the quality of groundwater is expected to be minor and limited to the immediate vicinity of the space to be quarried on the island of Hästholmen, which is a separate body of groundwater in relation to the mainland. Potential impacts on the quality of groundwater attributable to the rock quarrying include the migration of nitrogen compounds and traces of explosives into the groundwater as well as temporary turbidity in the vicinity of the quarried area. No areas in the vicinity of the power plant are categorised as groundwater areas, water catchments or private domestic water wells which could be impacted by the excavation.

When the L/ILW repository is closed and filled with groundwater filtering into the facility, both the level of the groundwater and the boundary between the fresh and saline water will gradually return to their original state.

Table 9-47. Significance of impacts: groundwaters.

Significance of impacts: groundwater			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Minor**	**No change**	**No impact,** given that extended operation would not cause an impact differing from the present state on the quality or volume of groundwater.
Decommissioning	**Minor**	**Minor negative**	**The significance of the impacts is minor and negative,** because the expansion of the L/ILW repository in the decommissioning will temporarily increase the volume of seepage waters, and because the quality of groundwater will be subject to minor impacts in the immediate vicinity of the bedrock spaces. The impact of the L/ILW repository's expansion is expected to be smaller than the impact of the excavation of the original space, given that the expansion will not change the present state of the groundwater conditions as strongly as the excavation and construction of the original space. There are no groundwater areas, water catchments or private wells of domestic water in the vicinity of the power plant which could be impacted by the excavation. Following the L/ILW repository's closure, the repository will be gradually filled with groundwater filtering into the facility, meaning that both the level of the groundwater and the boundary between the fresh and saline water will gradually return to their original state.
Radioactive waste generated elsewhere in Finland	**Minor**	**No change**	**No impact,** because the volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the long-term safety case.

The location of the L/ILW repository has been designed, on the basis of the area's bedrock and groundwater studies as well as modelling, so that the significant zones of fragmented rock within the bedrock do not intersect with the final disposal facilities. This will also be accounted for in the placement of the L/ILW repository's expanded spaces, so that the migration of radionuclides into the environment via the groundwater flow can be limited. According to the current long-term safety case, the final disposal of Loviisa power plant's operational waste and decommissioning waste can be carried out safely within Loviisa's L/ILW repository. The long-term safety of the final disposal is based on technical release barriers and the surrounding bedrock, which serves as a natural release barrier.

The magnitude of the change concerning the area's groundwater is expected to be *minor and negative.*

9.15.6 Radioactive waste generated elsewhere in Finland and its impact

The maximum volume of radioactive waste generated elsewhere in Finland will be 2% of the total volume of waste generated at the power plant and placed in the L/ILW repository. The volume and properties of waste generated elsewhere in Finland are accounted for in the L/ILW repository's expansion and the long-term safety case, and would therefore not have a significant impact on the groundwater.

9.15.7. Significance of impacts

Table 9-47 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (Chapter 9.1.4).

9.15.8 Mitigation of adverse impacts

Instructions for the L/ILW repository's maintenance, ageing management and monitoring are given in the power plant's instructions. These include regular measurements involving groundwater chemistry and hydrology.

To prevent migration occurring via the flow of groundwater, the L/ILW repository's expansion will be designed so that the significant zones of fragmented rock within the bedrock do not intersect with the final disposal halls. This will contribute to efforts aiming to prevent an increase in the volume of seepage waters filtering into the repository. The long-term safety of the L/ILW repository and the measures to ensure it are described in Chapter 9-10-5-2.

When the L/ILW repository is closed and is allowed to be filled with groundwater filtering into the facility, both the level of the groundwater and the boundary between the fresh and saline water will gradually return to their original state.

9.15.9 Uncertainties

Current research data on the groundwater do not include uncertainties which would be significant in terms of the impact assessment. Data on the area's groundwater will be supplemented with further research if necessary as the project's planning progresses.

9.16 SURFACE WATERS

9.16.1 Principal results of the assessment

In extended operation, the thermal load on the surface waters would continue for approximately 20 years beyond the current operating licence, at most until around 2050. The impact of the thermal load is local and limited, primarily to the area of Hästholmsfjärden.

The limits for the temperature of the cooling water to be discharged, which are set in the conditions of the environmental permit, limit the thermal impact. In the long run, the increase in warm summers resulting from climate change, coupled with the thermal load, may increase the thermal effect to a small degree in Hästholmsfjärden, close to the discharge location. The long-term development of the diffuse source input on the coast of Loviisa involves uncertainty attributable to the materialisation of climate change scenarios and particularly to the extent to which and how fast the measures reducing the agricultural pollution will be implemented. The input is expected to remain roughly at the current level or to decrease slightly, in which case the state of Klobbfjärden body of water would remain unchanged. However, a minor degradation in the state of the Klobbfjärden body of water resulting from the combined impact of the thermal effect and input cannot be completely ruled out, because the thermal effect contributes to the eutrophication resulting from an excess of nutrient inputs. The significance in terms of Hästholmsfjärden was deemed to be at most moderate and negative, given that the impacts last a long time. In the other nearby sea areas, the significance was deemed to be minor at most. The quality of water and the state of the water environment elsewhere in the nearby sea areas are mainly influenced by the long-term development of the nutrient inputs and the general development in the Gulf of Finland's condition.

In decommissioning, Hästholmsfjärden's temperature and stratification conditions and the length of the growing season will return to the natural state. Consequentially, the oxygen conditions of the hypolimnion are expected to improve gradually; this will contribute to a reduction of the internal input, thereby reducing eutrophy. The positive impacts may become apparent only after a delay as a declining trend in the nutrient level and basic production, a reduction in aquatic flora (the number of one-year filamentous algae) and an improvement in the state of the benthic fauna. The significance in terms of Hästholmsfjärden was deemed to be moderate and positive, and in terms of the other nearby sea areas, minor at most.

The water intake is not expected to have an impact on the present state of Lappomträsket lake if the use remains in line with current use. If an end to the regulation is sought at some point during the decommissioning, the impact on the quality of water is expected to be minor and negative, given that the end of the oxidising may have a negative impact on the quality of water.

The transport and handling of radioactive waste generated elsewhere in Finland would not generate impacts that would concern the surface waters.

9.16.2 Baseline data and assessment methods

9.16.2.1 The data

The power plant's impact on the quality of the surface waters and the biological sea environment has been monitored from a long-term perspective since the 1970s, thanks to which the state of the sea area in front of Loviisa power plant and the long-term changes that have taken place in it are well known. With the exception of the thermal load, the input caused by the power plant is minor compared to the other inputs to which the sea area is subject.

The data used for the description of the present state included the annual reports of Loviisa power plant's cooling water and wastewater monitoring, the annual reports of Loviisa power plant and Oy Loviisan Smoltti Ab's joint monitoring of the sea area, satellite images, separate surveys carried out during the EIA procedure as well as the Hertta database available through the environmental administration's open data services and the data in the environmental administration's watershed model VEMALA.

The emissions of radioactive substances and their impacts are discussed in Chapter 9.8.

9.16.2.2 Modelling of cooling water intake and discharge

The modelling methods are described in detail in the modelling report (Lahti 2021; Appendix 4). The modelling examined the impact that the extension of Loviisa power plant's current operation and its decommissioning (in which the plant would no longer produce electricity) would have on the temperature of the seawater in the plant's nearby sea areas. In the present state, cooling water for the power plant is taken from Hudöfjärden using an onshore intake system, and the warmed cooling water is discharged at Hästholmsfjärden, on the eastern side of the island.

There were two modelling scenarios:

- the thermal load caused by the power plant continuing in the current manner at most until around 2050 (modelling of the summer's ice-free season and the winter situation);
- the power plant has been decommissioned, and the thermal load has come to an end (modelling of the summer's ice-free season and the winter situation).

The following examines the selection of the modelling years. The key criteria for the selection of the modelling period was a large number of observations from the nearby sea areas, which is a prerequisite for the model's calibration and a description of the conditions.

During the summer's ice-free season (1 June – 1 September 2011), seawater temperatures in the power plant's nearby sea areas were modelled while the seawater was density stratified. In addition to the continuous temperature measurements of seawater which constitute part of the power plant's operations, the data available for the selected ice-free modelling season consisted of temporarily installed continuous measurements and momentary manual measurements from the surrounding sea areas. The modelling of the winter situation (March 2018) examined a scenario in which the sea area, excluding the discharge area, was covered by an ice sheet. Both modelling years (2011 and 2018) were normal in terms of the timing of the start of the annual outage and the increase in the temperature of the cooling water discharged from the power plant (8–10 °C in the summer, and approximately 12 °C in the winter) (Lahti 2021; Appendix 4).

The selected modelling period for the ice-free season was markedly warm in terms of the summer. The temperature conditions were nearly identical to the conditions which would, according to climate scenarios, be typical in the middle of this century. This being the case, the selected review period also allows the impact of climate change to be assessed to some extent. Projections expect climate change to increase the mean annual temperature, due to which warmer-than-average conditions may occur in the sea more often. According to different climate scenarios, the global mean temperature may rise by roughly 1.5–5.8 °C by 2100, when accounting for the uncertainty in the projections (IPCC 2014) (Figure 9-27). In 2006–2015, the global temperature was 0.87 °C higher than between 1850 and 1900 (Allen et al. 2018). Currently, the global climate is warming by approximately 0.2 °C a decade, and in 2017, the increase in temperature attributable to human activities rose to 1 °C in relation to pre-industrial times. If the warming continues along these lines, the temperature will increase by approximately 1.5 °C around 2040 (Allen et al. 2018).

In Finland, the rise in the annual mean temperature may outpace the global change (Ruosteenoja 2016) (Figure 9-28). Depending on the RCP scenario, the change during the 2030–2050 period may be nearly 1.5–3 °C compared to the early 2000s (Figure 9-28). The RCP (short for Representative Concentration Pathways) scenarios describe the possible developments of the concentrations of greenhouse gases which produce various radiative forcings, i.e. global warming potential (W/m^2), in which the number of the scenario refers to the magnitude of the radiative forcing. RCP2.6 is the most optimistic scenario (low emissions) and requires the perfect success of climate policies, while RCP8.5 stands for the severest scenario, in which greenhouse gas emissions will continue to grow throughout the 2000s. RCP4.5 and RCP6.0 are the intermediate forms between these two. In the RCP4.5 scenario, climate policies are partly successful, and greenhouse gas emissions will start declining in the 2040s. In the

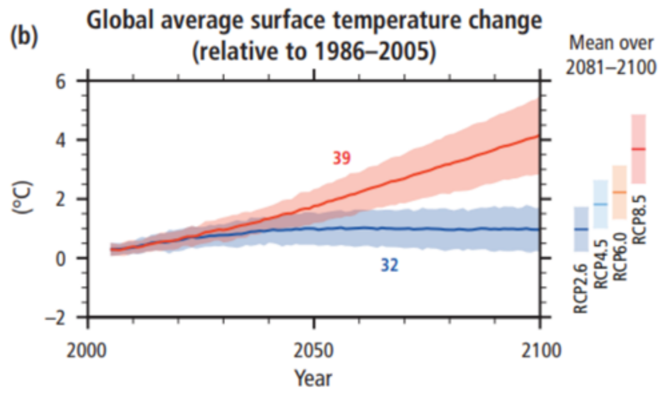

Figure 9-27. Time series of the change in global mean temperature in the RCP2.6 and RCP8.5 greenhouse gas emission scenarios between 2006 and 2100 compared to the period between 1986 and 2005. The figures in the time series describe the number of the CMIP5 models used for the calculation of the means in the modelling results (CMIP: Coupled Model Intercomparison Project). The diagrams on the right-hand side of the figure describe the average (2081–2100) increases in global temperature produced by the various RCP scenarios and the projection's range of variation (IPCC 2014).

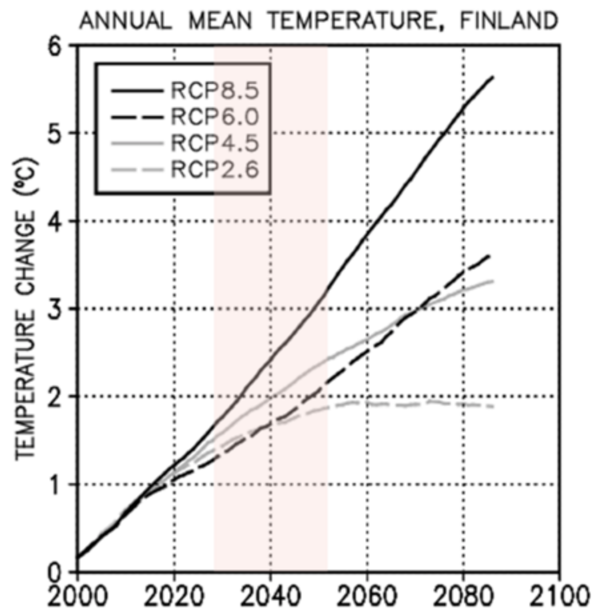

Figure 9-28. Increase in the annual mean temperature in Finland according to different greenhouse gas emission scenarios between 2000 and 2085 compared to the period between 1981 and 2010 (Ruosteenoja et al. 2016). The shading added to the figure represents the period reviewed in the EIA.

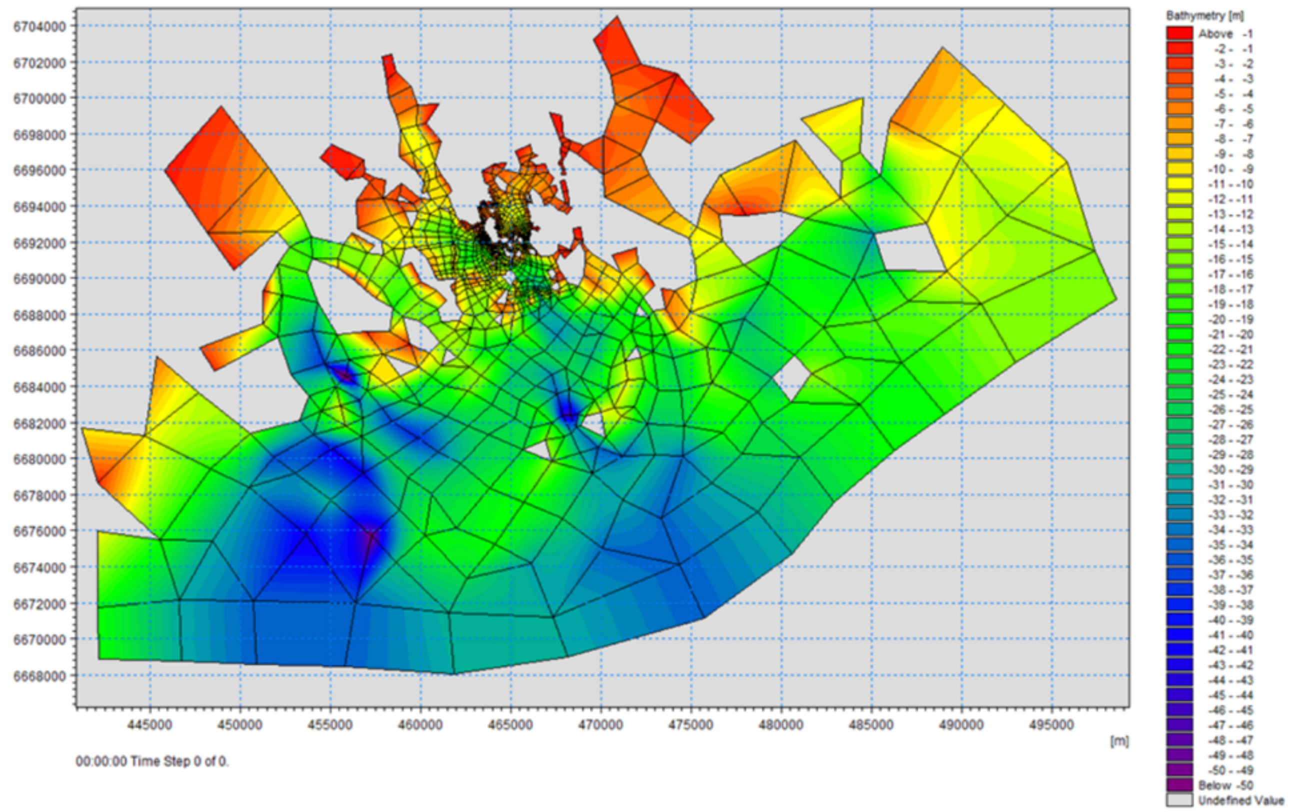

Figure 9-29. The model's computational mesh and the area's depth profile. The density of the computational mesh is at its greatest near the power plant at Hästholmsfjärden and Hudöfjärden. The model's computational mesh is described in detail in the modelling report (Lahti 2021).

RCP6.0 scenario, the emissions will initially remain at the current level, but will increase to fairly high levels later on during this century (IPCC 2014). According to the projections, the warming will not divide equally over a year. Ruosteenoja et al. (2016) expect the changes in temperature to be greater in the winter. The mean summer temperature is also expected to rise, but to a lesser extent. In Finland, long-term trends in the change of mean temperature have been studied by Mikkonen et al. (2015), Irannezhad et al. (2015) and Aalto et al. (2016), among others. The average increase in temperature per decade arrived at in the studies has been around 0.14–0.4 °C. According to the estimates, the annual mean surface temperature of seawater in the Gulf of Finland may be approximately 2–3 °C higher between 2069 and 2098 than it was between 1978 and 2007 (BACC II Author Team 2015).

During the modelling year for the summer's ice-free season (2011), the air temperature was 1.5–2 °C higher than average (1981–2000) on the southern coast of the Gulf of Finland (Finnish Meteorological Institute 2020). In Helsinki, June was 2 °C, July 3 °C and August 1.3 °C warmer than average. The data from 2011 is therefore deemed suitable for the impact assessment of the summer situation for the 2030–2050 timespan, examined in the case of extended operation (VE1) within the EIA.

The warming is also significant from the perspective of ice conditions. Climate change is expected to reduce the surface area and average thickness of the Baltic Sea's ice cover and shorten the ice winter. While projections expect the variability between winters to remain a natural characteristic of ice conditions, the likelihood of severe ice winters is expected to decrease. During the mildest winters, sea ice would also occur solely at the head of the Bay of Bothnia (Luomaranta et al. 2011, Climate Guide 2021). The length of ice winters in the eastern Gulf of Finland nowadays is between 80 and 100 days. Should the warming progress linearly, the climate of the Baltic Sea region in 2030 would be 0.5–1 °C warmer than today (Climate Guide 2021). In this case, the ice conditions in the Baltic Sea would be slightly milder than their currently levels, and the length of the ice winter in the Baltic Sea would be roughly 10–20 days shorter than in the current climate (Climate Guide 2021). During the mildest winters, ice would occur only in the Bay of Bothnia, the Archipelago Sea and the eastern Gulf of Finland.

Conditions during the ice season differ from those during the ice-free season, particularly in that the warmed cooling water, being warmer than the surrounding water, can be carried along beneath the insulating ice cover for relatively long distances (Lahti 2021). The ice cover prevents the transfer of heat into the atmosphere and the wind's mixing impact on layers of water, which will slow down the rate at which the cooling water mixes into the surrounding water column. The ice-free winters or reduction in the size of the ice cover in the winter resulting from climate change will accelerate the transfer of heat into the atmosphere and reduce the increase in the temperature of seawater caused by cooling water. In

2018, selected to serve as a modelling year, the ice cover in March was more extensive than average in Loviisa power plant's nearby sea areas, due to which the modelling provides a conservative estimate of the spread of the thermal effect.

The calculation relied on hydraulic modelling, carried out with DHI's Mike 3 FM non-hydrostatic flow model (Figure 9-29) with an adjustable computational mesh, which calculates with complete three-dimensional equations (DHI 2017); it was released in 2019. The model allows both the hydraulics of smaller areas and the phenomena of more extensive areas to be described simultaneously, and in addition to flows, it calculates the temperature of the seawater. Among other things, the baseline data consisted of wind conditions, the sea level (including variations), air temperature, ice cover, and components of the net radiation of the sea and atmosphere. The boundary conditions and initial values of the modelling are presented in detail in the report (Lahti 2021). The model's use is based on extensive and comprehensive surveys of the bottom of the sea area previously conducted by Fortum with various echo ranging methods, for example, and on the continuous observations of seawater temperature, salinity and flows. The modelling area extended from the coast up to Orrengrund (Figure 9-29).

The model calculation's verification and validation are presented in detail in the report (Lahti 2021). The model was calibrated by comparing the calculated values to the observations made during the 2011 ice-free season. The temperatures modelled on the discharge side in Hästholmsfjärden followed the measured temperatures quite closely to a depth of 7.5 metres throughout the summer. The temperatures modelled on the intake side at Hudöfjärden corresponded with the observations fairly well in the surface layer. Compared to the continuous measurements, the model repeats the rapid temperature changes observed in the sea area's continuous measurements more gently than observed. In the modelling results of Hästholmsfjärden and Hudöfjärden, the temperatures of the deeper water increase more towards the end of August than in the sea area observations. With respect to Vådholmsfjärden, the modelled temperatures of the deeper water are lower than those observed. However, the surface layer temperature most relevant in terms of the modelling follows the measured temperatures quite well. In conclusion, it can be said that the seawater temperature calculated in the modelling corresponded with the measured values reasonably well, and that the modelling results are representative.

9.16.2.3 Assessing the input caused by the expansion of the L/ILW repository

The expansion of the L/ILW repository will be carried out by drilling and blasting. Estimates put the volume of construction wastewater to be generated over a period of three years at approximately 300,000 m^3.

During excavation, part of the soluble nitrogen in the explosives will remain in the quarry material, while part of it will dissolve in the water. In addition, the construction site water will contain inorganic stone dust originating from the rock. The waters to be conducted are often mildly alkaline due to the concrete in the repository's walls. In this assessment, the magnitude of the input on the surface waters was estimated on the basis of the average quality of the discharge waters generated in 2021 during the excavation of the treatment plant excavated into bedrock in Blominmäki, Espoo, and the quality requirements for construction site waters to be removed according to HSY's worksite water instructions:

- nitrogen 6.3 mg/l[1]
- solids 300 mg/l[2]
- pH 8.51
- oils 5 mg/l and with no visible film of oil[2]

[1] The average quality of discharge waters during the excavation of the Blominmäki wastewater treatment plant within the bedrock in 2021

[2] The City of Helsinki's instructions for construction site water (City of Helsinki)

The estimate on the total discharges over a period of three years is:

- nitrogen 1.9 t
- solids 90 t
- oils and greases 1.5 t

The calculated input quantity of nitrogen was proportioned to the population equivalent (PE), the calculation of which employed the specific pollution inputs (nitrogen = 14 g N per person a day) given in the Wastewater Decree (157/2017). The mixing concentration for nitrogen and solids was calculated for a sea area of 500 x 500 m, with a depth of 5 m.

9.16.2.4 Impact assessment

The impact that an extension of Loviisa power plant's operation and decommissioning would have on the water quality of the surface waters, their potential indirect impact on aquatic organisms, and their impact on the ecological and chemical status of bodies of water and the marine strategy was assessed in the form of expert work. The assessment was based on descriptions of the measures and any changes thereto, information on the present state of the water environment and, in terms of the impacts of Loviisa power plant's cooling waters, the cooling water modelling based on computational fluid dynamics, the methods of which are described above and more extensively in the modelling report (Lahti 2021).

The project's compliance in relation to the EU's Water Framework Directive (2000/60/EC) and Marine Strategy Framework Directive (2008/56/EC) is assessed on the basis of the results of the impact assessment. The goal set for member states by the European Union's Water Framework Directive is to prevent the impairment of the ecological and chemical status of surface waters. According to the Directive, the goal is to achieve a good status in all bodies of surface water no later than by 2027. The binding character of the status objectives in the permit considerations of projects was specified in the ruling given by the Court of Justice of the European Union in what is referred to as the Weser case (C-461/13). According to the Water Framework Directive, the project under assessment may not impair the ecological or chemical status of a body of surface water, or compromise the achievement of surface waters' good status. In marine strategies, the ecological and chemical state of surface waters is assessed per each body of surface water. In the environmental impact assessment, compliance with legislation is assessed specifically for each body of surface water from the perspective of the classified quality factor of each ecological and chemical status. The assessment also accounts for the impact in terms of the marine strategy.

9.16.3 Present state

9.16.3.1 General description

The island of Hästholmen is located on the boundary of the coastal and outer archipelago in the Gulf of Finland. Figure 9-30 shows the sea areas surrounding the island of Hästholmen, the rivers running to the sea off Loviisa and the Lappomträsket lake, which is the power plant's current source of raw water. The bay areas of Hästholmsfjärden and Klobbfjärden, east of the island of Hästholmen, together form the Klobbfjärden body of water (2_Ss_017), which is representative of the surface water type of coastal archipelago in the Gulf of Finland (Figure 9-54). The warmed cooling water is discharged into Hästholmsfjärden, the western part of the Klobbfjärden body of water.

West of the island of Hästholmen lies Hudöfjärden, which is located primarily in the Keipsalo body of water (2_Ss_019), which belongs to the surface water type of coastal archipelago in the Gulf of Finland. Loviisa power plant's cooling water intake is located in Hudöfjärden. The Loviisa-Porvoo body of water (2_Su_030), representative of the surface water type of the outer archipelago in the Gulf of Finland, is located south of Hästholmen. Orrengrundsfjärden is a fairly open sea area, and the open sea begins at Orrengrund, approximately 12 kilometres south of Hästholmen.

The sea area off Loviisa is characterised by pools separated by inlets and shallow underwater thresholds. Water exchange at the bottom of these pools is minimal compared to the outer sea area. Hästholmsfjärden is a relatively shallow semi-enclosed inlet area (Figure 9-30), with a surface area of approximately 9 km^2 and a volume of 68.5 million m^3. Its maximum depth is approximately 18 metres, while the average depth is 7.6 metres. The water exchange between Hästholmsfjärden (part of the Klobbfjärden body of water) and the outer sea area is restricted by a number of fairly narrow straits and underwater thresholds (Launiainen 1979). The shallower Klobbfjärden is located northeast of Hästholmsfjärden. Water exchange between these two pools is limited by a shallow, interrupted only by a narrow water area that is approximately 10 metres deep. Klobbfjärden is connected to the river Tesjoki (i.e. Taasianjoki) and the delta of the river Kymijoki's Ahvenankoski branch, Kullafjärden and Abborrfjärden, located northeast of the areas, via the narrow Jomalsund canal (Figure 9-30).

The volume of Hudöfjärden (Figure 9-30) is greater than that of Hästholmsfjärden, and its deepest spot is 24 metres. The sea area is more open than Hästholmsfjärden, although to the south, there are thresholds that limit water exchange in the hypolimnion layer near the bottom. The 9.5-metre shipping lane to the Port of Valko is likely to improve water exchange in the sea area in question to some extent. Further out in the sea area the water exchanges more efficiently than in the coastal archipelago.

Lappomträsket lake (81V026.1.004_001) is a clear and shallow humic lake. Its surface area is approximately 1.1 km^2, volume 1.47 million m^3, and it has an average depth of only 1.35 m (Figure 9-30). Lappomträsket lake has been charaterised as a shallow humic lake.

9.16.3.2 Loads

The state of the seawater is impacted by the area's point source pollution and diffuse pollution originating from a larger area and several sources. Point sources in the sea area off Loviisa include the Vårdö wastewater treatment plant, the pisciculture facilities of Ab Loviisan Smoltti Oy and Semilax Oy, and Loviisa power plant. The power plant's input on waterways consists largely of thermal loads. In its current operations, the power plant uses an average of 1,300 million m^3 of sea water for cooling every year, while the annual thermal load on the sea area in the discharge side is 57,000 TJ, on average. The annual thermal load conducted to the sea and the temperature of the cooling water fed there are regulated in the conditions of the environmental permit. The perspectives related to the use of cooling water are described in more detail in Chapter 4.2. The discharge of radioactive substances into the sea is discussed in Chapter 4.12.2 and Chapter 9.8.3.2.

Table 9-48. Average point source pollution in the sea area in 2018–2019 (Anttila-Huhtinen & Raunio 2019 and 2020).

	Total phosphorus	Total nitrogen
	t/year	
Loviisa power plant (process wastewaters and wastewater treatment plant*)	0.007	1.3
Oy Loviisan Smoltti Ab	0.2	2.8
Semilax (Vastaholmen and Stenören)	0.4	3.7
Loviisan Vesi's Vårdö wastewater treatment plant	0.2	21.9
Total	**0.8**	**29.7**

**The input data of Loviisa power plant's wastewater treatment plant include the treatment of Smoltti's supernatants, in addition to the treatment of the power plant's sanitary wastewaters.*

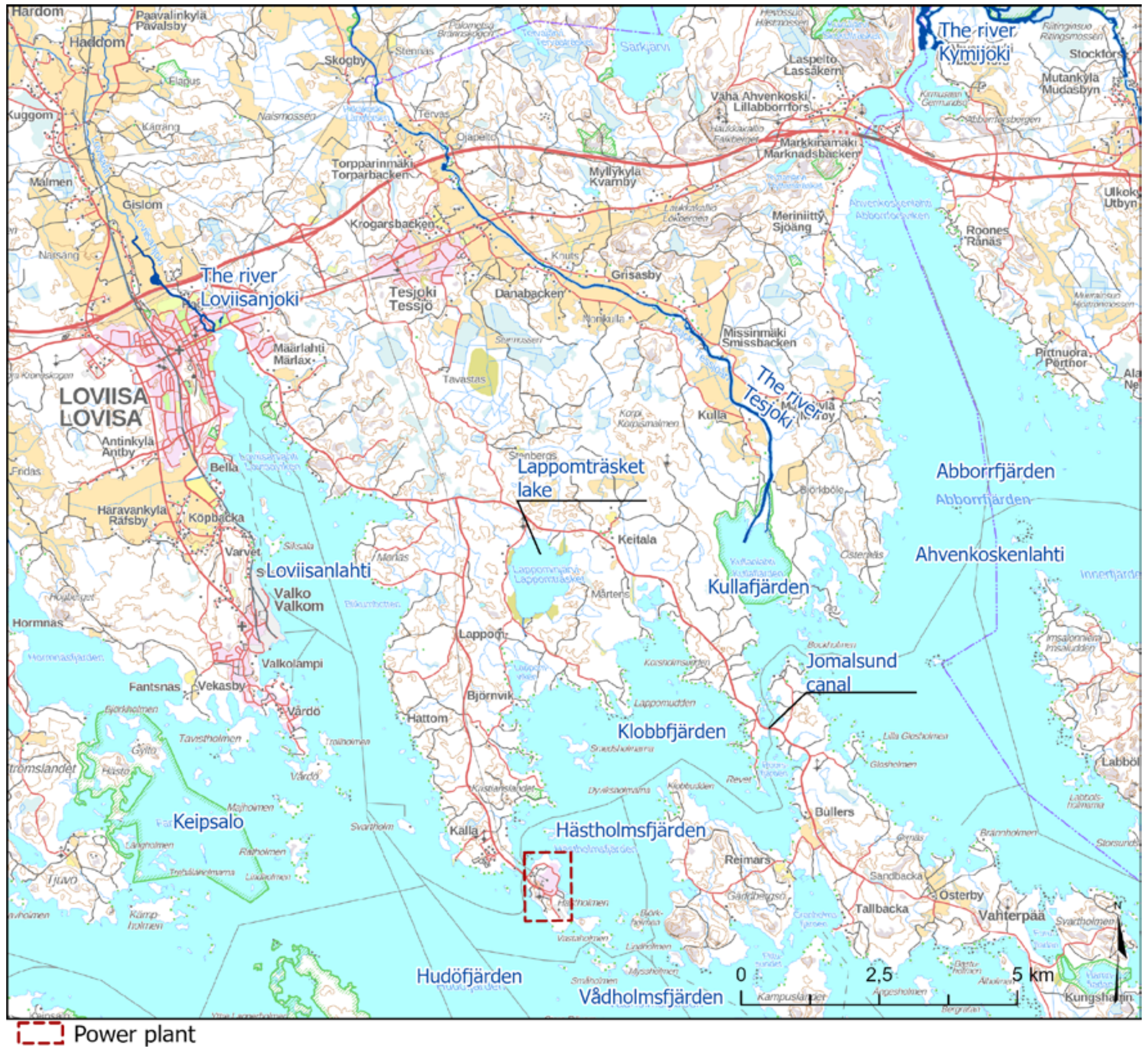

Figure 9-30. Adjacent sea areas surrounding Loviisa power plant, the rivers running to the sea and the Lappomträsket lake (source: National Land Survey of Finland 2019).

Loviisa power plant's share of the sea area's point-based nutrient inputs is currently very low. The wastewater inputs of Loviisa power plant are discussed in Chapter 4.4. The average combined input of process wastewater and sanitary wastewater has been some 18 kg a year in terms of phosphorus, and roughly 1,600 kg a year in terms of nitrogen. In recent years, Loviisa power plant has accounted for approximately 1% of the point-based phosphorus input of the water area near Hästholmen (Table 9-48). In terms of nitrogen, the input has ranged between 3–6%.

Most of the nutrient input arrives at the sea as the diffuse source input carried by the river waters. Regarding Loviisa's nearby sea area, the river Loviisanjoki empties into Loviisanlahti bay, from where the waters flow towards Hudöfjärden (Figure 9-30). East of the Klobbfjärden body of water, Tesjoki empties into the Kullanlahti bay, and the Ahvenkoski branch of the river Kymijoki into Ahvenkoskenlahti. While part of the water carried to the sea by the river Tesjoki and the Ahvenkoski branch flows through the narrow Jomalsund canal to Klobbfjärden and onward to the sea area circling Hästholmen, most of it is carried further out into the sea area. The rivers' discharges have varied greatly from one year to the next (Figure 9-31). The share of the discharges accounted for by the rivers Loviisanjoki and Tesjoki is low compared to the discharge of the Ahvenkoski branch of the river Kymijoki. In 2010–2020, the share was typically around 4%, with a range of 2–20%.

Table 9-49 shows the average total phosphorus and nitrogen input carried to the sea area within river waters (VEMALA 5 February 2021). The amount of the nutrient input attributable to river waters is greatly influenced by the rainfall at any given time. During years rich in precipitation, the leaching of nutrients may be two- or threefold compared to years with low rainfall (Karonen et al. 2015). Occasionally, the internal phosphorus input caused by the bad oxygenation conditions of the seabed is considerable in both Hästholmsfjärden and Hudöfjärden (Leino 2012). In the Gulf of Finland, the substrate's capacity to retain phosphorus is generally bad, and the internal input maintains the eutrophication development across the entire Gulf of Finland.

9.16.3.3 Sea area's current and stratification conditions

The water in the Gulf of Finland, as in the entire Baltic Sea, moves in currents due to wind, differences in atmospheric pressure and differences between the densities of different water columns. In the Baltic Sea, the currents largely depend on the weather and therefore vary (Finnish Meteorological Institute 2021). In the Gulf of Finland, the direction of surface currents is primarily anti-clockwise (Andrejev et al. 2004), and in the northern coast of the Gulf of Finland, the average current moves west along the coastline. Water exchange between the Gulf of Finland and the Baltic Sea proper is intensive, given that there are no thresholds reducing the currents between them.

In front of Loviisa power plant, the net current of seawater moves west. At the local level, the most significant factor with an impact on currents in the nearby sea area is the wind, which influences the sea level in addition to atmospheric pressure. Other factors with a local impact include the area's topography (such as islands and straits), the seabed's profile (such as underwater thresholds) and depth profile as well as river runoff.

Based on the hourly averages in 2010–2020, the most common wind direction in the vicinity of Loviisa power plant is from the southwest or east-southwest (28%) (Lahti 2021, Appendix 4). The most common wind speed during the same period was 3–4 m/s.

Loviisa power plant measures the sea level, the daily averages of which have most often varied between -30 cm and 30 cm. The other closest station measuring the sea level is located in Emäsalo, Porvoo, the tide gauge of which registers the level every hour (Figure 9-32). In 2020, the daily sea level averages in Emäsalo varied between -34 cm and 87 cm relative to the theoretical mean water level (Finnish Meteorological Institute 2021).

In the sea area surrounding Hästholmen, the current of the surface layer moves towards Hästholmsfjärden under a south-easterly wind, while simultaneously, the current from Hästholmsfjärden to Vådholmsfjärden is largely impeded. When the wind blows from the west, southwest or northwest, surface water is discharged from Hästholmsfjärden towards Vådholmsfjärden. A rise in the sea level weakens the water exchange in Hästholmsfjärden, while the surface water's flow to Vådholmsfjärden is easier when the sea level is low. The fairly narrow, shallow straits between Hästholmsfjärden and the outer sea area restrict water exchange between the areas (Fortum Power and Heat Oy 2019b).

In the present state, the cooling water circulation of Loviisa power plant has a minor impact on the currents in the nearby sea area. The cooling water circulation moves an average of 44 m^3/s of water from Hudöfjärden to Hästholmsfjärden. The impact increasing the flow velocity is strongest in the surface layer and concerns mainly the vicinity of the cooling water's discharge location as well as the straits between Hästholmsfjärden and Vådholmsfjärden, but does not extend to Klobbfjärden (Marjamäki 2012). Part of the cooling water circles Hästholmen from the southern side of the island towards Hudöfjärden. The embankment built between Hästholmen and the mainland weakens currents in the area.

The temperature's seasonal variation is the most important factor regulating the seawater's vertical stratification

Table 9-49. Input carried to the sea area by the rivers Loviisanjoki and Kymijoki as well as the Ahvenkoski branch of the river Kymijoki in 2010–2020 (VEMALA 5 February 2021).

	Total phosphorus t/year		Total nitrogen t/year	
	Average	Range	Average	Range
Loviisanjoki (va 81.027)	87	57–111	1,380	917–1,928
Tesjoki (va 15.001)	28	14–45	347	170–613
Kymijoki, Ahvenkoski branch (va 14.111)	45*	24–61	2,564	1,144–3,249

** The total phosphorus content of the water originating from the bed of the river Kymijoki's Ahvenkoski branch is markedly lower than the total phosphorus content of the rivers Loviisanjoki and Tesjoki. Because of this, the load originating from the bed is at an equal level to the load carried along by the Rivers Loviisanjoki and Tesjoki, which have a smaller flow rate.*

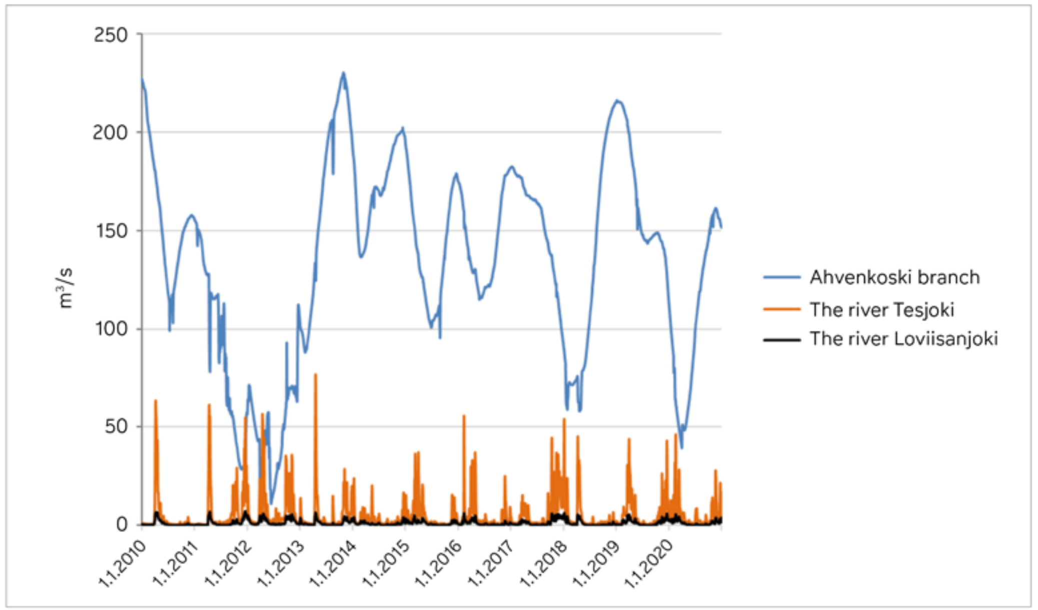

Figure 9-31. Variation in the discharges of the river Kymijoki's Ahvenkoski branch as well as in the discharges of the rivers Tesjoki and Loviisanjoki in 2010–2020 (VEMALA, data retrieved on 5 February 2021).

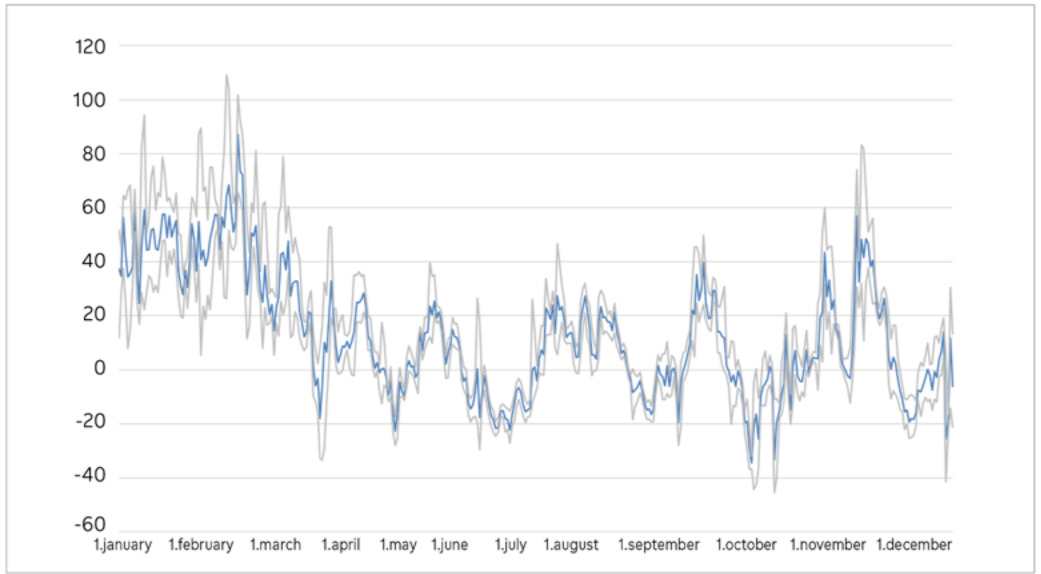

Figure 9-32. Daily sea level averages and the (daily) range of variation in Emäsalo, Porvoo relative to the theoretical mean water level (Finnish Meteorological Institute 2021).

in the sea area near the coast. In the spring, once the ice has melted and solar radiation increases, the warming of the seawater surface results in a vertical rotational movement (spring overturn) until the temperature of the surface water exceeds the temperature of the water's maximum density (4 °C). Following the overturn, the warming of the surface layer progresses, and the water column stratifies as the lighter, warm water stays in the surface layer, above the denser, cool water. A thermocline usually forms at a depth of 10–20 m, sinking deeper as the summer progresses and the mixing surface layer thickens. The thermocline prevents the mixing of and exchange of substances between the colder hypolimnion and the surface layer. The existence of the thermocline also contributes to the freshwater carried by rivers staying in the surface layer, given that any vertical mixing of water through the thermocline is weak. The wind's impact on the stratification of seawater is significant in shallow sea areas, and when the wind is strong, mixing also takes place during summer stratification. In late summer, the seawater gradually cools, and the thermocline begins to weaken. During the autumn, an overturn occurs, at which point the temperature is the same throughout the body of water. The seawater continues to cool towards the winter, and gradually a layer of lighter, cooler water with a temperature close to the freezing point forms in the surface layer. In the vicinity of coastal estuaries, the river's lighter freshwater can form a bed of freshwater under the ice and thereby influence the stratification of the water column. In Finland's sea areas, the ice cover usually forms in mid-winter.

The water's stratification dynamics are also closely related to the upwelling/downwelling phenomenon that occasionally influences the temperature of surface water in the coastal and outer archipelago. In an upwelling, surface water from the coastal area flows offshore and is replaced by the nutrient-rich and cooler water rising from deeper parts of the sea (Raateoja and Setälä 2016), which results in a sudden cooling of the water column. Off Loviisa, wind blowing from the west for sufficiently long periods of time along the coast can cause upwelling. Correspondingly, long-lasting winds from the east may cause downwelling, in which warm surface water flows to the coast of Finland, and an upwelling of cool water takes place on the coast of Estonia (Raateoja and Setälä 2016). From time to time, downwelling also raises the temperature of the seawater off Loviisa (Fortum Power and Heat Oy 2019a).

For example, in the coastal archipelago at Hudöfjärden, the seawater is strongly stratified in terms of temperature during summers, and the deeps contain water that is significantly cooler than the water in the surface layer (Figure 9-33). During the 2011 measuring campaign, the temperature of the surface water rose until late July, after which the water column began to cool. Upwelling situations, during which the temperature of the seawater's surface layer rapidly plummeted, were observed in July–September. The autumn overturn took place around mid-October.

The thermal load on the cooling water's discharge side is Loviisa power plant's most significant environmental impact, which is why seawater temperatures have been monitored with a long-term view since the 1960s. Based on the monitoring results, continuous measurement results, separate measuring campaigns and modelling, the cooling water increases the temperature of the seawater and has impacted the natural temperature stratification described above, particularly in the vicinity of the cooling water's discharge location in Hästholmsfjärden (Fortum Power and Heat Oy 2019b, Lahti 2021).

The results show that the surface layer's temperature increases, on average, by more than 3 °C at a distance of approximately 1–1.5 km from the discharge location. A more than 2 °C impact can be detected at a distance of approximately 1.5–2.5 km, and a more than 1 °C impact extends to a distance of approximately 3–3.5 km (Marjamäki 2012). The thermal effect of the cooling waters is also clearly visible in the results of the long-term monitoring of water quality, in which the mean and maximum temperatures of Hästholmsfjärden's monitoring points during the ice-free season are higher than those in the other sea areas (Table 9-50).

The temperature of the seawater in the cooling water's intake and discharge sides is monitored continuously with data buoys, the locations of which are shown in Figure 9-37. Figure 9-34 shows the development of the seawater temperature over the year in different layers of water in the cooling water's intake and discharge sides and at different distances from the discharge location in 2002, from which the most complete time series were available. In terms of its temperature conditions, 2002 was a conventional year. As can

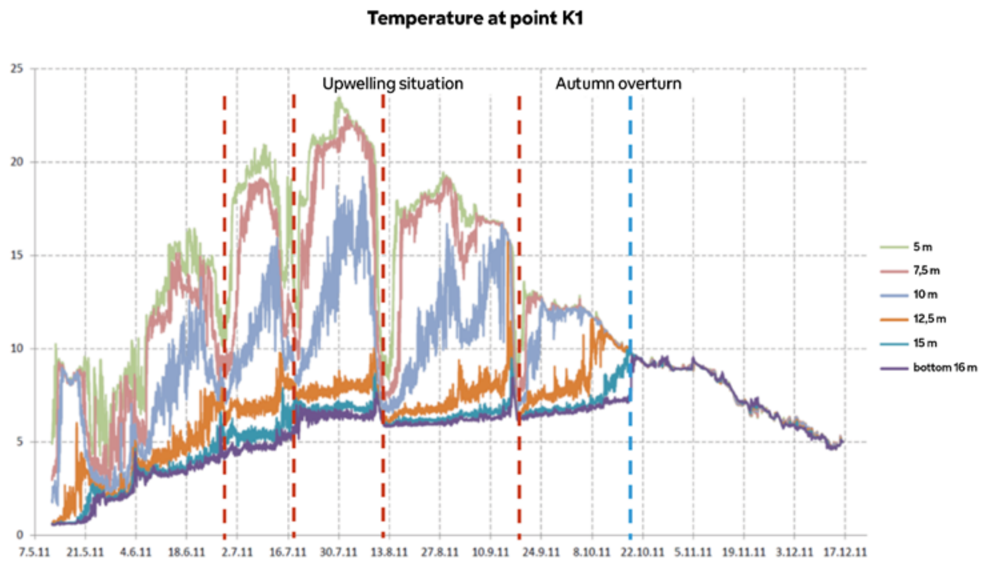

Figure 9-33. Development of seawater temperature at Hudöfjärden's point K1 in May–December of the 2011 measuring campaign. The upwelling situations are indicated by the broken red line. The temperature differences between the water layers levelled off in late October (Lindfors et al. 2012).

Table 9-50. The surface water's mean, maximum and minimum temperature (°C) during the ice-free season in June–September 2000–2020 , and the sample size (n). The locations of the monitoring points are shown in Figure 9-37 (Open data, Hertta database, 11 February 2021).

Monitoring point	Temperature	Temperature	Temperature	n
	Average	Maximum	Minimum	
Hudöfjärden 1	18.4	23.5	14.1	22
Hudöfjärden 2	17.6	24.1	11.2	32
Hudöfjärden 3	16.7	24.5	8.6	154
Hästholmsfjärden 11	20.4	28	14.8	87
Hästholmsfjärden 12	19.4	27.6	11.9	89
Hästholmsfjärden 8	19.2	27.6	11.9	153
Hästholmsfjärden 9	19.3	27.5	14.3	56
Klobbfjärden 6	18.5	26.4	12.7	87
Orrengrundsfjärden 15	15.9	23.1	9	87
Vådholmsfjärden 20	17.2	24.5	11	88

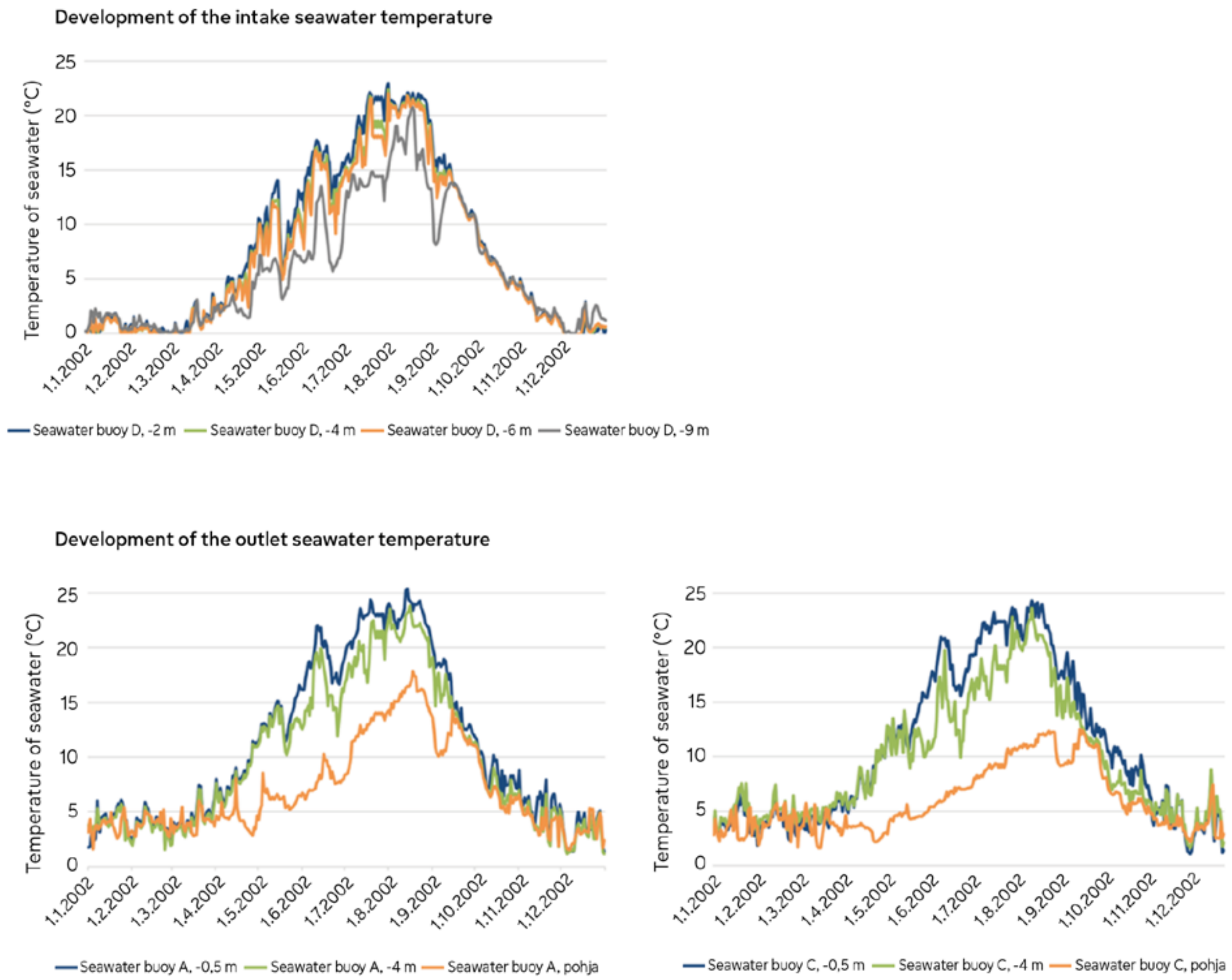

Figure 9-34. The annual development of seawater temperature at the continuous data buoys in 2002 on the cooling water's intake side at Hudöfjärden (topmost image) and discharge side, at data buoys A (image on the left) and C (image on the right) in Hästholmsfjärden. The locations of the buoys are shown in Figure 9-37.

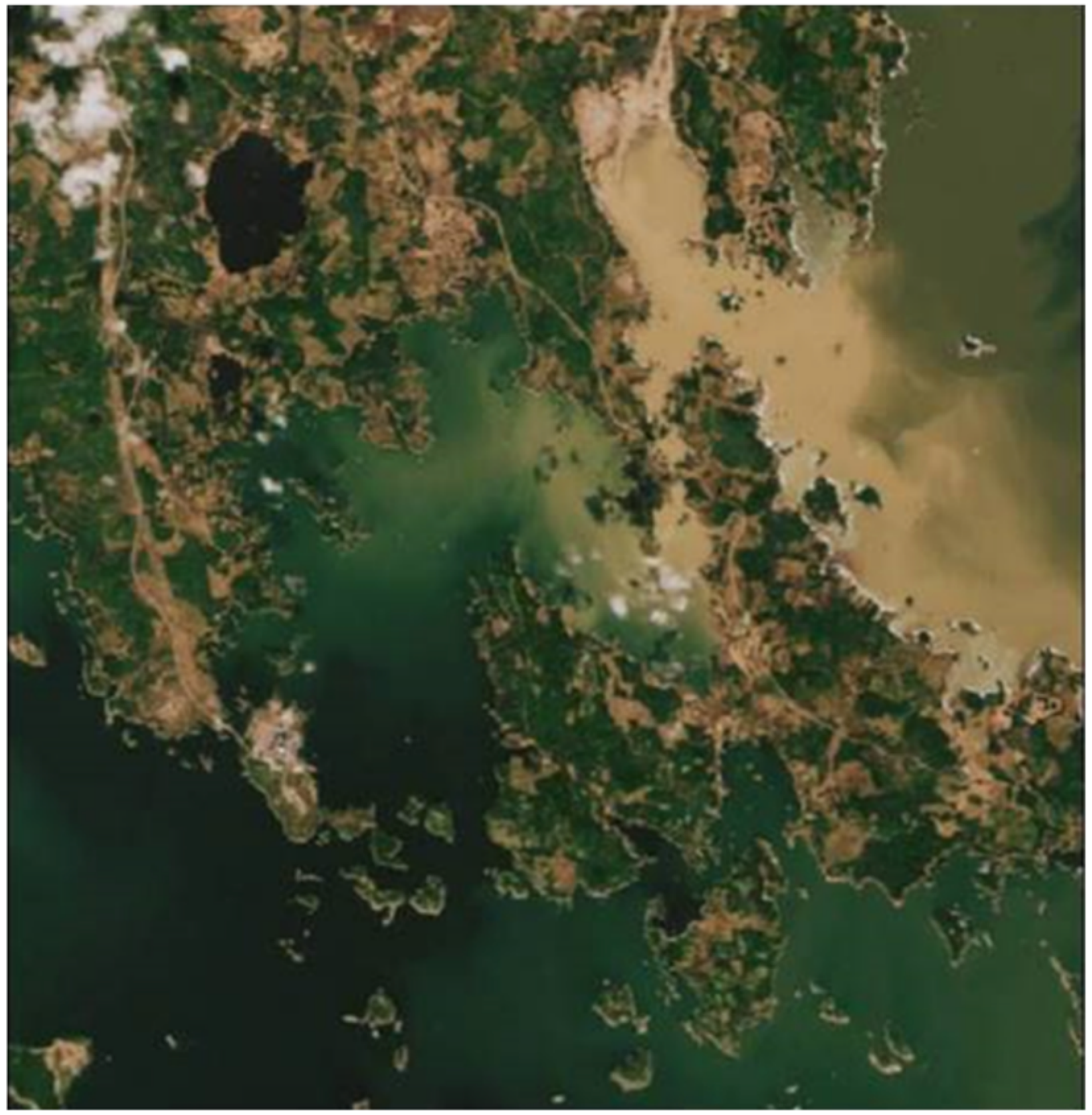

Figure 9-35. Satellite image of the river Tesjoki's impact on Loviisa power plant's nearby sea area in the spring (23 April 2018), in which fresh river water clouded by clay is carried to Klobbfjärden. Original image: ESA Copernicus Sentinel Data, processed by SYKE (SYKE 2018).

be seen from the figure, the layer formed by warm cooling water spreads in the sea area as a surface water layer that is a few metres thick and does not easily mix with the denser water below. The thermal effect has been found to strengthen Hästholmsfjärden's vertical temperature stratification (Fortum Power and Heat Oy 2019b). The spread and thermal effect of the warm cooling water are also discussed in Chapters 9.16.4.1 and 9.16.4.2.

The seawater currents, described above, regulate the spread of warm cooling water in the sea area. During a south-easterly wind, the thermal effect is primarily confined to the area of Hästholmsfjärden. The same phenomenon is visible when the sea level rises. When the wind blows from the southwest or northwest, and when the water level is lower than average, the warm water also spreads more easily to the Vådholmsfjärden side (Fortum Power and Heat Oy 2019b).

Based on the temperature monitoring and the modelling carried out in the area, the greatest temperature increase focusing on the surface layer (1 metre) as a result of the discharge of cooling water is typically limited during the ice-free season to the area east of Hästholmen, consisting of the islands of Smedsholmarna, the island of Reimars, and the islands and straits south of the discharge location (Figure 9-54 and in Chapter 9.16.4.1). The thermal load is distributed evenly in the surface layer of the water, with minimal mixing with lower water layers. The impact in Vådholmsfjärden and the deeper layers of water is therefore minor. Occasionally, rising temperatures in the surface water can be observed in a larger area, depending on the wind conditions or ice situation.

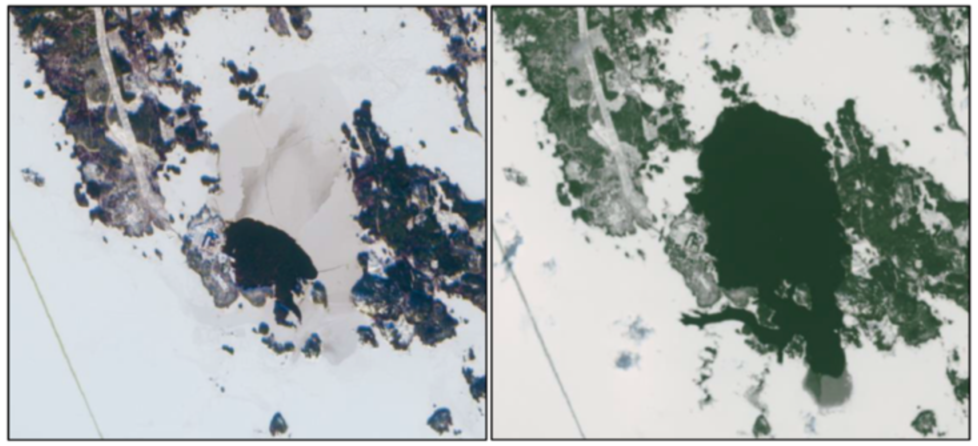

Figure 9-36. Variation in the size of the area of meltwater in the power plant's sea area in the winter of 2018. The satellite image on the left was taken in late February (27 February 2018), when the area of meltwater was at its smallest. The image on the right was taken in early April (3 April 2018); the ice in the sea area melted entirely around mid-April. Original images: ESA Copernicus Sentinel Data, processed by: SYKE (SYKE 2018).

Some warmed water also circles back to the intake side in Hudöfjärden (Marjamäki and Lahti 2012, Fortum Power and Heat Oy 2019b, Lahti 2021).

The spread of warm cooling water in the nearby sea area is most clearly observable in winter, when the warm cooling water keeps the part of Hästholmsfjärden in front of the discharge location free of ice throughout the year (Ilus 2009). In the immediate vicinity of the discharge location, the warm cooling water lies initially in the surface layer, in which the temperature rises by approximately 5–15 °C (Lahti 2021). The saline and warm cooling water sinks gradually, in proportion to its density, between the surface layer of the cold freshwater carried by rivers and the cold, more saline layer of seawater, forming an intermediate layer of warm water close to the surface. This layer is most clearly visible in Hästholmsfjärden and in front of the straits leading to Vådholmsfjärden. The maximum temperature increase in the intermediate layer is around 5 °C (Lahti 2021). Further out, the temperature of the intermediate layer decreases gradually as the surrounding cold water mixes with it. Warm cooling water also pushes, within the intermediate layer, into the Hudofjärden side, where the temperature increase has been around 0–3 °C (Marjamäki 2012, Lahti 2021).

In the Gulf of Finland, salinity decreases towards the east, and in the coastal archipelago, the differences between the hypolimnion and the surface layer in terms of salinity are typically fairly small. The average long-term salinity of the surface layer has remained fairly stable and typical of brackish water in the sea area near Hästholmen, with a range of 3.5–5‰. In the hypolimnion, the average concentration is slightly higher, roughly 4–6 ‰. The rivers Loviisanjoki and Tesjoki and the Ahvenkoski branch of the river Kymijoki carry freshwater into the bay areas, which contributes to the stratification. The impact of rivers can be detected easily from satellite images taken in the spring, for instance, when turbid water can spread over a wide area in the bays, and when water from the river Tesjoki, among others, pushes into Klobbfjärden via the Jomalsund canal (Figure 9-35).

9.16.3.4 Ice conditions

The sea area's ice situation is also monitored as part of the plant's required monitoring. Permanent ice cover in the area forms later than normal, and the ice breaks up earlier, compared to areas that are not exposed to the thermal load. The impact of the power plant's cooling water on the ice cover is manifested as a large area of meltwater, which is also visible in satellite images. In 2018, for example, the area of meltwater seen in the satellite images was at its smallest at the end of February (Figure 9-36). By the beginning of April, the area of meltwater had grown considerably, and around mid-April, the ice in the sea area melted completely. Thus, the ice cover is normally quite thin in the sea off the plant and in the inlets leading out of Hästholmsfjärden. In the northern parts of Hästholmsfjärden and on Klobbfjärden, the ice is usually solid (Ilus, 2009).

The ice situation and the size of the meltwater area varies to a considerable degree, depending on how severe the winter is. During severe winters, the area of meltwater can be very small, whereas during mild winters, it is at its largest. Warning boards and the local newspaper are used to warn people of a weakened ice situation.