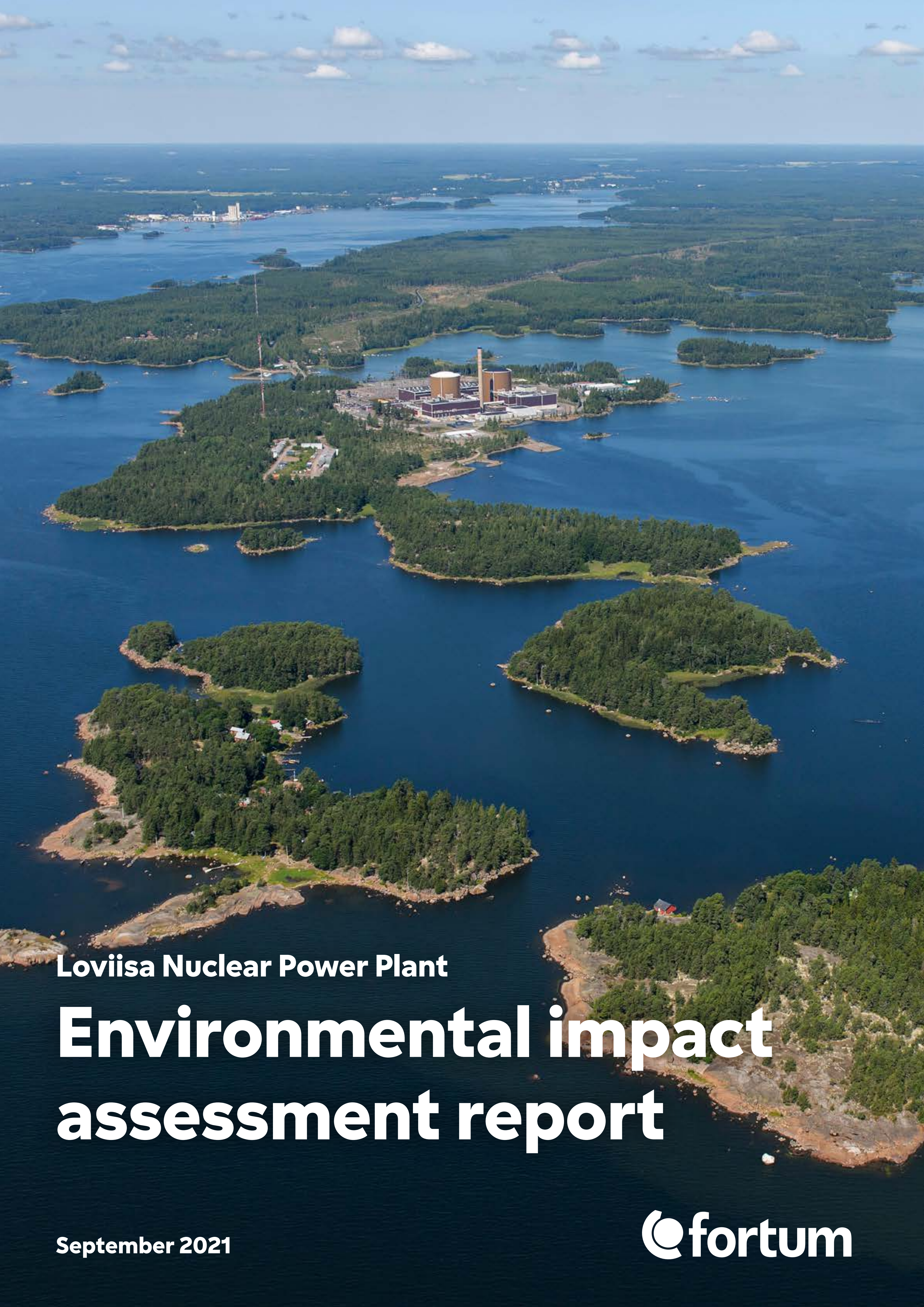

Loviisa Nuclear Power Plant

Environmental impact assessment report

September 2021

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Introduction

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

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

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

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

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

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

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

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Arbets- och näringsministeriet

Ympäristöministeriö
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Summary

PROJECT OWNER AND THE PROJECT BACKGROUND

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

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

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

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

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

POWER PLANT'S CURRENT OPERATION

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

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

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

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

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

PROJECT DESCRIPTION AND THE OPTIONS REVIEWED

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

EXTENDED OPERATION (VE1)

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

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

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

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

DECOMMISSIONING (VE0 AND VE0+)

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

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

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

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

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

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

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

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

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

PROJECT SCHEDULE

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

ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE

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

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

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

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

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

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

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

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

DESCRIPTION OF PROJECT AREA AND ITS ENVIRONMENT

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

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

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

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

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

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

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

ENVIRONMENTAL IMPACT ASSESSMENT METHODS

IMPACTS TO BE ASSESSED

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

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

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

TIME OF THE IMPACTS AND REVIEW OF OPTIONS

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

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

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

APPROACH TO AND METHODS OF IMPACT ASSESSMENT

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

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

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

REPORTS AND OTHER MATERIALS USED IN THE ASSESSMENT

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

SUMMARY OF THE PROJECT'S ENVIRONMENTAL IMPACTS

ENVIRONMENTAL IMPACTS OF THE DIFFERENT OPERATIONAL PHASES

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

OPERATIONAL PHASE OF EXTENDED OPERATION

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

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

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

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

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

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

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

OPERATIONAL PHASE OF DECOMMISSIONING

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

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

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

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

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

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

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

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

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

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

RADIOACTIVE WASTE GENERATED ELSEWHERE IN FINLAND

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

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

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

COMPARISON OF OPTIONS AND CONCLUSIONS ON THE MOST SIGNIFICANT ENVIRONMENTAL IMPACTS

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

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

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

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

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

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

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

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

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

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

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

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

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

INCIDENT AND ACCIDENTS

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

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

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

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

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

MONITORING AND OBSERVATION OF IMPACTS

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

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

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

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

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

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

THE PROJECT'S PERMIT PROCESS

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

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

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

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

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

1. Project owner and the project background

1.1 PROJECT OWNER

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

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

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

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

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

1.2 PROJECT BACKGROUND

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

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

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

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

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

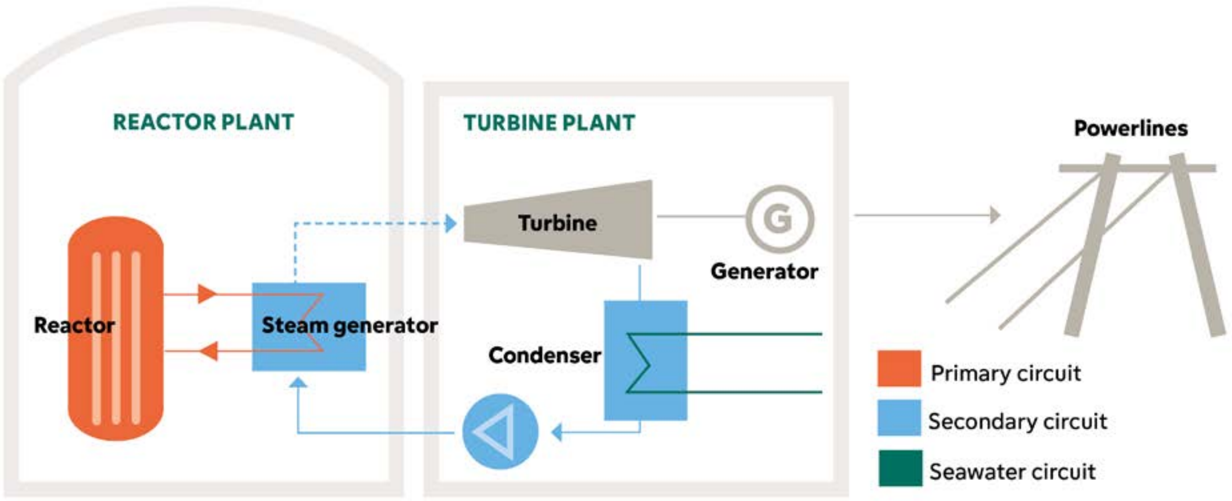


Figure 1-1. Operating principle of a pressurised water plant.

1.3 CURRENT OPERATION OF THE POWER PLANT

1.3.1 Operating principle

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

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

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

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

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

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

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

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

1.3.2 Production

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

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

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

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

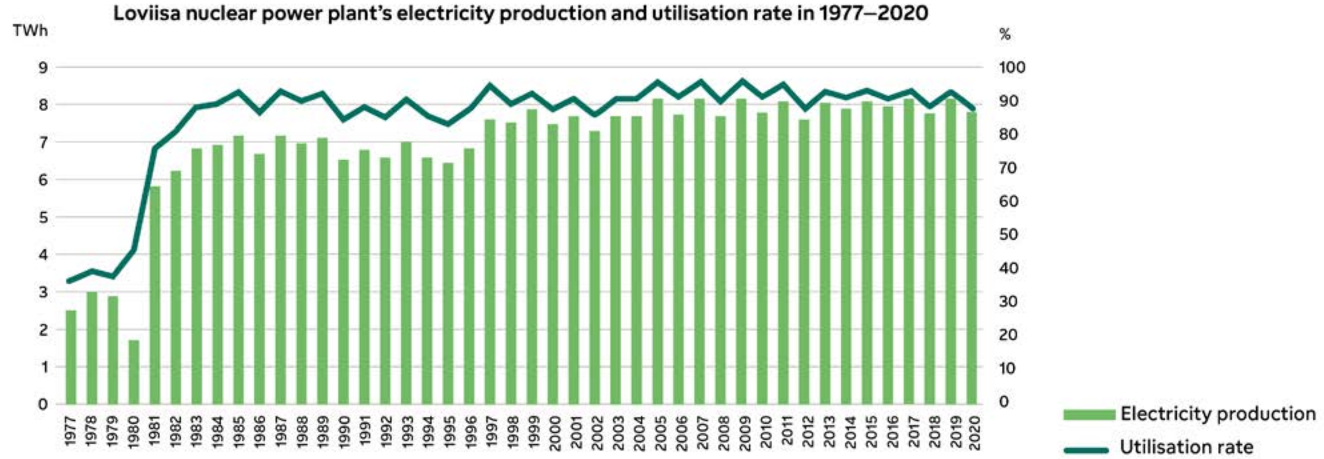


Figure 1-2. The electricity production and load factor of Loviisa power plant during the plant's operating history.

1.3.3 Location

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

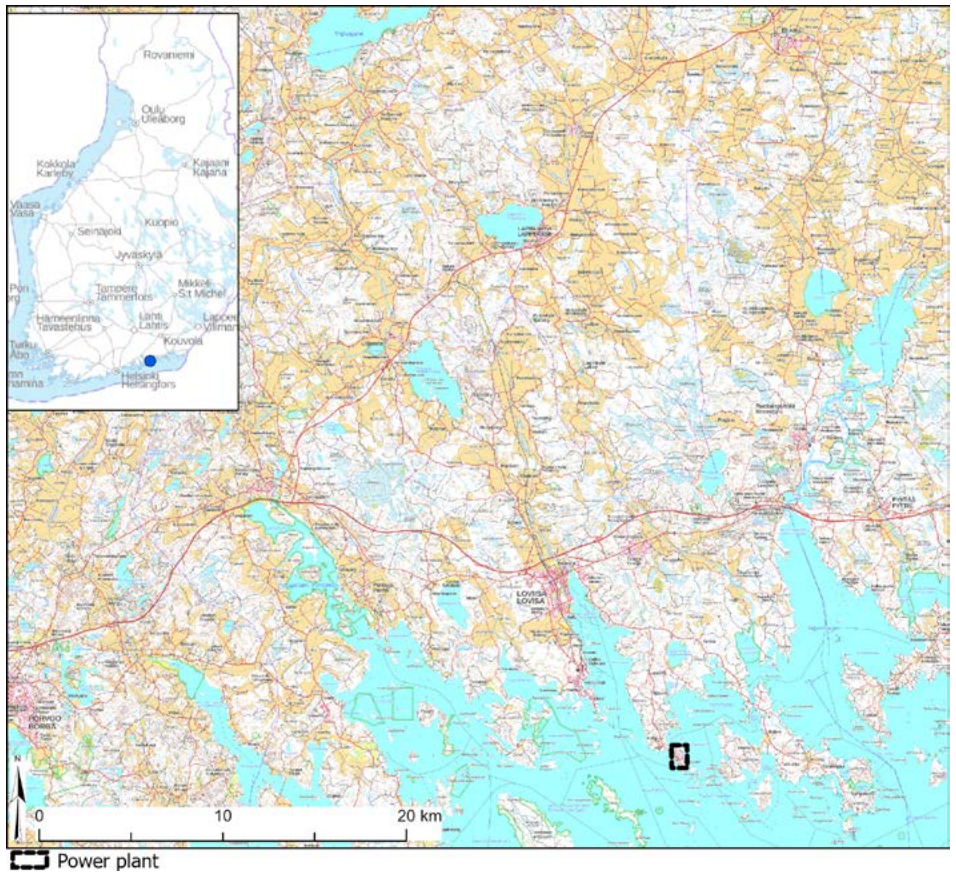


Figure 1-3. Location of Loviisa power plant.

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

1.3.4 Functions in the power plant area

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

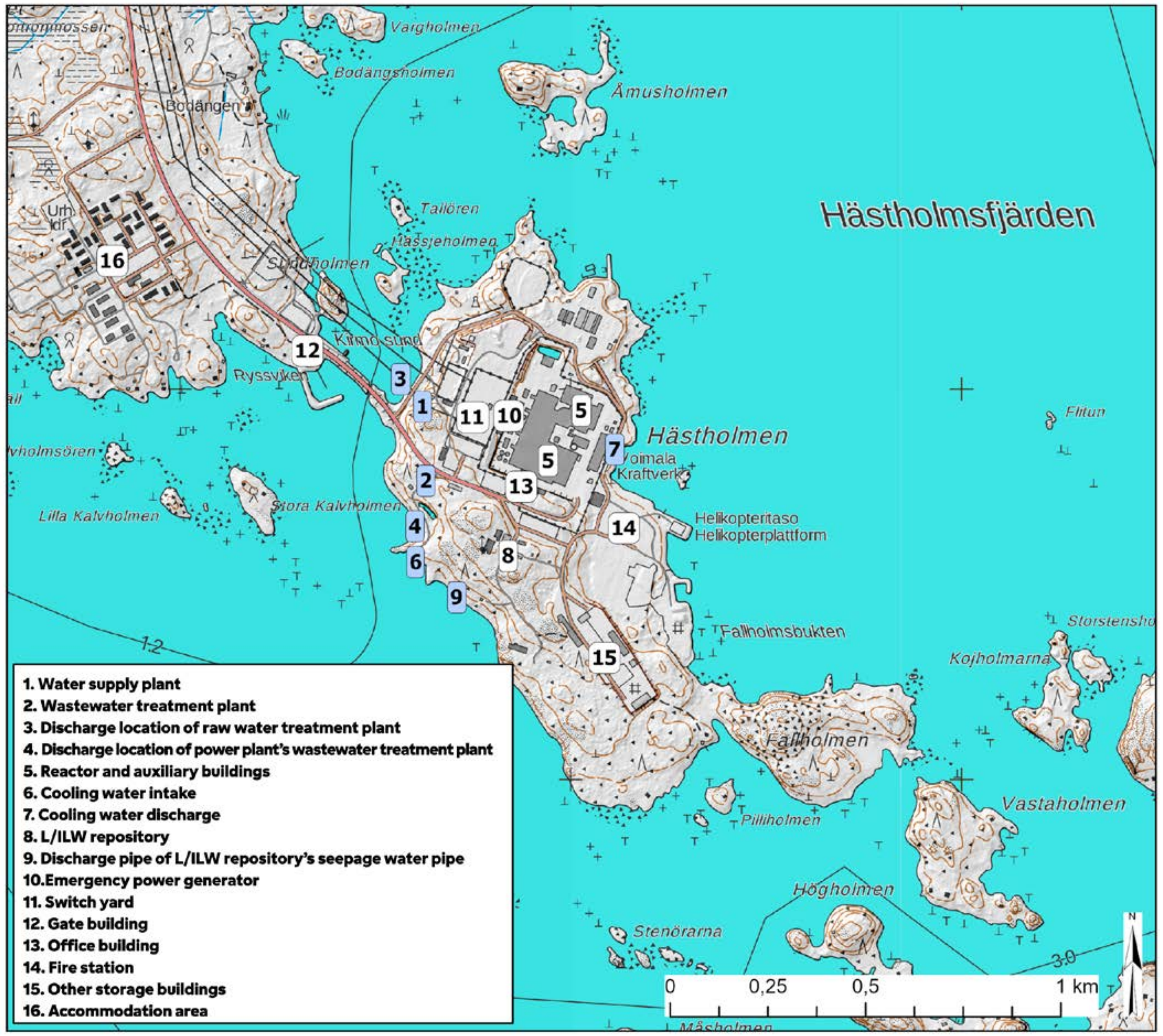


Figure 1-5. The most central buildings and functions in Loviisa power plant area.

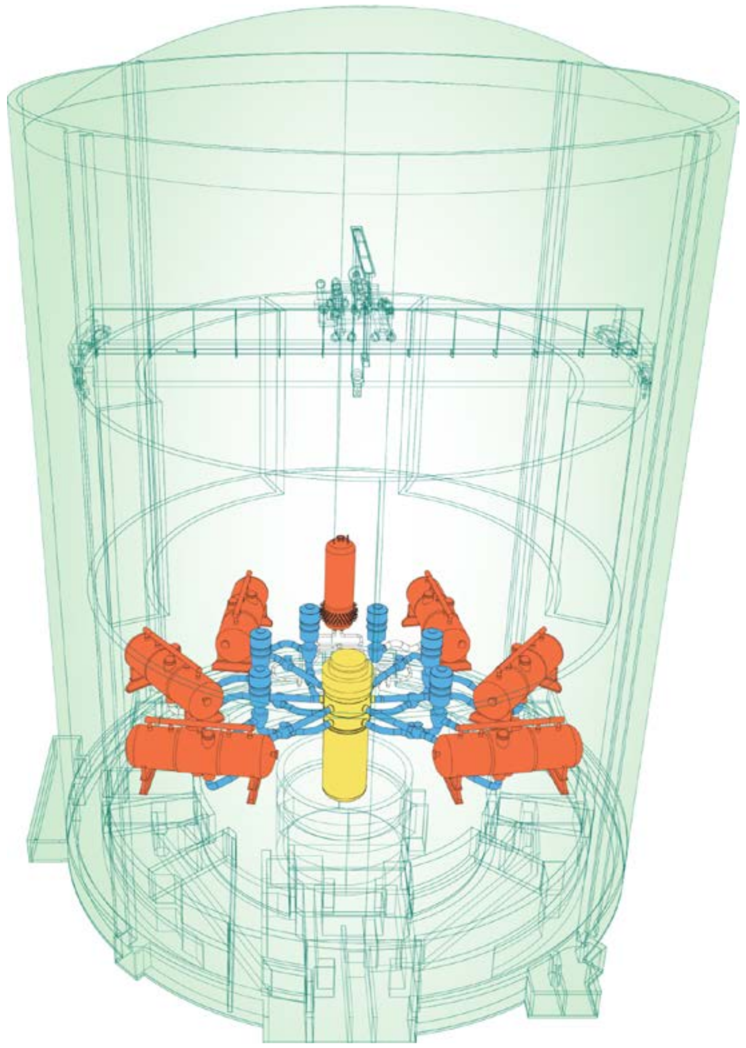


Figure 1-6. Illustration of reactor building and the location of the primary system's main components. The reactor pressure vessel is shown in yellow, the six steam generators and the pressuriser in red, and the main coolant loops of the reactor's cooling system in blue.

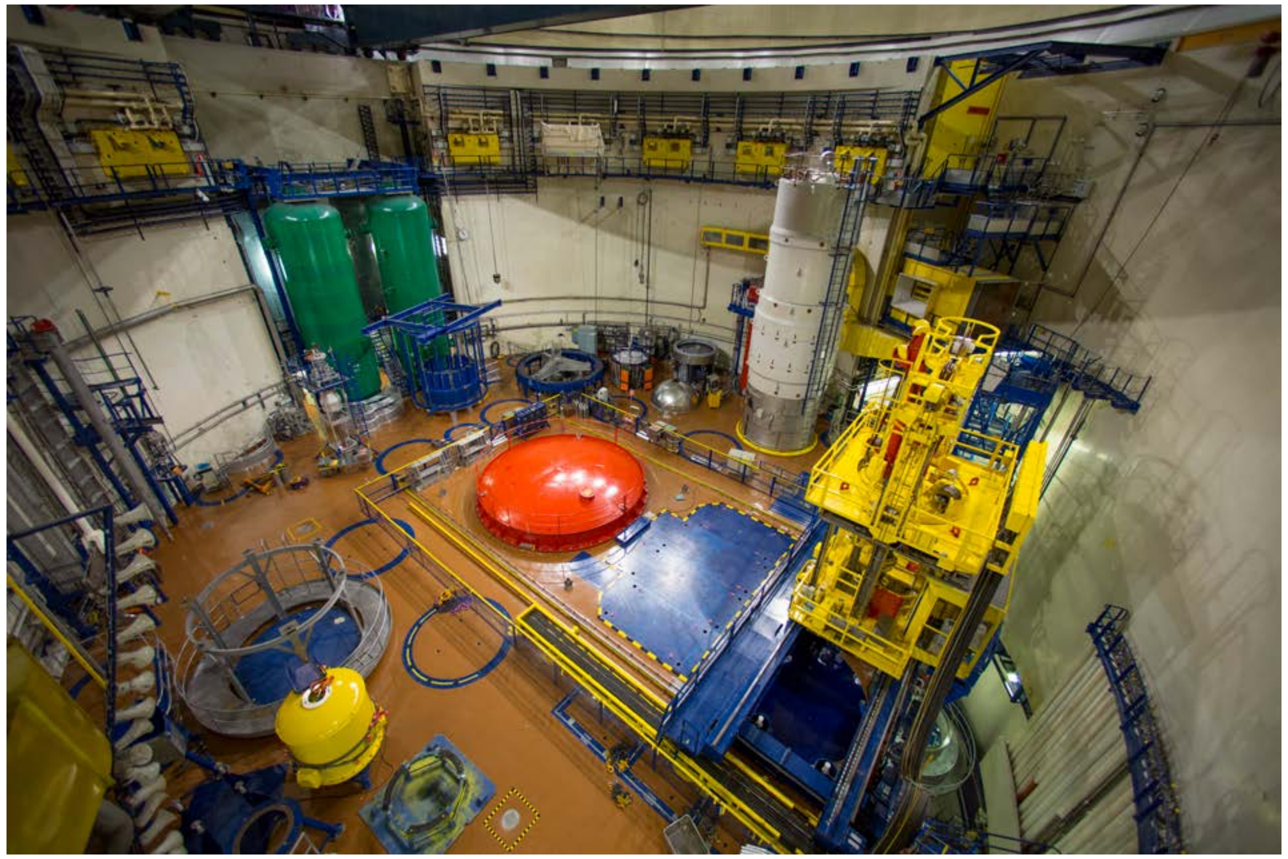


Figure 1-7. The interior of the containment building. The green hydro accumulators can be seen on the left. The reactor's red cover can be seen in the middle and adjacent to it the refuelling pool, covered with blue plates. The yellow refuelling machine can be seen on the right-hand side of the picture.

1.3.4.1 Reactor and containment building

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

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

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

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

1.3.4.2 Auxiliary building and covered tank area

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

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

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

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

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

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

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

1.3.4.4 Intake and discharge of cooling water

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

1.3.4.5 Interim storage for spent nuclear fuel

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

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

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

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

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

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

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

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

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

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

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

1.3.4.8 Diesel generators and engines

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

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

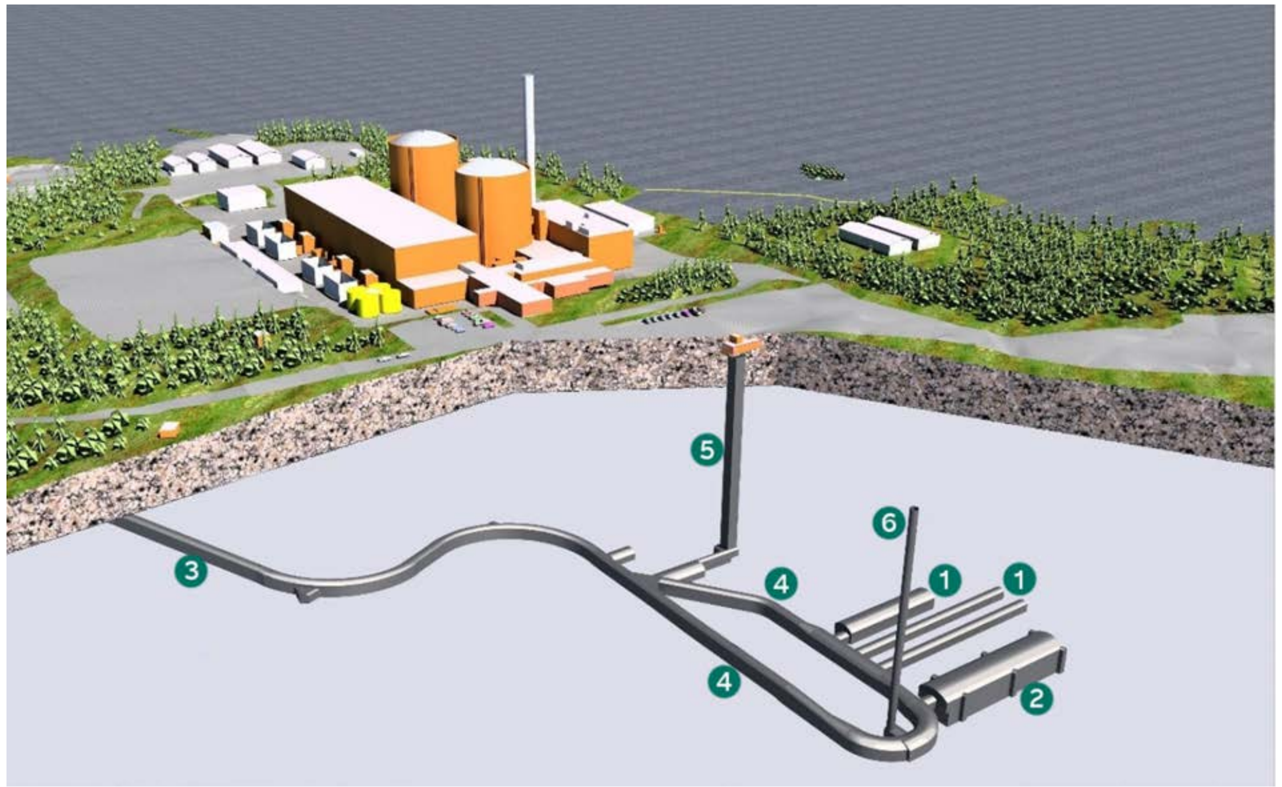


Figure 1-8. Loviisa power plant's final disposal facility for low- and intermediate-level waste (L/ILW repository) in its current size. Layout: Timo Kirkkomäki, Fortum.

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

In addition to the aforementioned, there are, in the power plant area, diesel generators for a severe reactor accident and small diesel generators in the auxiliary emergency 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.

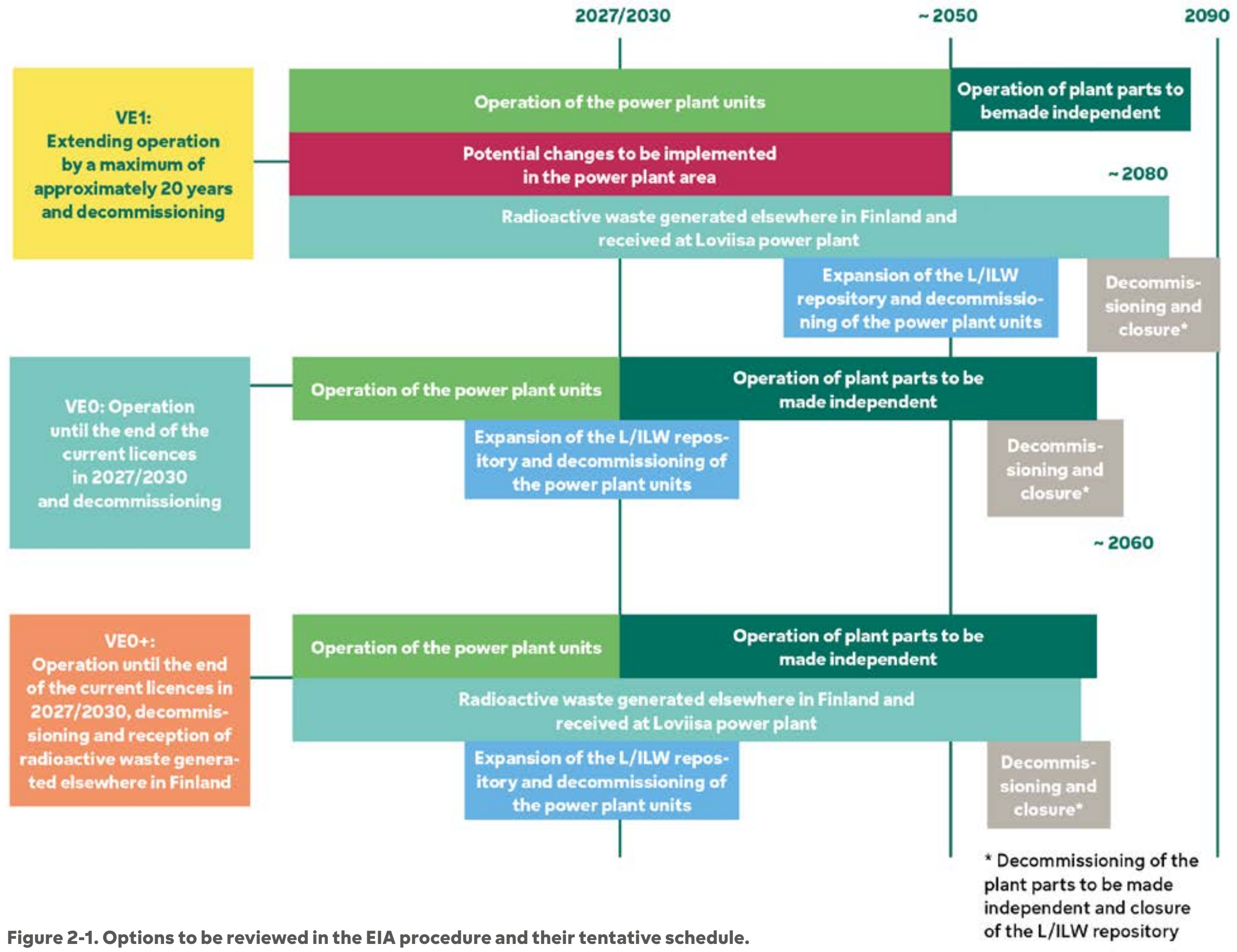


Figure 2-1. Options to be reviewed in the EIA procedure and their tentative schedule.

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

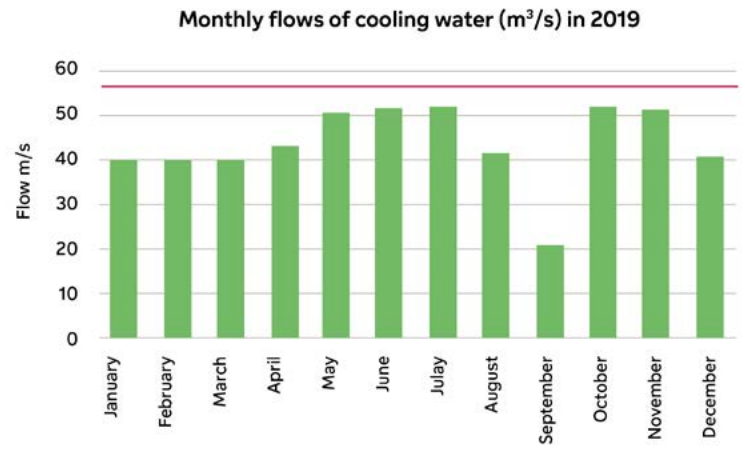


Figure 4-1. Monthly flows of cooling water in 2019 The environmental permit's limit value (56 m^3/s) is indicated with a red line.

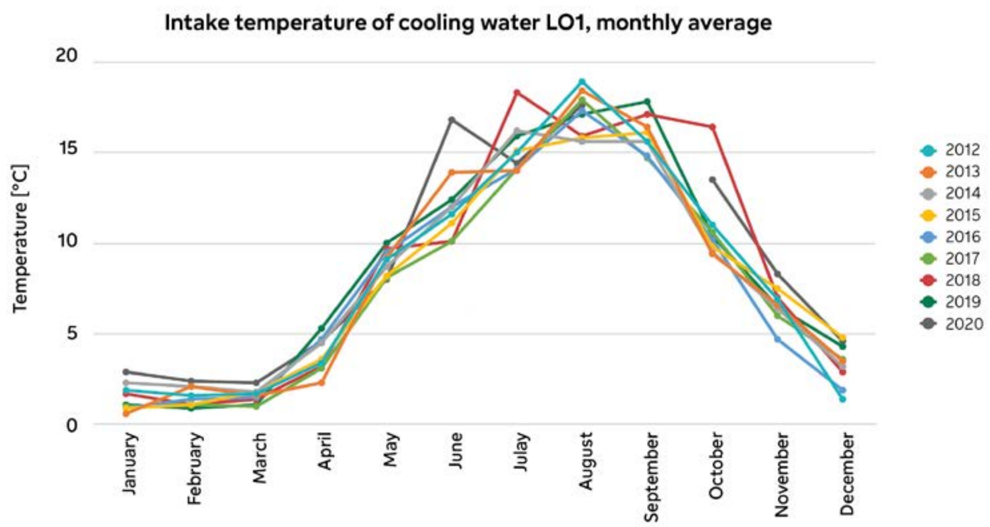


Figure 4-2. The average monthly temperatures of the cooling water taken for power plant unit Loviisa 1 in 2012-2020.

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

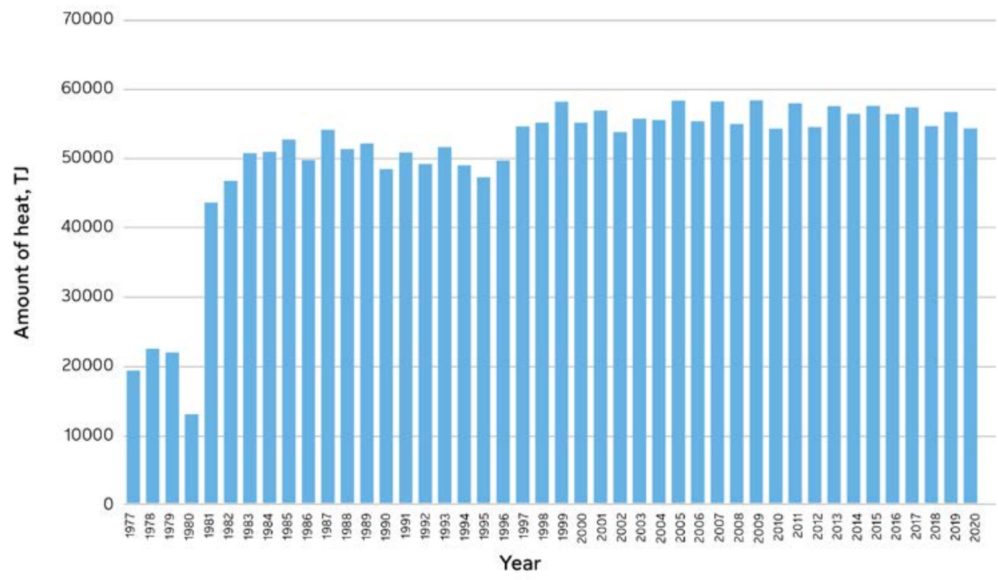


Figure 4-4. Loviisa power plant's thermal load (TJ) into the sea in 1977–2020.

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 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.

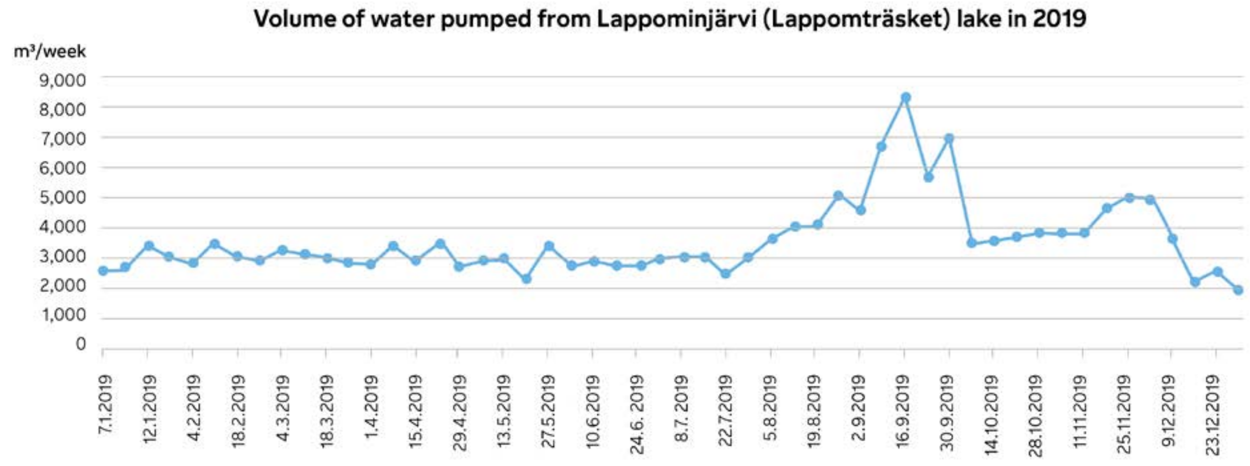


Figure 4-5. Volume of raw water taken by the power plant from Lappomträsket lake in 2019.

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 m^3/h on a short-term basis and at a maximum rate of 150 m^3/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 m^3/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 m^3. 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 m^3 and 160 m^3, as well as in two underground water pools, both with a volume of 1,500 m^3. 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 m^3 tanks. Both power plant units have two tanks. Figure 4-6 shows how the raw water entering the raw water treatment plant is divided into the process water led to the water demineralising plant for treatment and the domestic water.

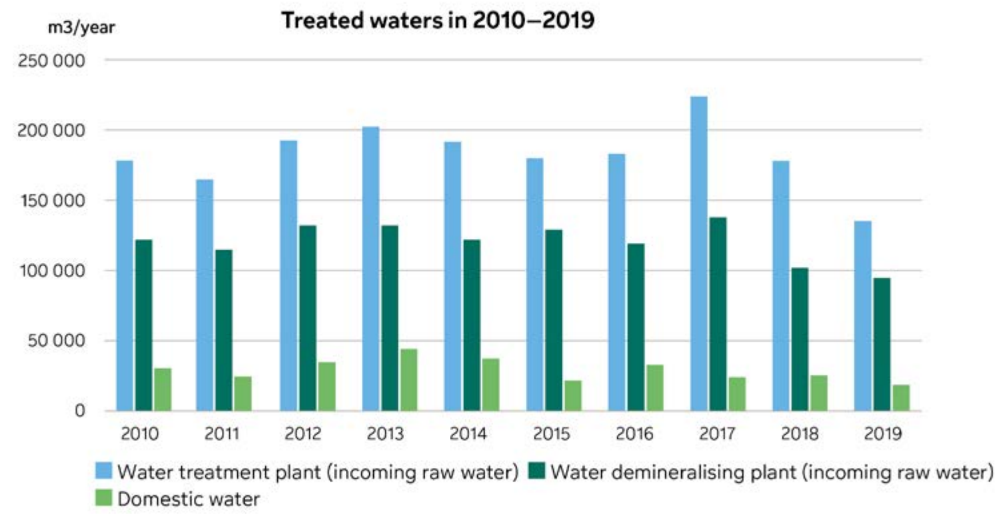


Figure 4-6. The volume of waters treated at the water supply plant, water demineralising plant and the wastewater treatment plant in 2010–2019.

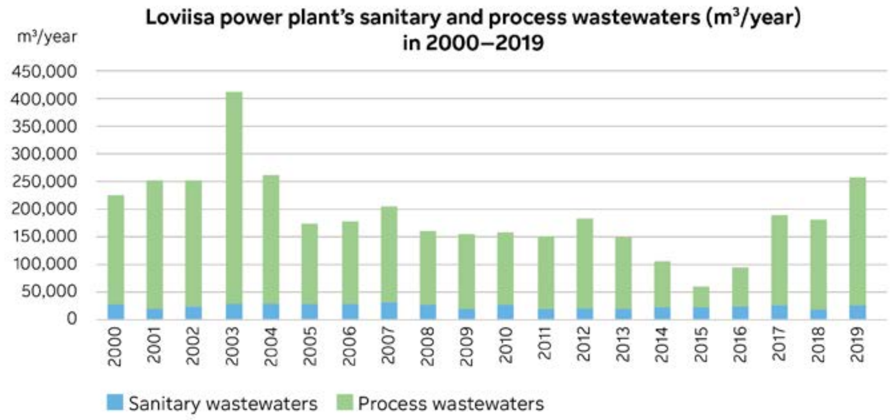


Figure 4-7. Volumes of Loviisa power plant's sanitary and process wastewaters (m^3/year) in 2000–2019.

4.3.2 Changes to service water procurement

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

4.4 WASTEWATER

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

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

4.4.1 Sanitary wastewaters

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

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

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

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

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

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

4.4.2 Process wastewater

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

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

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

4.4.3 Other waters led into the sea

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

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

Figure 4-8. VVER-440 fuel bundle.

4.5 PROCUREMENT OF NUCLEAR FUEL

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

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

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

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

4.6 SPENT NUCLEAR FUEL

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

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

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

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

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

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

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

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

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.

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 m³/year. The volume to be generated by the end of the current operating licences is approximately 2,700 m³.	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 m³ of low-level waste, i.e. approximately 3,300 m³ 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 m³/year, and when solidified and packed, 60–120 m³/year. The volume to be generated by the end of the current operating licences is approximately 4,900 m³.	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 m³ of intermediate-level packed waste, i.e. approximately 7,300 m³ 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 m³ of low-level waste a year and approximately 15–30 m³ of intermediate-level waste a year (approximately 60–120 m³ 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 m³ of low-level waste and approximately 2,400 m³ 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.

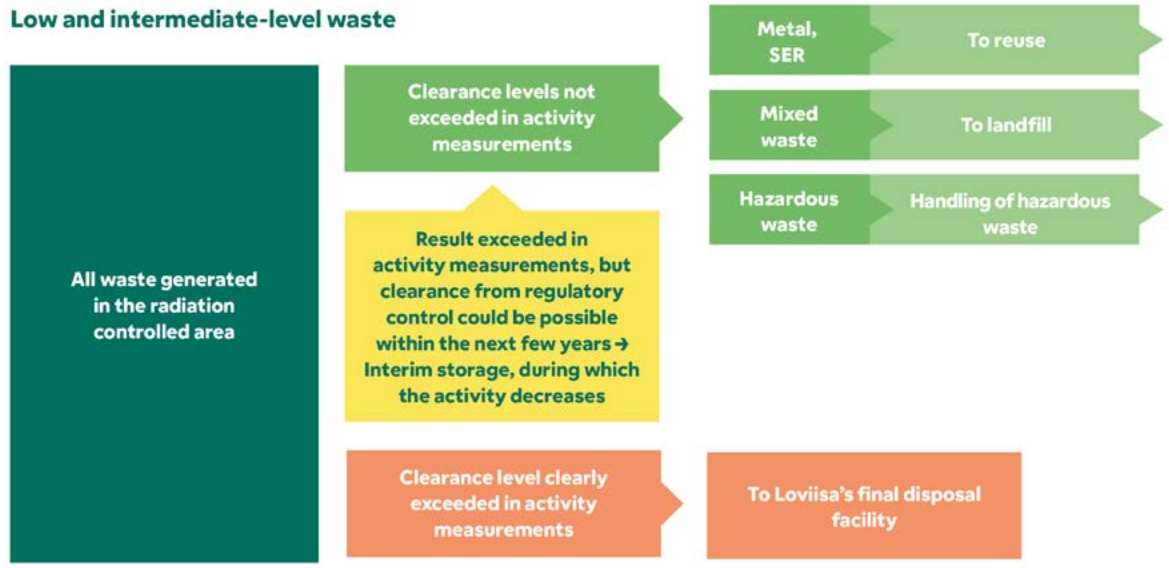


Figure 4-10. Breakdown of maintenance waste into waste to be cleared from regulatory control and waste to be deposited for final disposal.

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

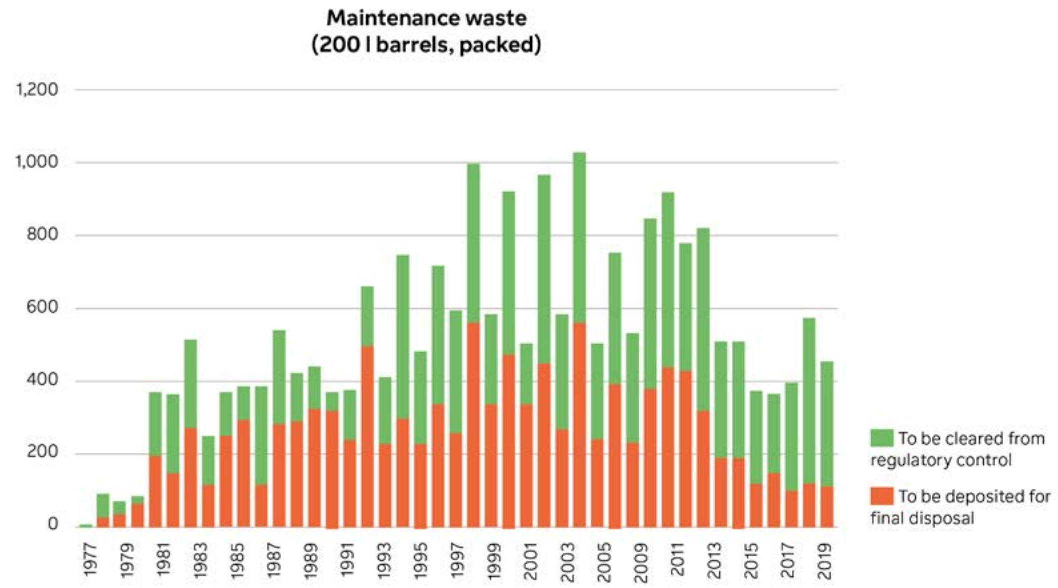


Figure 4-11. The number of waste barrels generated at Loviisa power plant divided by the barrels cleared from regulatory control and deposited for final disposal in 1977–2019.

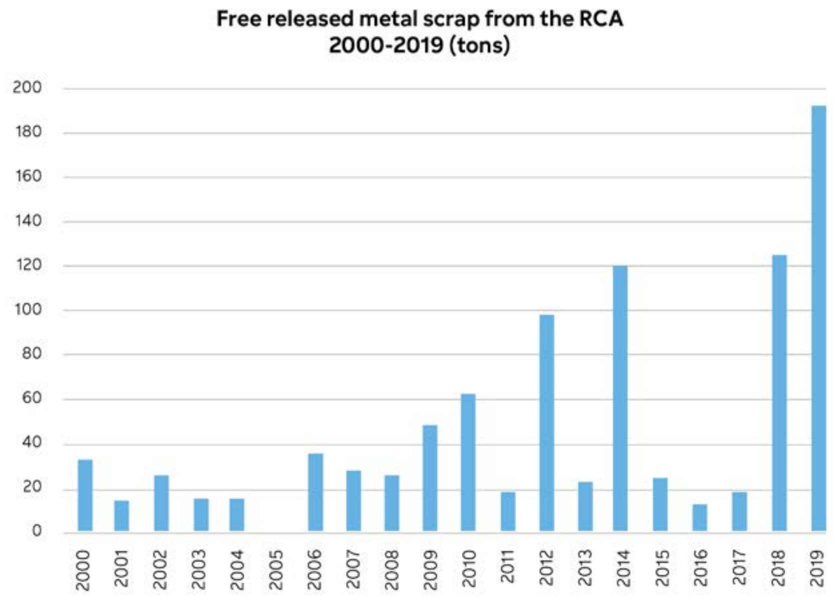


Figure 4-12. Amount of scrap metal cleared from regulatory control in 2000–2019.

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

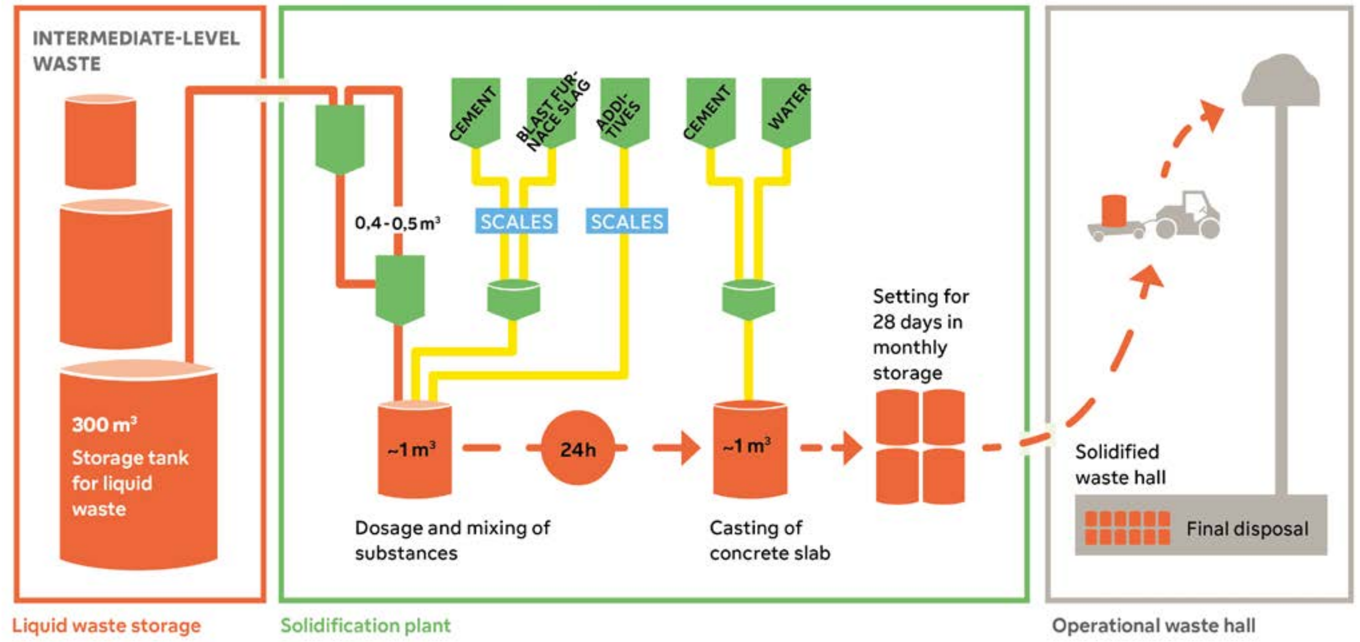


Figure 4-13. Handling of liquid waste.

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.

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

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.

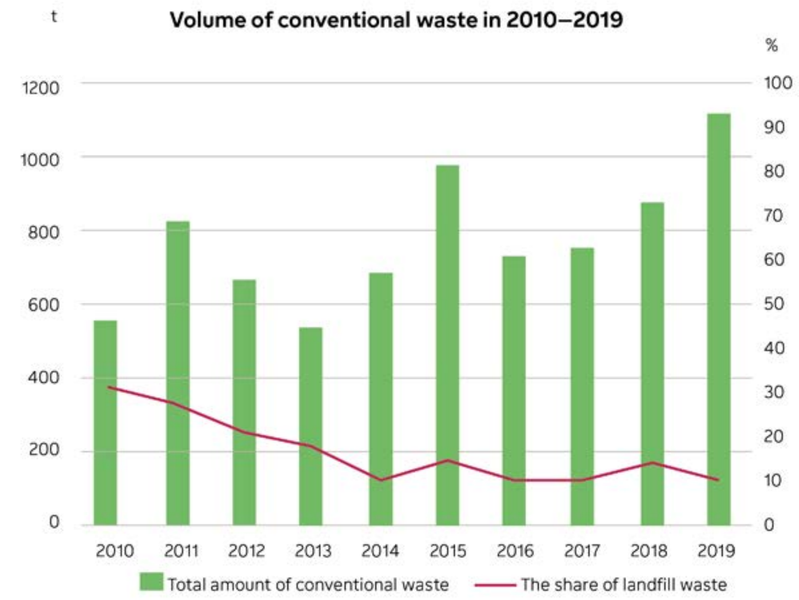


Figure 4-16. Total volume of Loviisa power plant's conventional waste and share of landfill waste in 2010–2019.

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.

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.

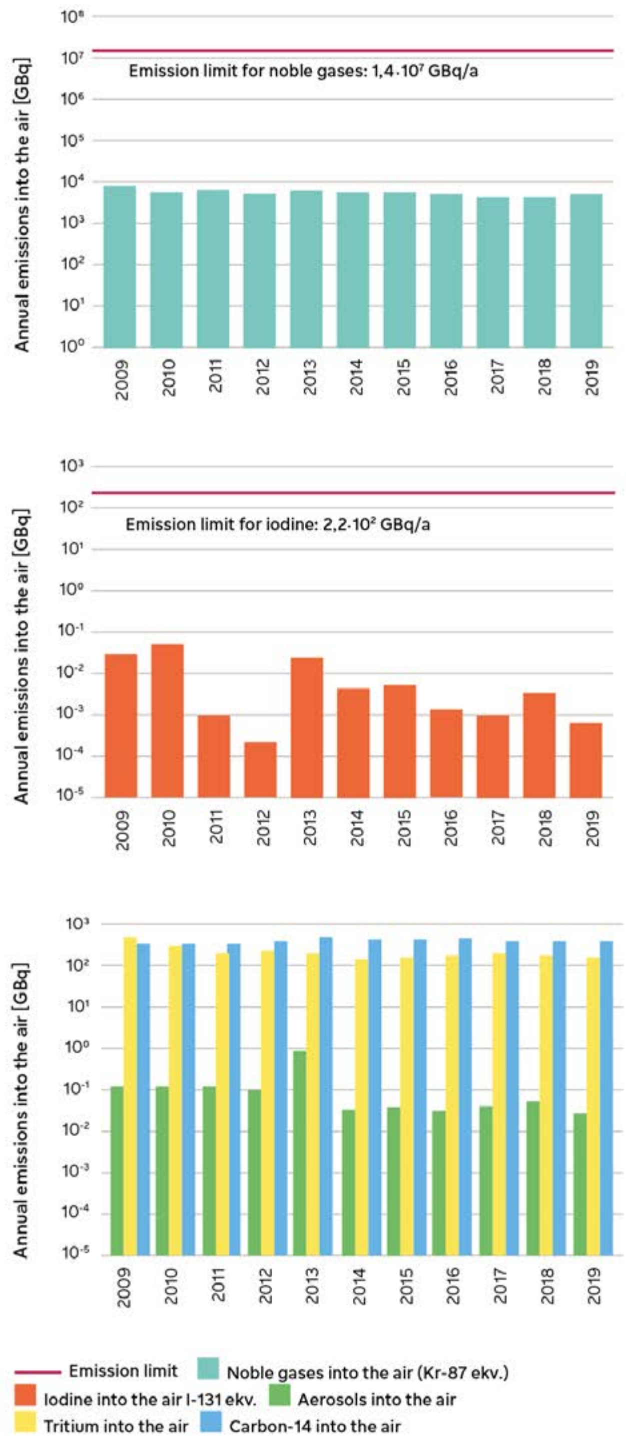


Figure 4-17. Loviisa power plant's radioactive emissions into the air in 2009–2019, and the emission limits for noble gases and iodine.

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

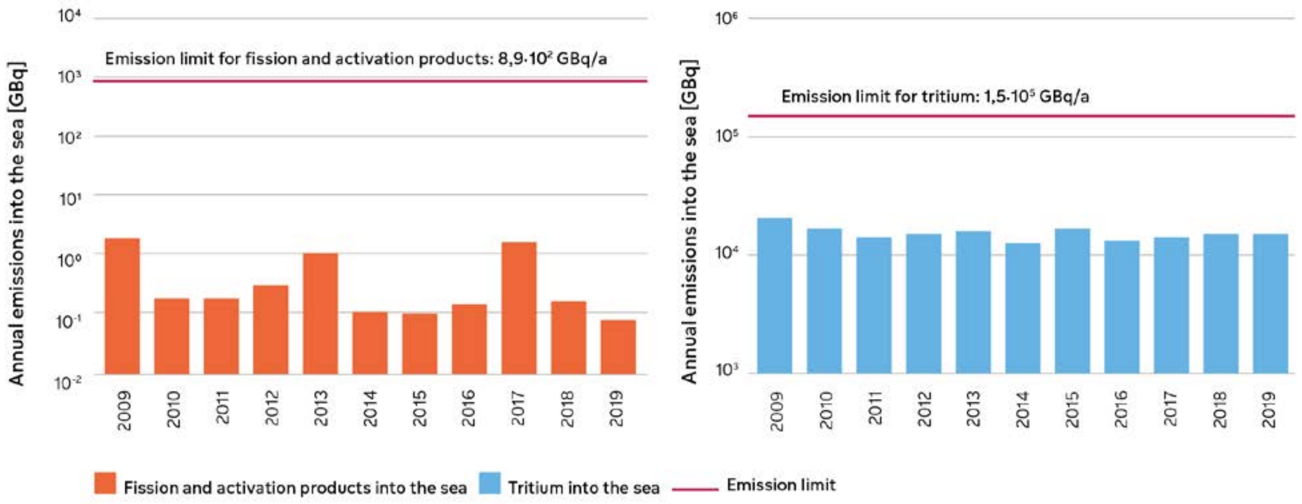


Figure 4-18. Loviisa power plant's radioactive discharges into the sea in 2009–2019 and the emission limits for tritium as well as for fission and activation products.

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.

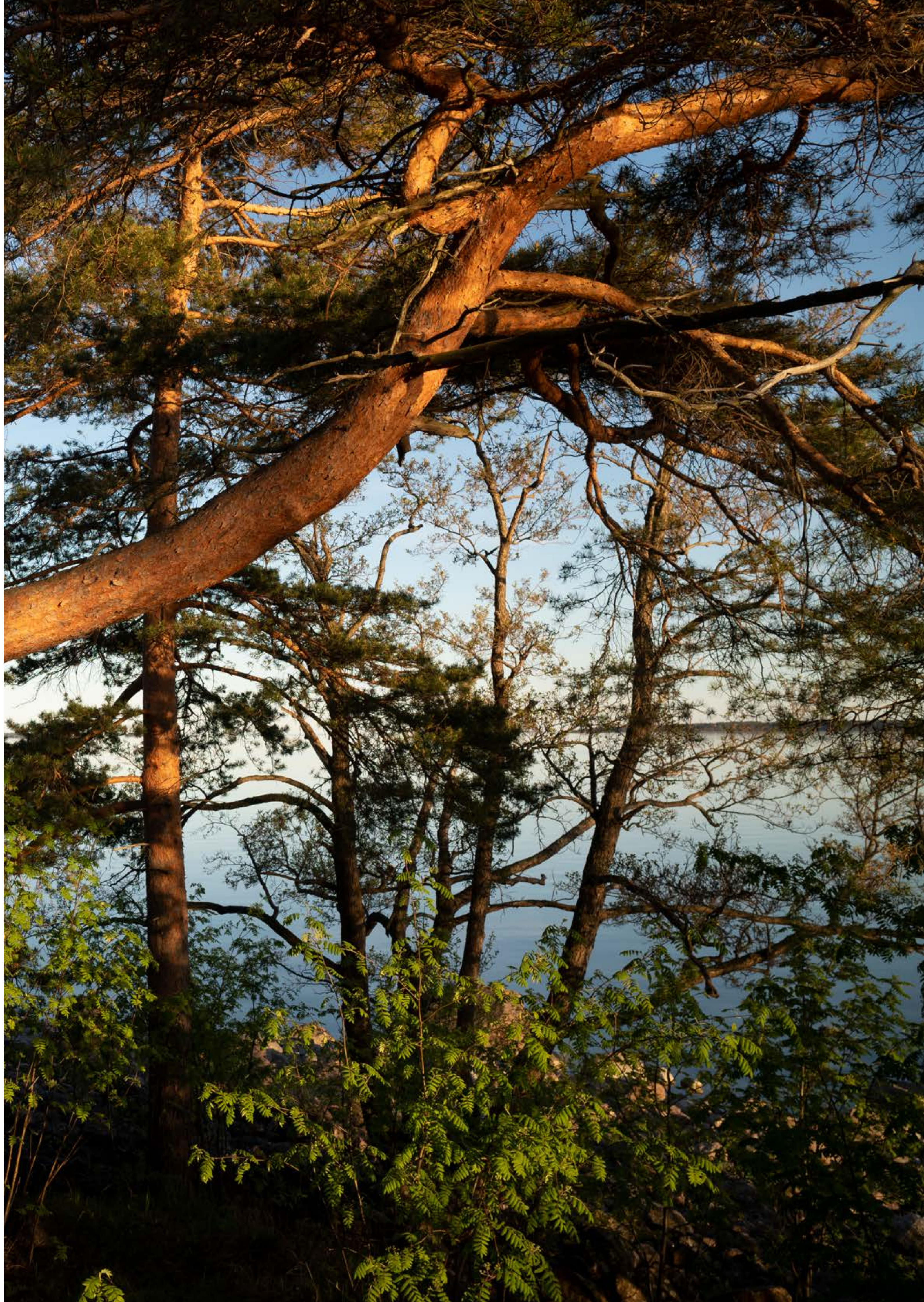
Table 4-15. Summary of the environmental aspects of extending the operation.

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

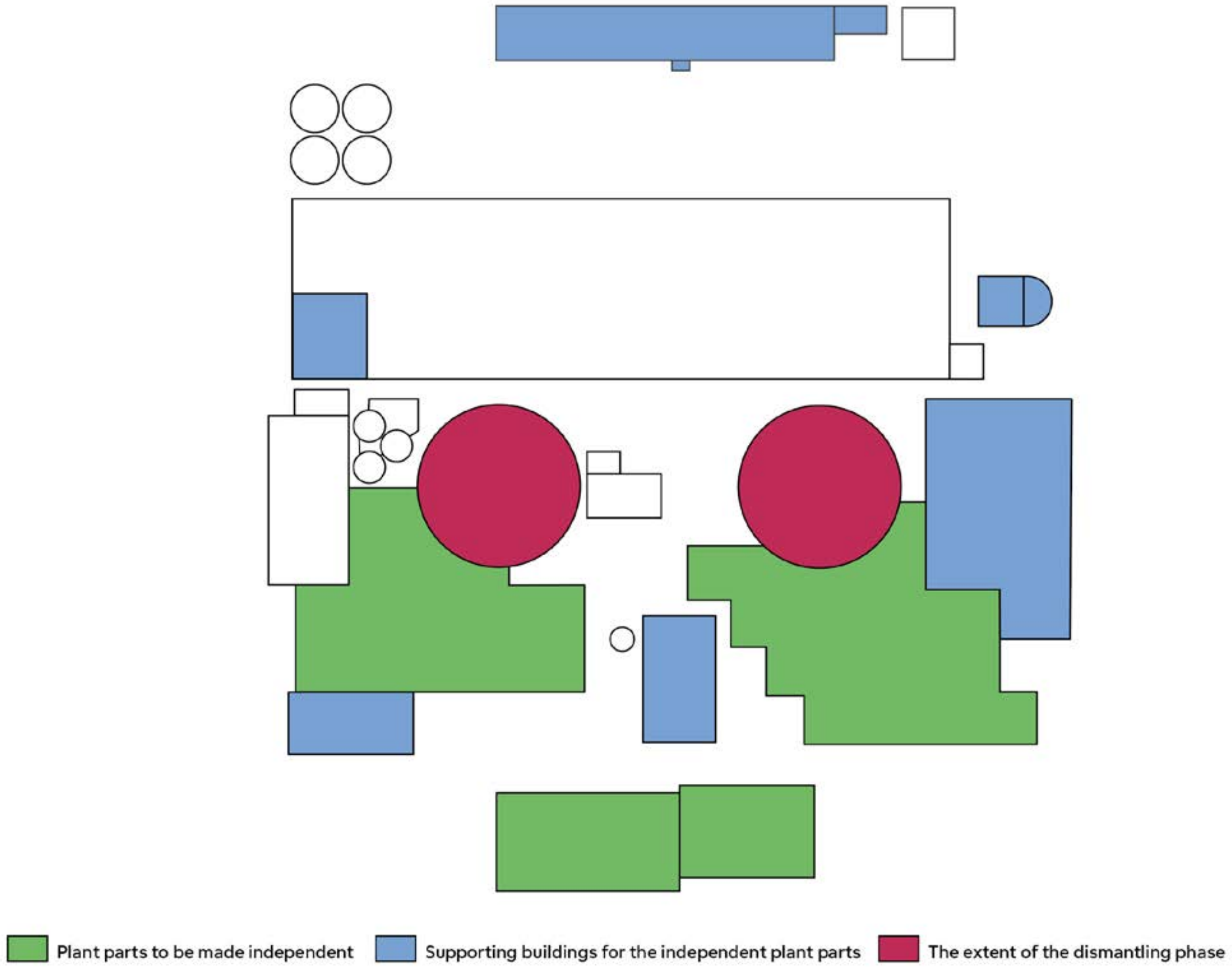


Figure 5-1. The activated and contaminated parts of the reactor buildings, marked in red, will be dismantled during dismantling phase 1, while the plant parts marked in green will be made independent. Their operation during independent operation will be supported by the buildings marked in blue.

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

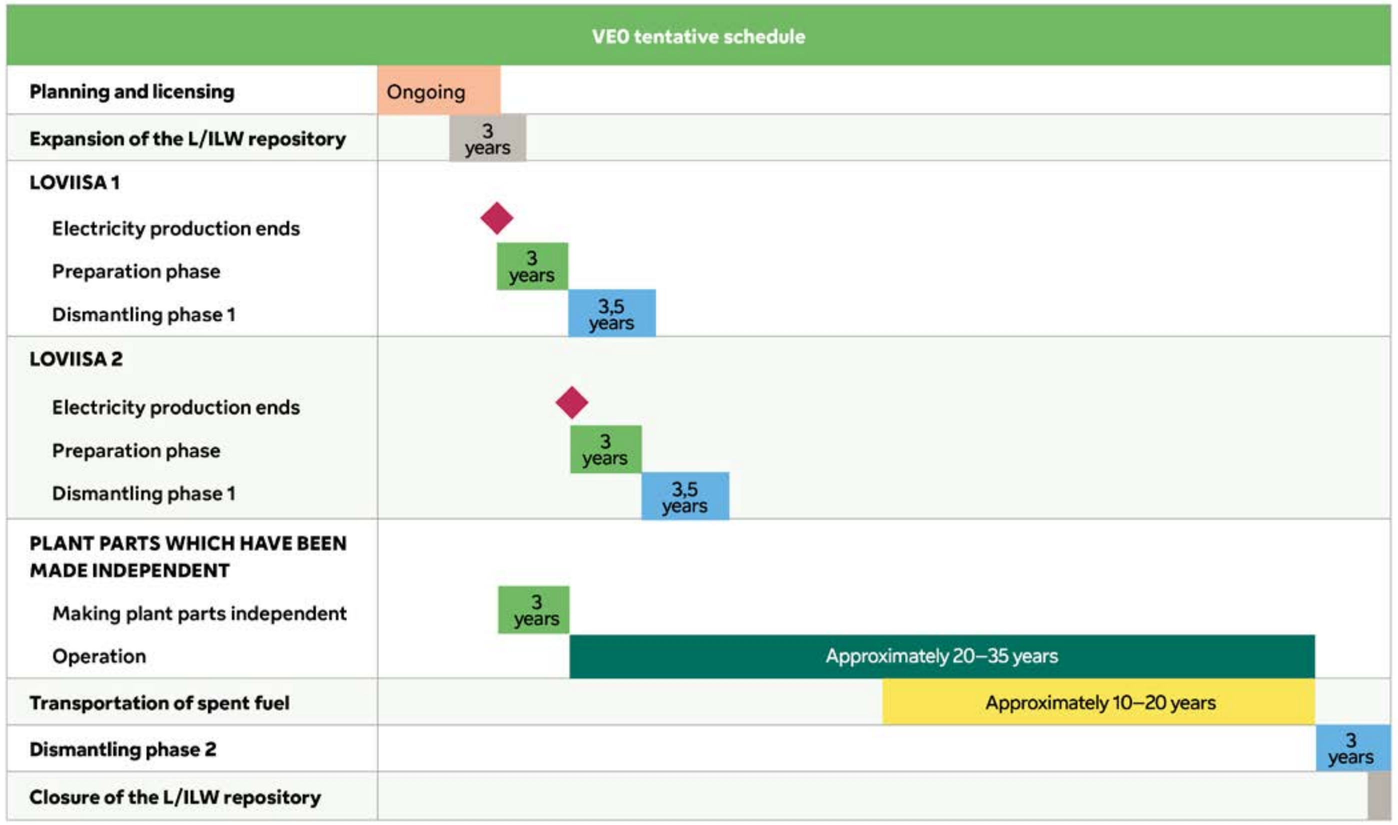


Figure 5-2. depicts a tentative schedule for the dismantling phases in accordance with VE0.

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

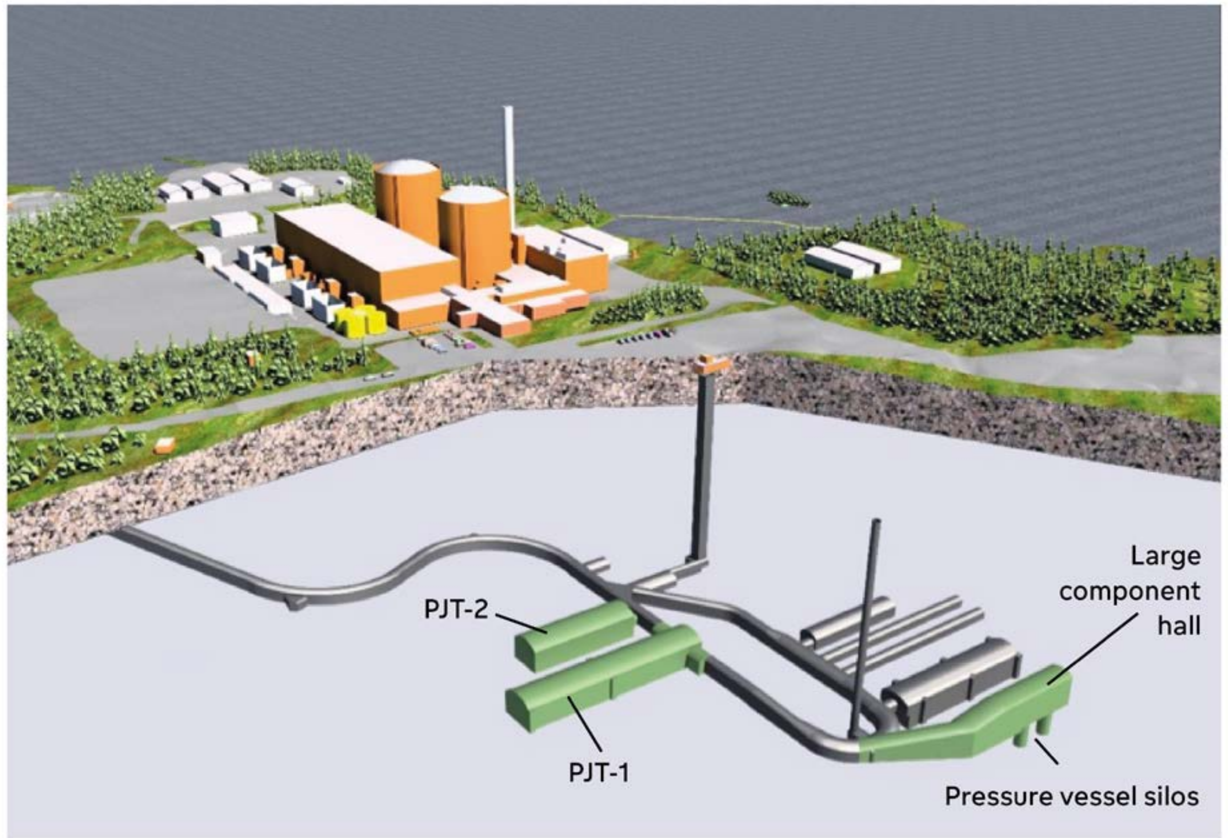


Figure 5-3. An illustration of the final disposal facility of Loviisa power plant for low and intermediate-level waste. In addition to the existing halls, the illustration shows the planned final disposal halls for decommissioning waste in green. In the illustration, PJT-1 and PJT-2 refer to halls 1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

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

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

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

5.2.2 Other construction work related to decommissioning

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

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

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

5.3 PREPARATION FOR DECOMMISSIONING AND DISMANTLING WORK

5.3.1 Preparation phase

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

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

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

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

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

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

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

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

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

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

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

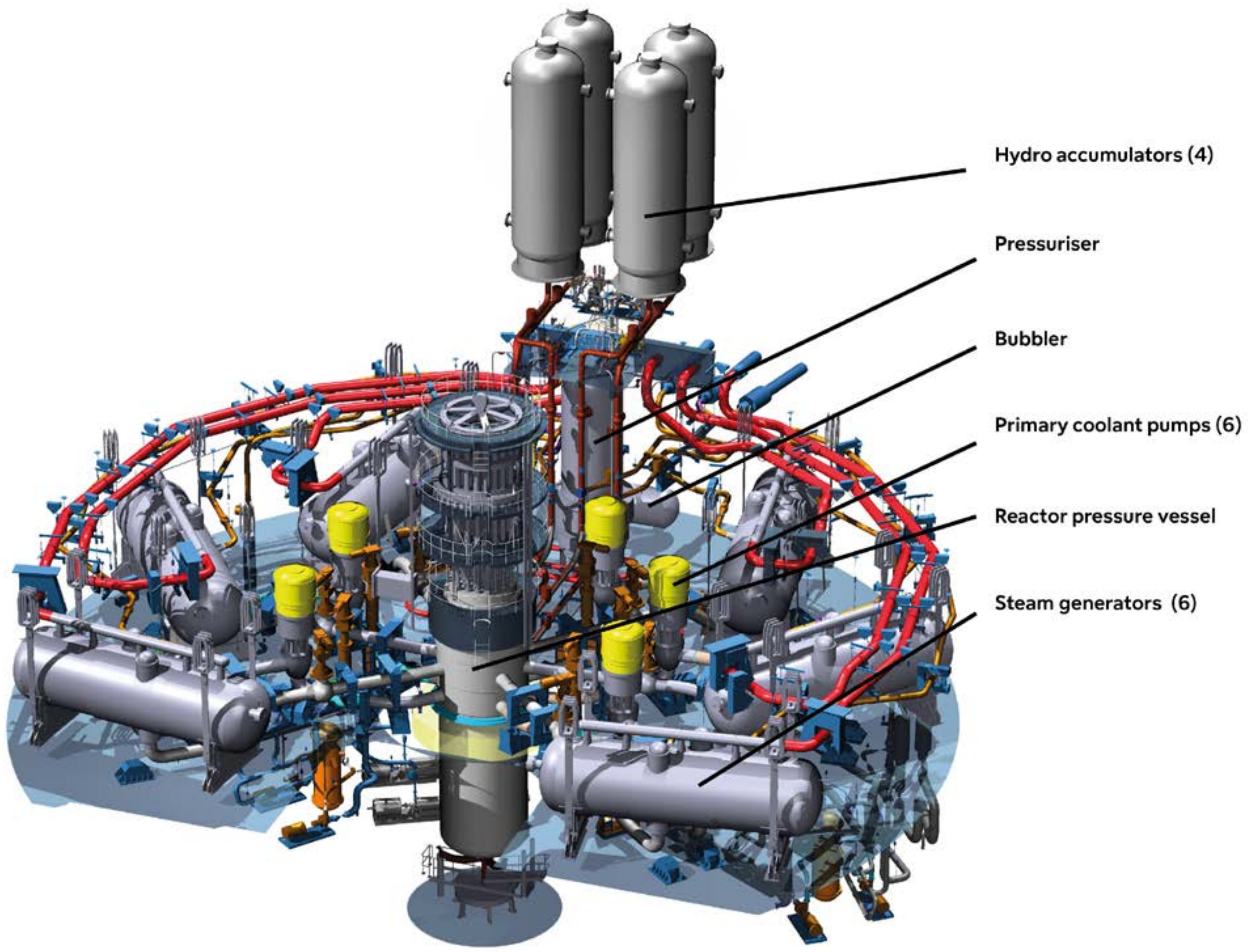


Figure 5-4. An illustration of the primary system of Loviisa power plant unit. The illustration indicates the large components which, according to current plans, are to be deposited for final disposal in one piece.

5.3.2 Dismantling of radioactive parts

5.3.2.1 Measures

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

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

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

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

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

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

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

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

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

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

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

5.3.2.2 Treatment and final disposal of radioactive waste

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.3.3 Conventional dismantling measures

5.3.3.1 Measures

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

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

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

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

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

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

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

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

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

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

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

5.3.3.2 Treatment and final disposal of conventional waste

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

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

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

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

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

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

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

5.4 PLANT PARTS TO BE MADE INDEPENDENT

5.4.1 Making plant parts independent, and their operation

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

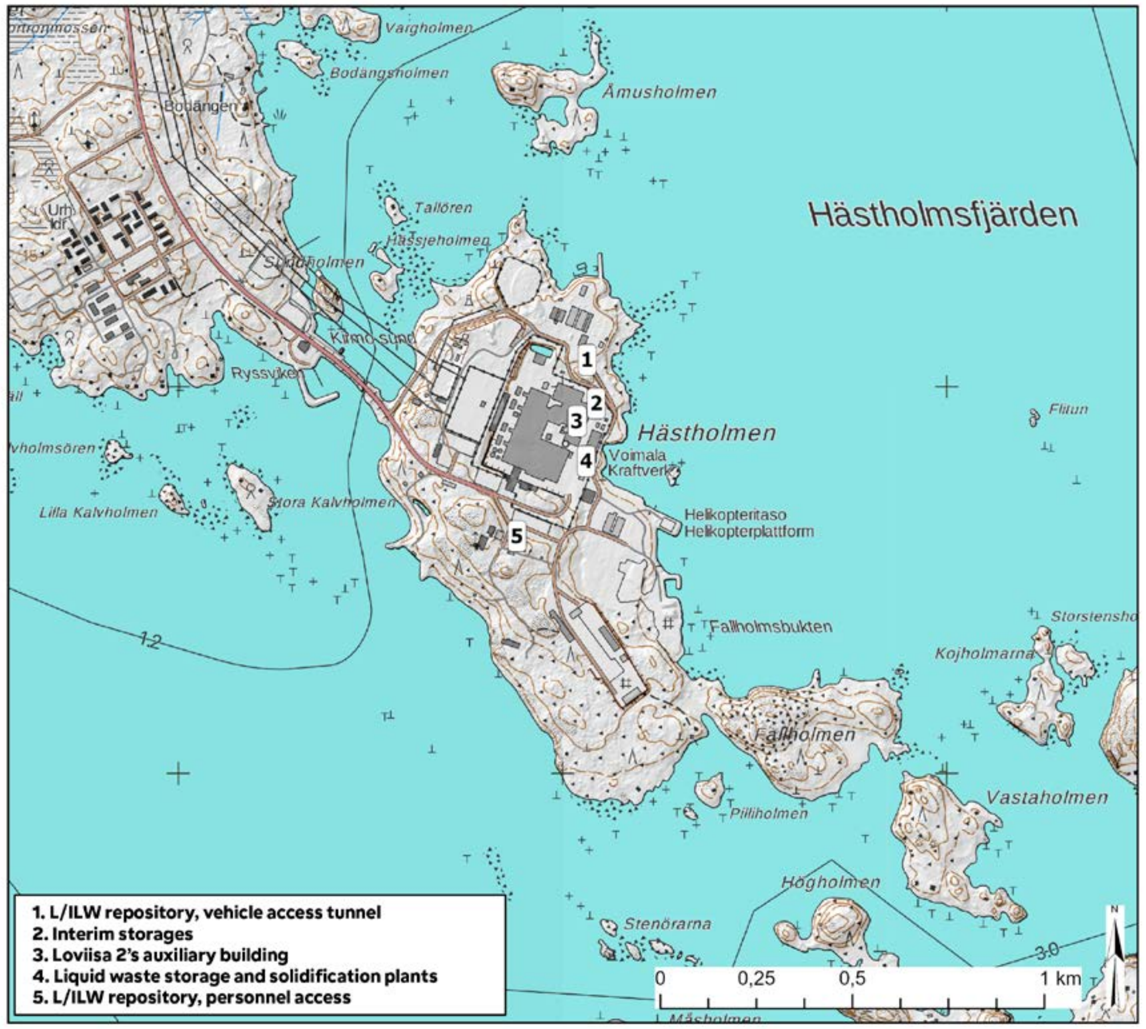


Figure 5-5. Plant parts to be made independent at Loviisa power plant.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.4.2 Dismantling of the plant parts to be made independent

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

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

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

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

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

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

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

5.6 FURTHER USE OF THE AREA

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

The area's further use as an industrial area

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

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

Restoring the area to a near natural state

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

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

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

5.7 SPENT NUCLEAR FUEL

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

5.7.1 Packing and handling of fuel

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

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

5.7.2 Transport

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

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

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

5.7.3 Encapsulation and final disposal

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

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

5.8 ENVIRONMENTAL ASPECTS OF DECOMMISSIONING

5.8.1 Cooling water

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

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

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

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

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

5.8.2 Service water

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

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

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

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

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

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

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

5.8.3 Wastewater

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

Sanitary wastewaters

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

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

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

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

L/ILW repository's construction wastewater and seepage water

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

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

Process wastewater

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

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

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

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

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

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

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

5.8.4 Spent nuclear fuel

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

5.8.5 Decommissioning waste and operational waste

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

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

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

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

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

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

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

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

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

5.8.6 Reusable material and conventional waste

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

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

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

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

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

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

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

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

5.8.7 Chemicals

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

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

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Chemicals	Explosives will be used in the quarrying of the L/ILW repository. At this point, the power plant will produce electricity normally. Chemicals will be used as during the current operation.	Chemicals will be used in decontamination work, the solidification of liquid waste, the neutralisation of waste solutions and in pH control, among other processes. Used in the decontamination of the primary system: Oxalic acid (11 tonnes) Permanganic acid (40 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.

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 m³, while the amount of oxalic acid ($C_2H_2O_4$) used was 5,300 kg. Hydrogen peroxide (H_2O_2) use amounted to 1,000 kg. The decontamination to be carried out during decommissioning will not require as much hydrogen peroxide as the decontamination carried out during operation, because during operation, it is used, in addition to UV degradation, to form a protective layer in the piping to prevent recontamination. The protective layer will not be necessary during the decommissioning, given that the risk of contamination is no longer relevant. The aforementioned figures concern a single power plant unit, meaning that the figures will be doubled for the decommissioning. The decommissioning's other decontamination work will rely on the same chemicals as during the power plant's operation. The chemicals to be used are oxalic acid ($(COOH)_2$), sodium hydroxide ($NaOH$) and potassium permanganate ($KMnO_4$). The dismantling work to be carried out in the power plant units and the decontaminations of small individual pieces to be carried out in the site will rely on various solvents and oils, for example.

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

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

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

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

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

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

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

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

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

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

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

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

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

5.8.9 Emissions of radioactive substances and their limitation

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

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

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

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

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

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

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

5.8.9.1 *Discharges into water systems*

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

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

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

5.8.9.2 *Emissions into air*

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

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

5.8.10 Summary of the environmental aspects of decommissioning

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

5.9 DIFFERENCES IN DECOMMISSIONING IN THE DIFFERENT OPTIONS

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

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

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

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

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Cooling water	The expansion of the L/ILW repository does not require cooling water. (At this point, the power plant produces electricity as usual; the need for and use of cooling water as during current operation: an average of 1,300 million m^3/year and 57,000 TJ/year).	The need for cooling water (roughly 1.6 million m^3/year) and the thermal discharge (at maximum 46.5 TJ a year) will be a fraction of what they are during the power plant's current operation.	
Service water requirement and supply	The quarrying work will require approximately 15,000–150,000 m^3 of water a year. (At this point, the power plant will continue to produce electricity; the need for service water is equal to current operation: Process water 100,000–200,000 m^3/year Domestic water 25,000–75,000 m^3/year	Domestic water 13,000–57,000 m^3/year Process water varyingly, but less than during operation, on average.	Domestic water less than during decommissioning. Process water markedly less than during operation.
Sanitary wastewaters	The impact of contractors' personnel will be minor.	The volume will be the same as or less than during operation.	The volume will be smaller than during the power plant's operation.
Construction and process wastewaters	Construction wastewater varyingly: 15,000–150,000 m^3/year for a period of three years; estimated total emissions: oils and greases < 2,000 kg phosphorus < 35 kg nitrogen < 2,600 kg solids < 63 t The volume of the L/ILW repository's seepage water will increase temporarily.	The average volume of conventional process wastewater is lower than during operation. Any unnecessary chemicals remaining in the tanks will be processed as harmful substances. Wastewater from the decontamination of individual pieces that falls below emission limits. Emptying of process systems: less than 12,000 m^3 of water that falls below emission limits.	The volume of conventional process wastewater will be markedly lower than during the power plant's operation. Emptying of process systems: less than 3,000 m^3 of water that falls below emission limits.
Spent nuclear fuel	At this point, the power plant still produces electricity, stored as during current use in the interim storages for spent fuel.	Stored in the interim storages for spent fuel which have been made independent of the power plant.	The use of the interim storages for spent fuel will end once the spent nuclear fuel has been transported for final disposal. The estimated number of road transports for final disposal is 6–8 per year; alternatively, approximately 2 maritime transports per year.
Operational waste	At this point, the power plant will continue to produce electricity; operational waste will be generated in the same manner as in current operation. The expansion of the L/ILW repository will not generate radioactive waste.	Operational waste will not be generated.	• Solidified liquid waste: 260 m^3 • Maintenance waste: 20 m^3.
Decommissioning waste		• Activated waste: 3,300 m^3 • Contaminated waste: 19,000 m^3 • Maintenance waste: 700 m^3 • Solidified liquid waste: 2,260 m^3 • Concrete with a very low level of activity: less than 50,000 m^3.	
Reusable material	The volume of rapakivi granite to be quarried is 71,000 m^3 which equates to 100,000 m^3 of quarry material. The L/ILW repository's expanded total volume will be around 188,000 m^3.	Recyclable metal (steel, stainless steel and copper) 21,000–37,000 t. Concrete resulting from the dismantling of buildings 178,000–320,000 t.	Recyclable metal (steel, stainless steel and copper) 4,000–21,000 t. Concrete resulting from the dismantling of buildings 36,000–178,000 t.
Maintenance waste cleared from regulatory control	At this point, the power plant will continue to produce electricity; conventional waste will be generated in the same manner as in the current operation. The expansion of the L/ILW repository will not generate maintenance waste, and the volume of conventional waste will be very low.	2 400 m^3	The amount of waste generated in the operation of the plant parts to be made independent which will be cleared from regulatory control will be specified later.
Hazardous waste generated during decommissioning		11,000–40,000 t	2,000–22,000 t
Other conventional waste		Approximately 100–200 t/year	The amount of conventional waste will be very low.
Chemicals	Explosives will be used in the quarrying of the L/ILW repository. At this point, the power plant will produce electricity normally. Chemicals will be used as during the current operation.	Chemicals will be used in decontamination work, the solidification of liquid waste, the neutralisation of waste solutions and in pH control, among other processes. Used in the decontamination of the primary system: Oxalic acid (11 tonnes) Permanganic acid (40 m^3) Hydrogen peroxide (2 tonnes) The chemicals will be treated appropriately.	At the liquid waste storage, chemicals will be used for solidification and the control of pH values, maintaining the boron content of the water in the interim storages for spent fuel and in the water demineralising plant/treatment of radioactive gaseous waste. The chemicals will be treated appropriately.
Noise	At this point, the power plant will continue to produce electricity; noise will be generated in the same manner as in current operation. The L/ILW repository's underground blasting work, ventilation system, transports of quarry material, the stacking of quarry material and the possible crushing of the quarry material will generate temporary noise.	The dismantling work and the crushing of concrete will cause occasional noise.	Some equipment generating noise will be in use; compared to the noise during the power plant's operation, this noise will be negligible.
Vibration	Vibrations will be generated by underground blasting work, heavy-duty transports and the stacking of quarry material.	Occasional vibrations will be generated during heavy-duty transports and dismantling work of a larger scale.	Not much vibration.
Traffic	At this point, the power plant will continue to produce electricity; traffic will be at the same level as during current operation (total volume of traffic 500 vehicles/day, of which heavy-duty traffic 40 vehicles/day). A small increase to the personnel traffic during operation. Transport of quarry material: approximately 5,000–11,000 trucks. Individual transports by special vehicles.	Maximum passenger traffic 800 cars/day. Maximum heavy-duty traffic 100 vehicles/day. Waste transports to the L/ILW repository: roughly 4,000 truckloads and less than 80 heavy and oversized transports.	The maximum volume of passenger traffic during independent operation will be 250 vehicles/day. Heavy-duty traffic less than 40 vehicles/day. The maximum volume of passenger traffic during the second dismantling phase will be 800 vehicles/day. The maximum volume of heavy-duty traffic will be fewer than 100 vehicles/day. Transports of filling material for repository's closure: roughly 5,000–11,000 truckloads.

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

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

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

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

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

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

6.1 GENERAL DESCRIPTION OF ACTIVITIES

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

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

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

6.2 ORIGIN AND AMOUNT OF WASTE

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

6.2.1 Decommissioning waste of the FiR 1 research reactor

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

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

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

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

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

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

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

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

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

6.2.2 Decommissioning waste of the Otakaari 3 research laboratory

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

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

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

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

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

6.2.3 Other waste

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

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

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

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

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

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

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

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

6.3 WASTE PROCESSING AT LOVIISA POWER PLANT

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

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

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

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

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

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

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

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

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

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

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

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

6.4 ENVIRONMENTAL ASPECTS

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

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

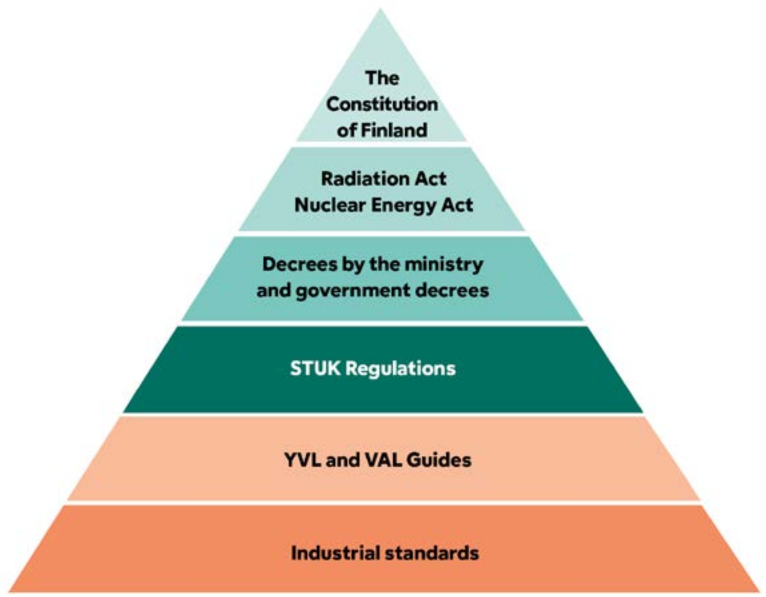


Figure 7-1. Hierarchy of requirements pertaining to nuclear facilities.

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 mansievert (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

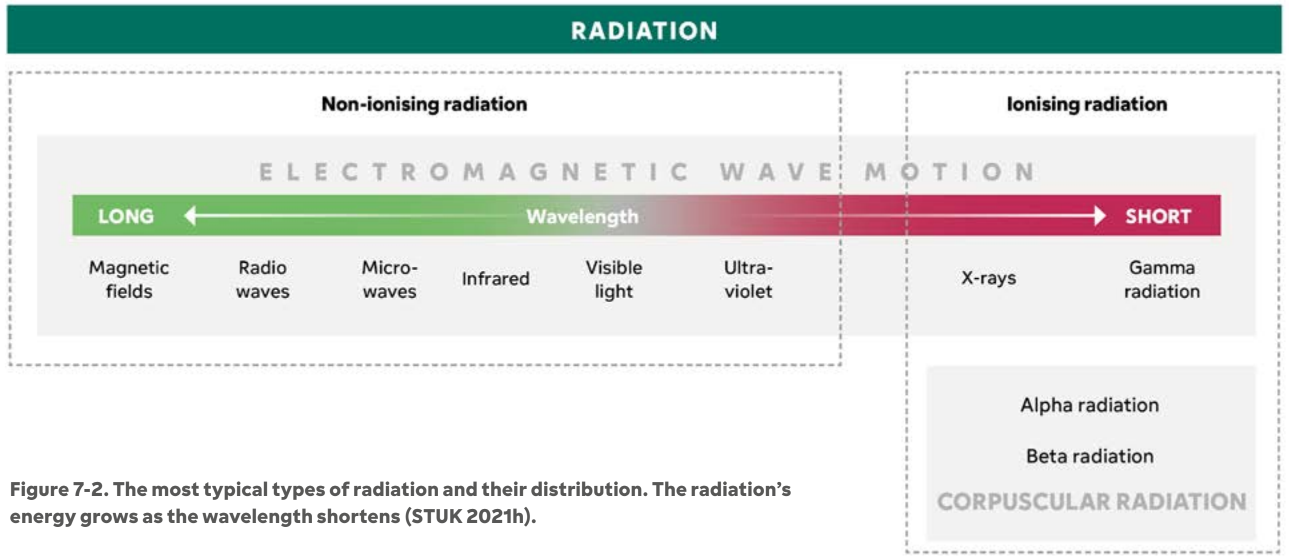


Figure 7-2. The most typical types of radiation and their distribution. The radiation's energy grows as the wavelength shortens (STUK 2021h).

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.

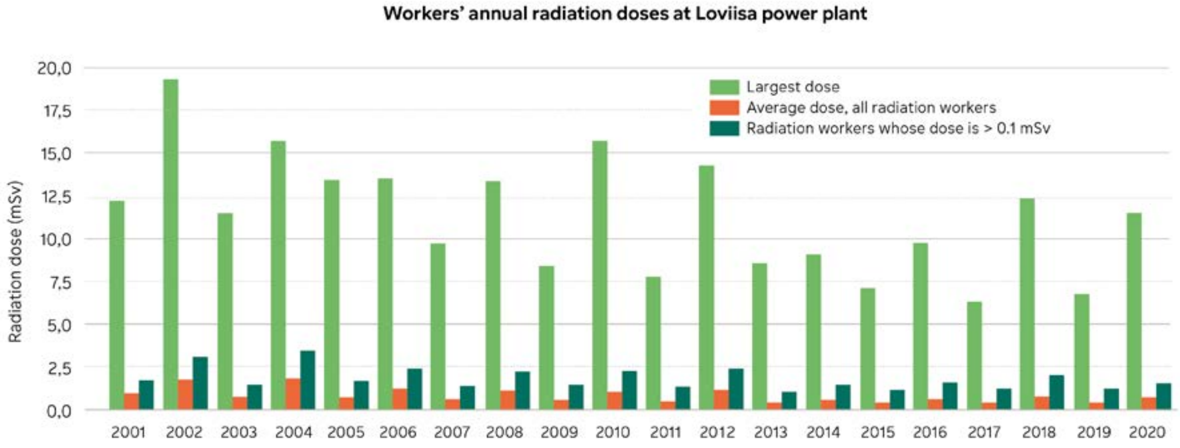


Figure 7-3. The annual radiation doses of Loviisa power plant's workers in 2001–2020.

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.

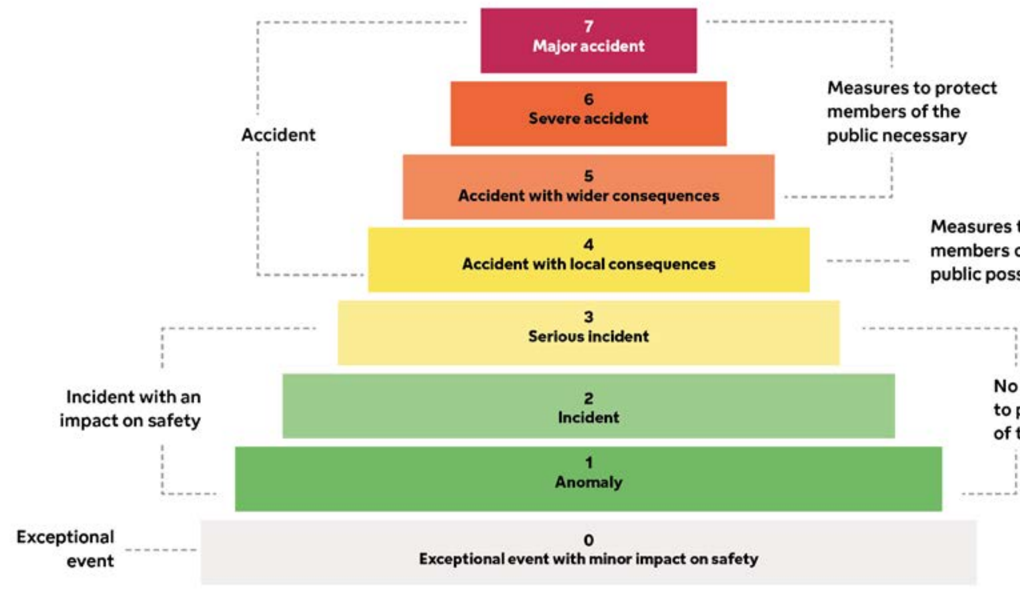


Figure 7-4. The International Nuclear and Radiological Event Scale (INES) and the rating of events.

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

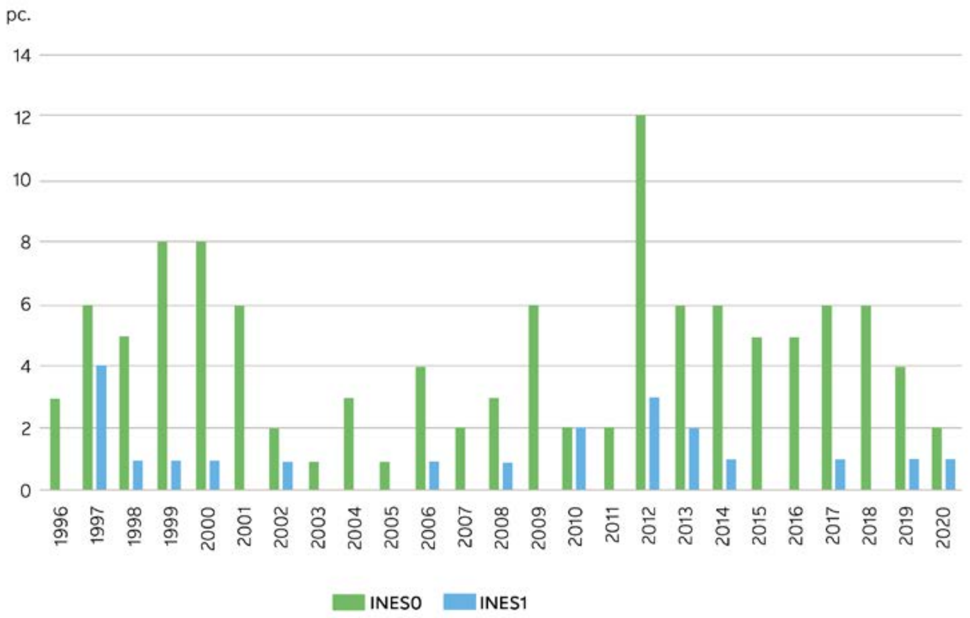


Figure 7-5. The number of INES events falling under INES levels 0 and 1 at Loviisa power plant in 1996–2020.

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

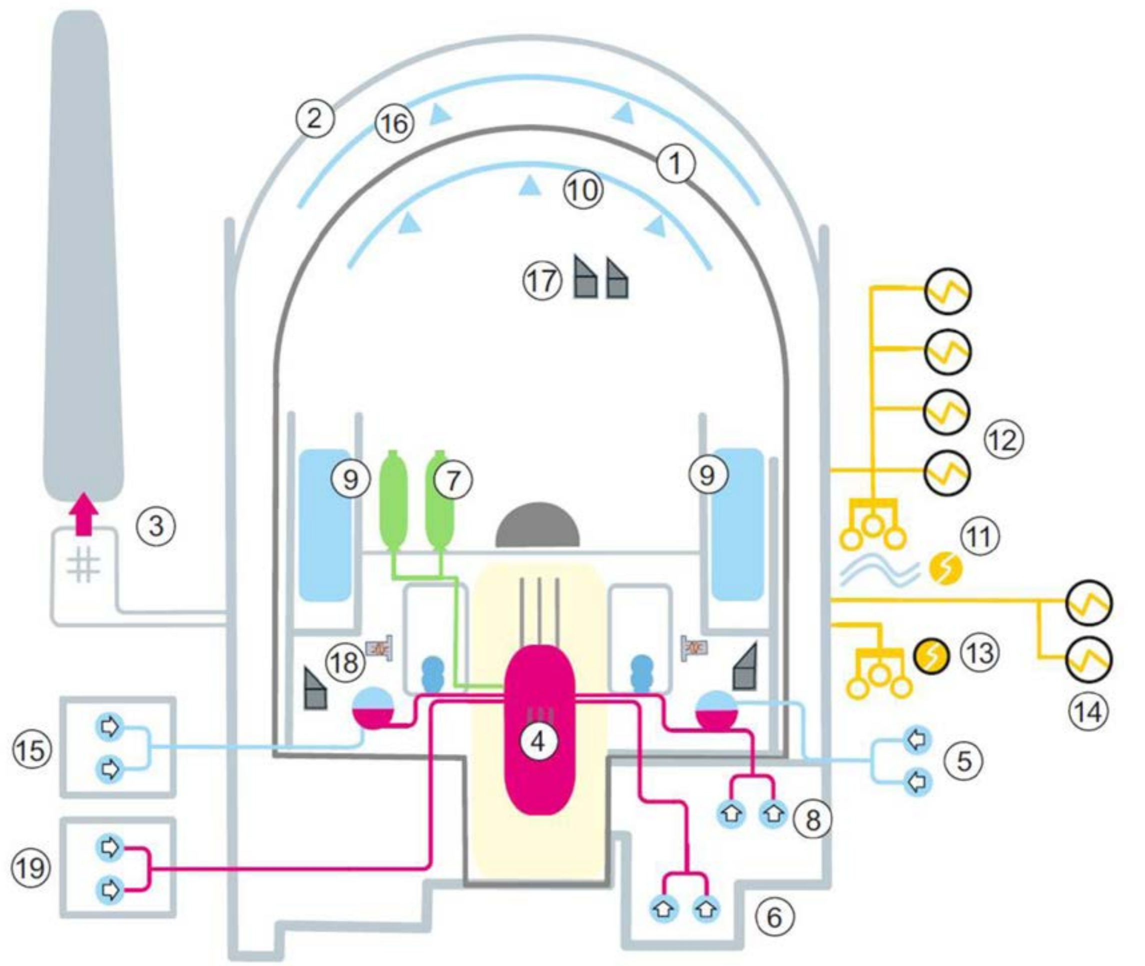


Figure 7-6. The most relevant systems related to the execution of safety functions at Loviisa power plant's power plant units.

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.

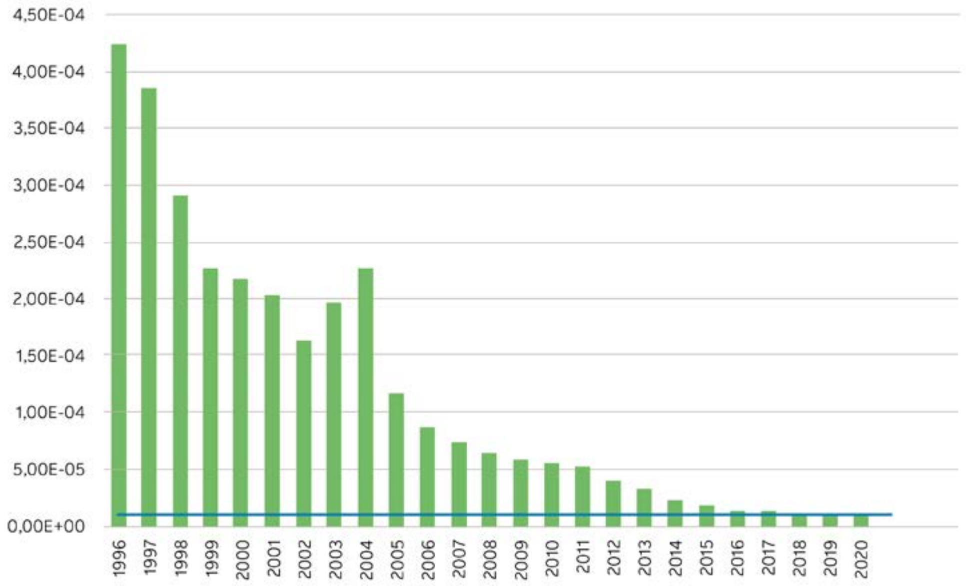


Figure 7-7. The frequency of considerable reactor core damage and nuclear fuel damage of spent fuel in the fuel pools in Loviisa power plant unit 1, assessed by means of PRA. The blue line indicates the requirement level (10–5/year) for new nuclear power plants presented in STUK's YVL Guide A.7.

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

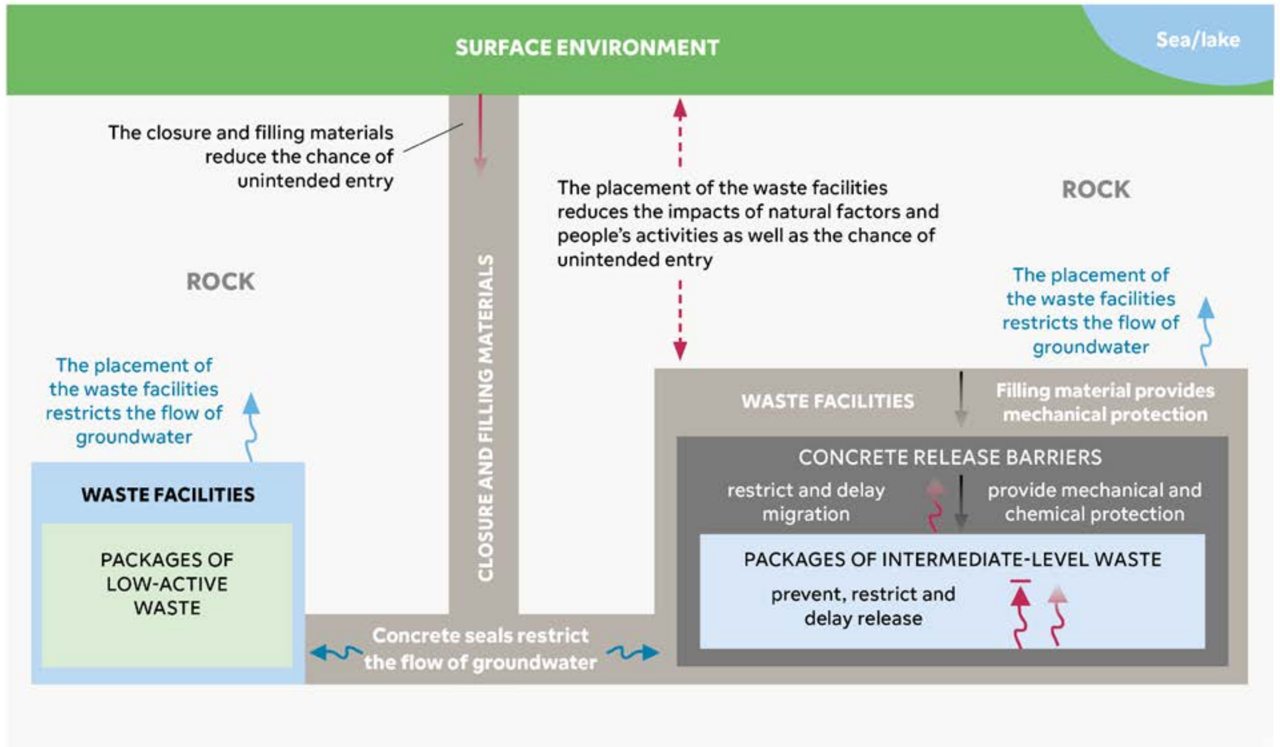


Figure 7-8. Diagram of the safety functions of long-term safety determined for the different components of Loviisa's final disposal (Nummi 2019, edited).

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.

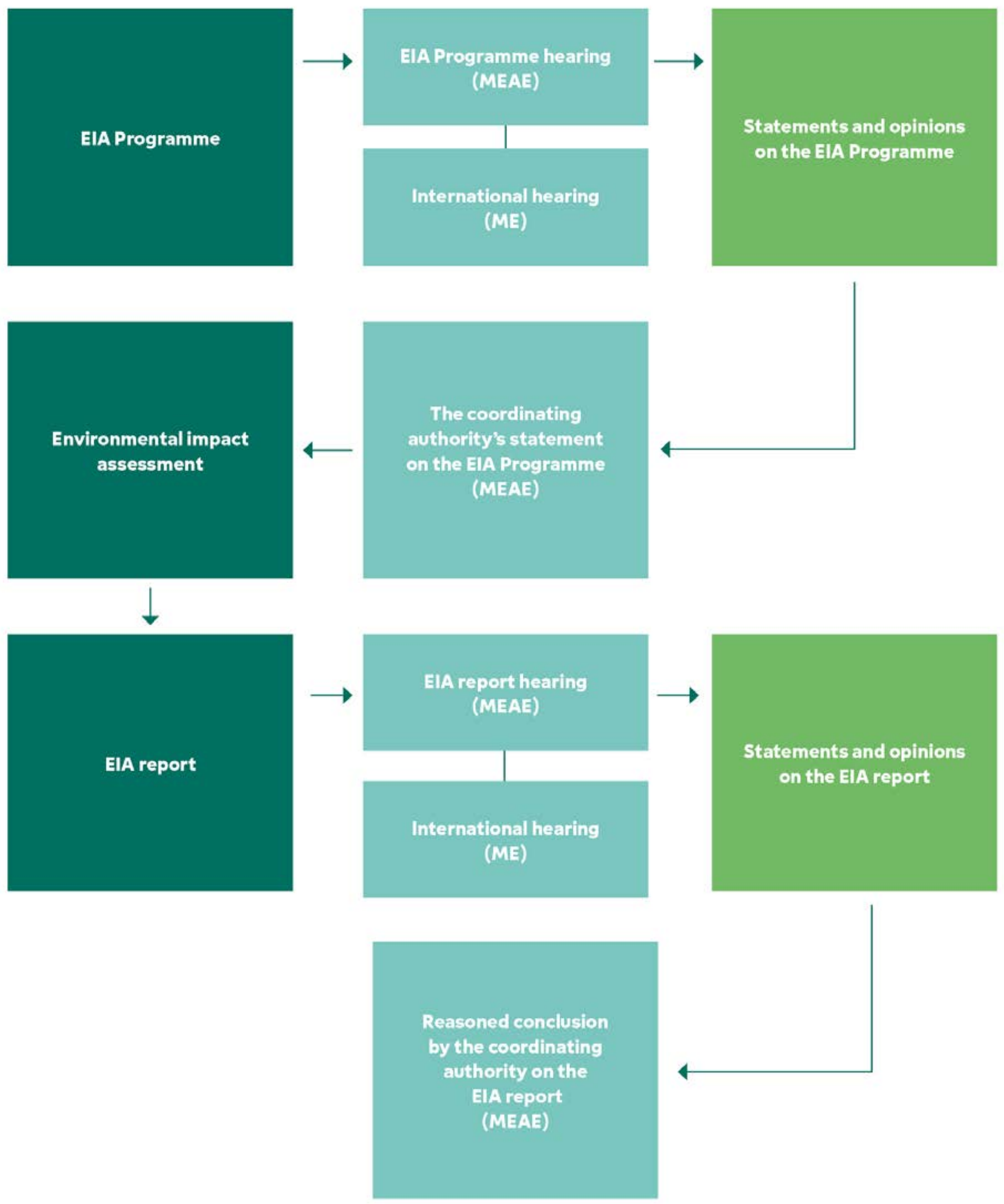


Figure 8-1. The stages of the EIA procedure. MEAE = Ministry of Economic Affairs and Employment, ME = Ministry of the Environment.

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.

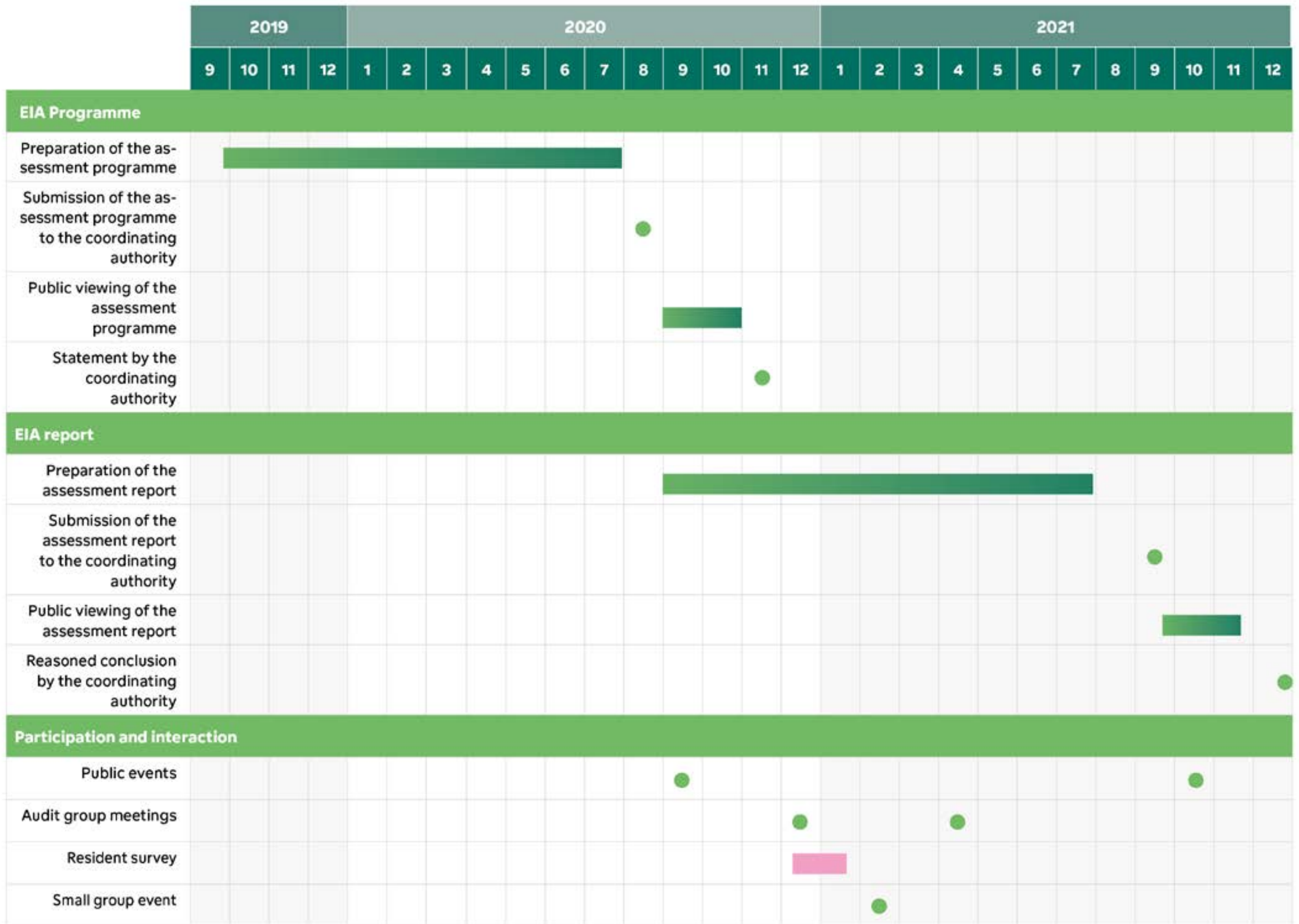


Figure 8-2. Indicative schedule of the EIA procedure.

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.

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.

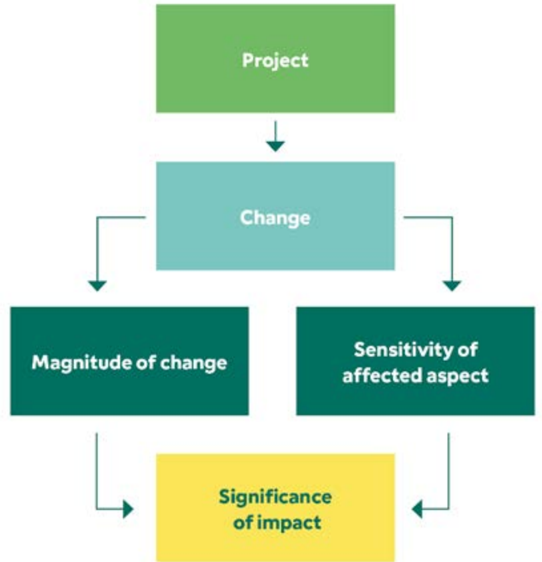


Figure 9-1. Factors affecting the significance of the impact.

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.

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

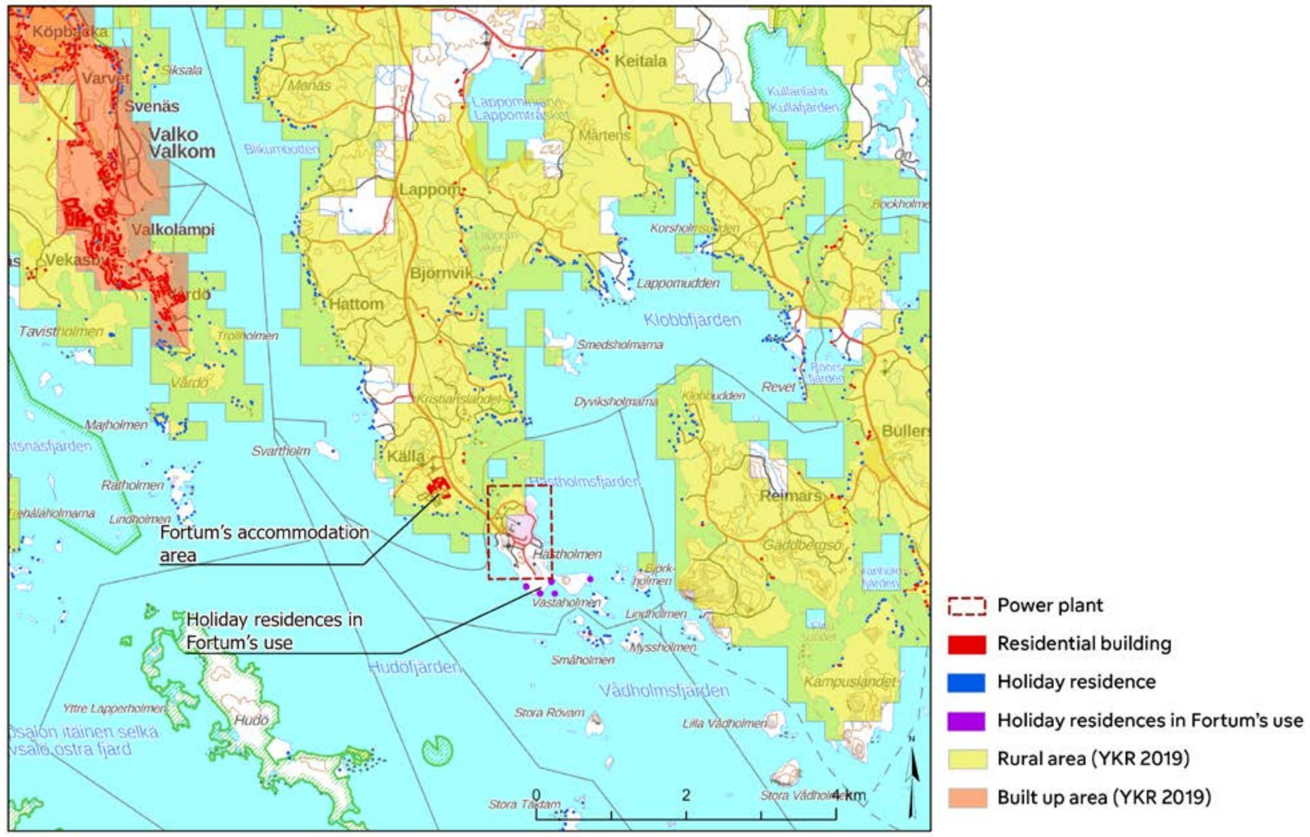


Figure 9-3. The community structure in accordance with the community structure monitoring data (YKR data, SYKE 2021) in 2019, as well as the residential and holiday buildings.

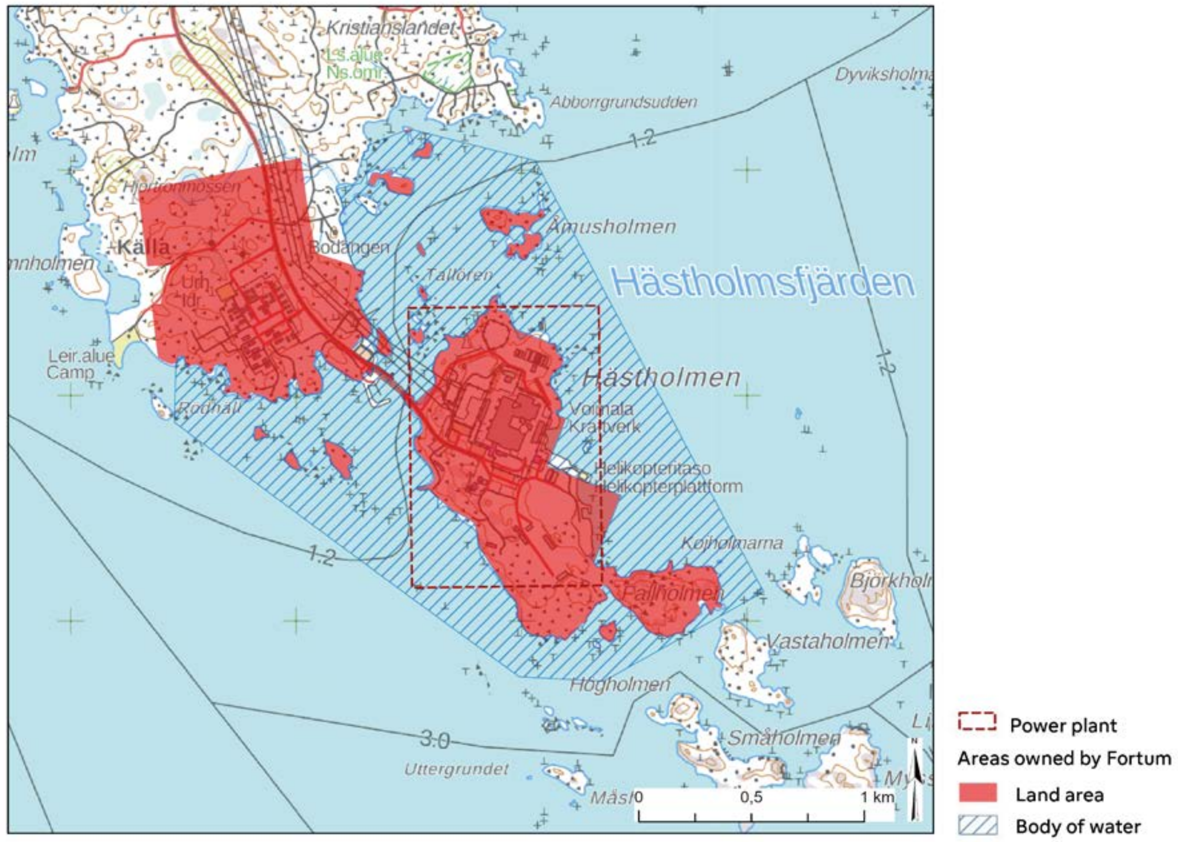


Figure 9-4. Land and water areas owned by Fortum Power and Heat Oy (National Land Survey of Finland 2021 and Fortum 2021).

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

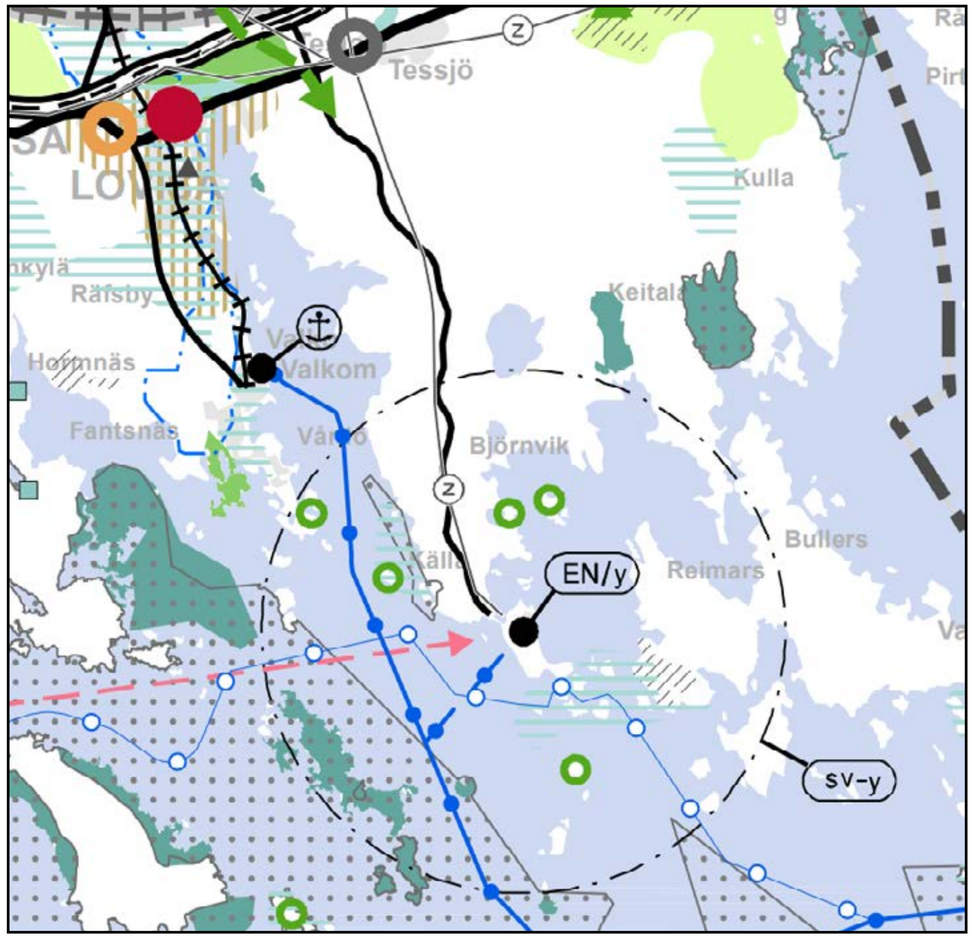


Figure 9-5. An extract of the land use plan map of the Helsinki-Uusimaa Land Use Plan 2050.

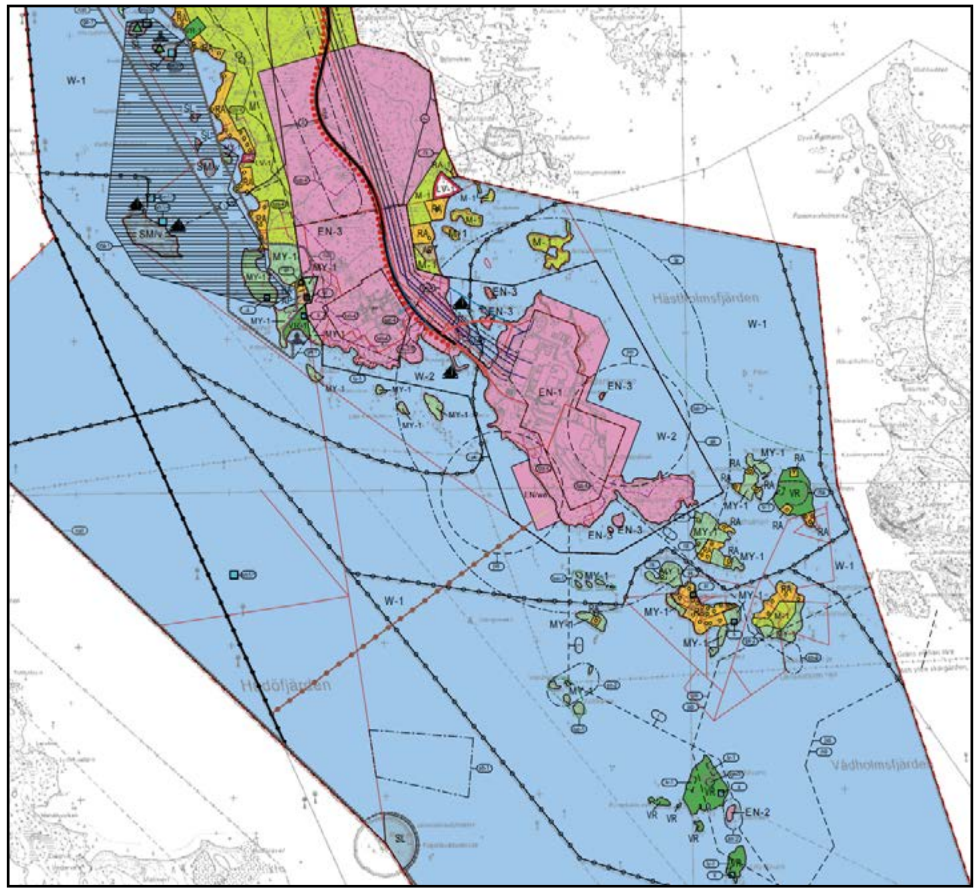


Figure 9-6. An extract of Loviisa's component master plan for shores.

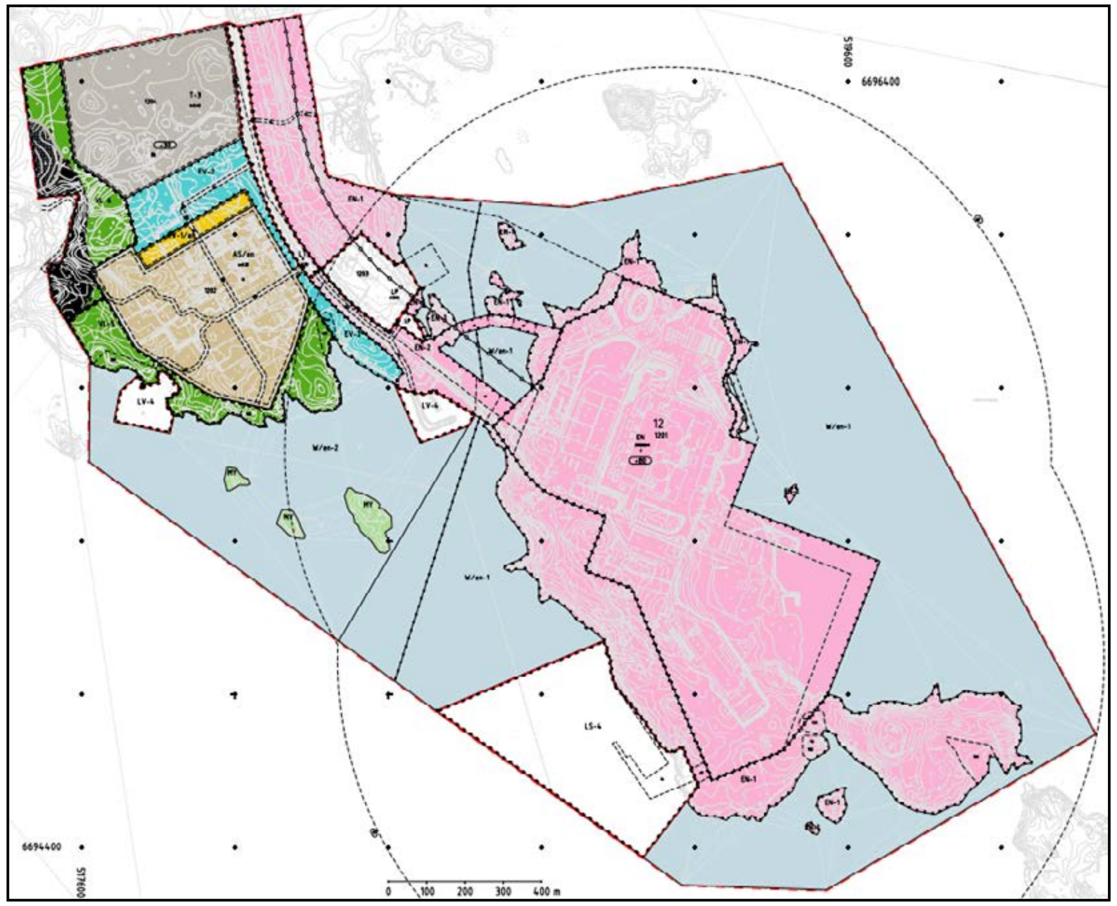


Figure 9-7. An extract of the revision and expansion of the local detailed plan of the Hästholmen nuclear power plant area.

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).

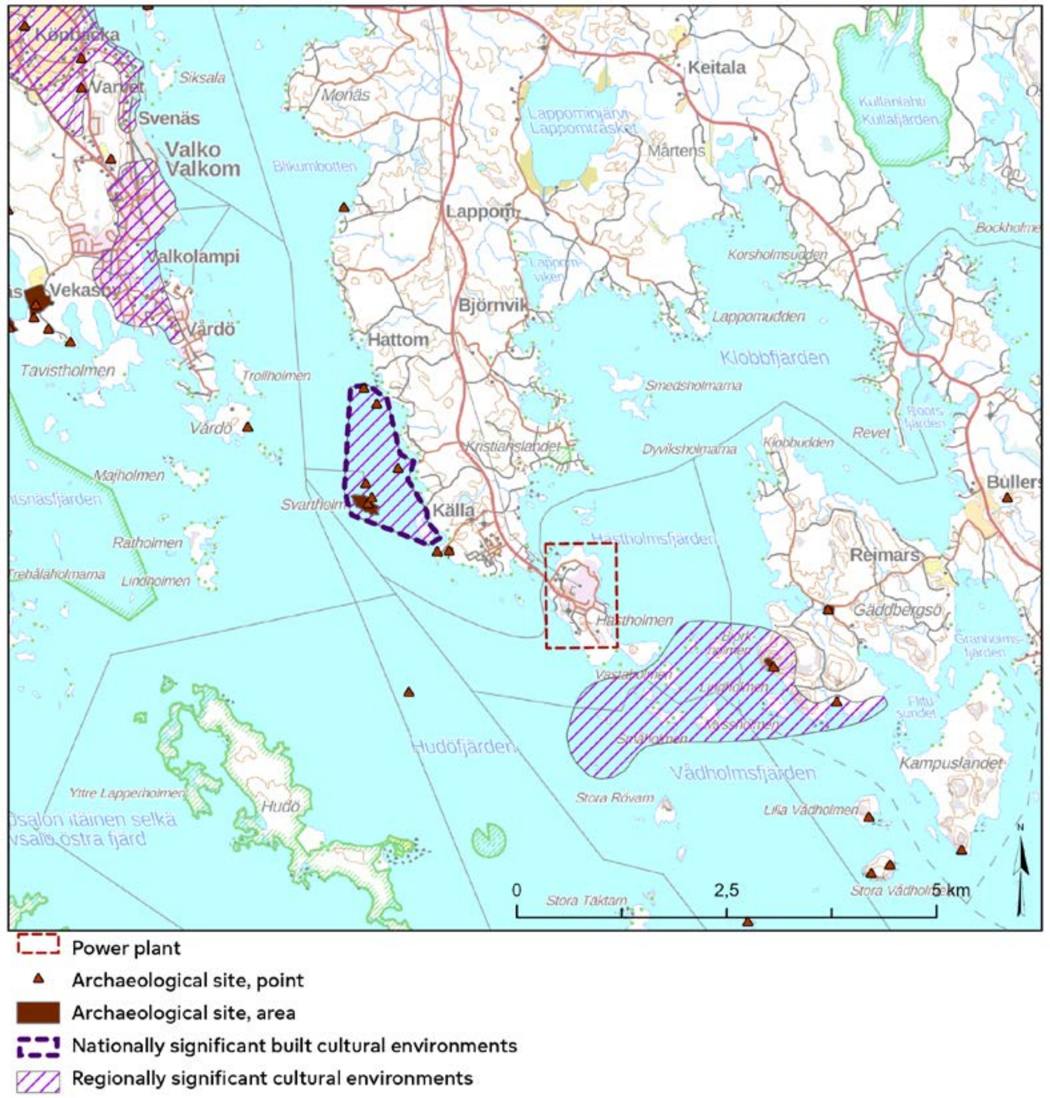


Figure 9-12. Landscape areas and cultural environments as well as fixed archaeological sites located in the surroundings of the power plant. (Source: Finnish Heritage Agency, 2021; Helsinki-Uusimaa Regional Council, 2019)

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

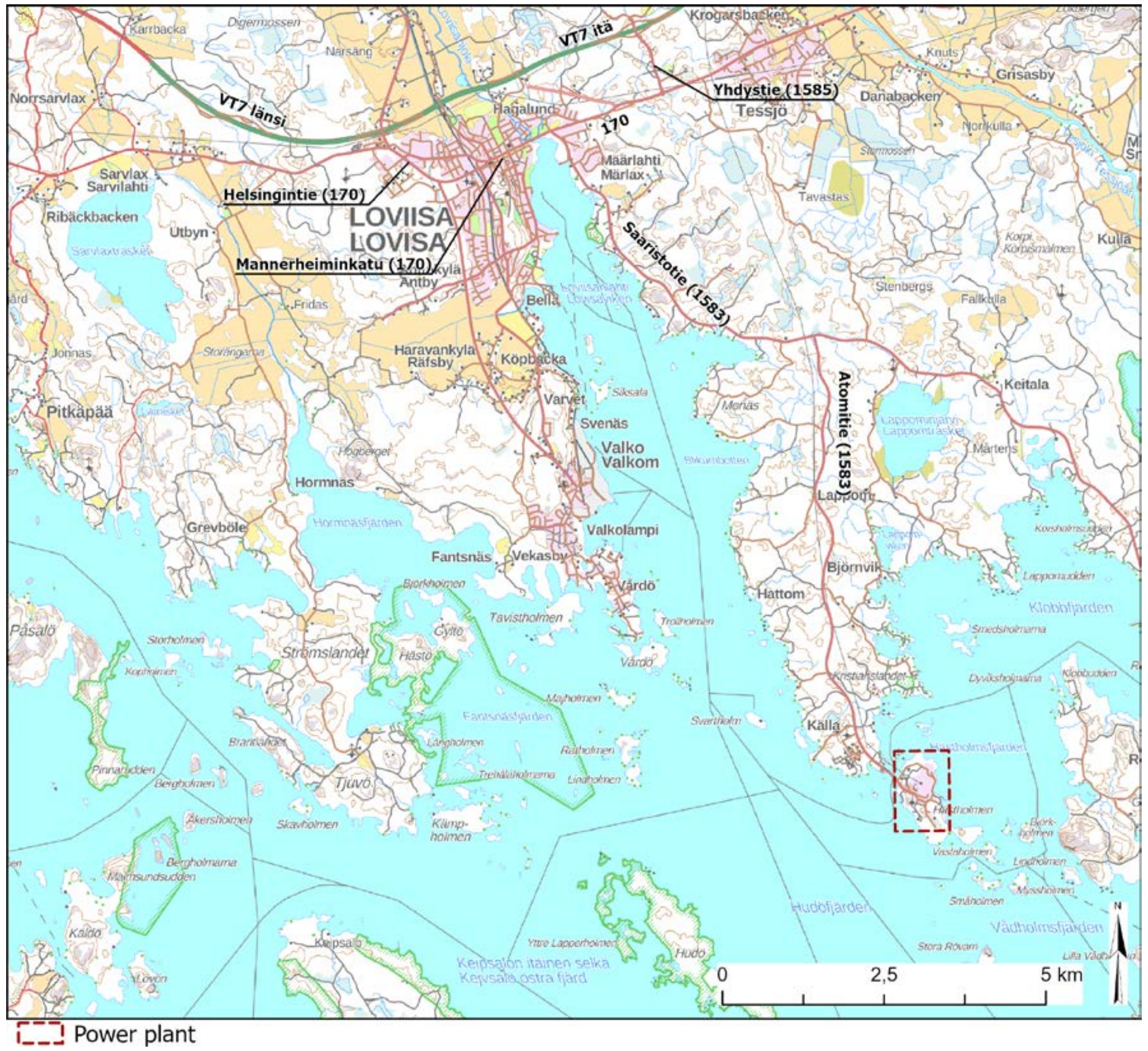


Figure 9-13. The roads, including their road numbers, leading from Highway 7 to Loviisa power plant (Source: National Land Survey of Finland 2021).

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.

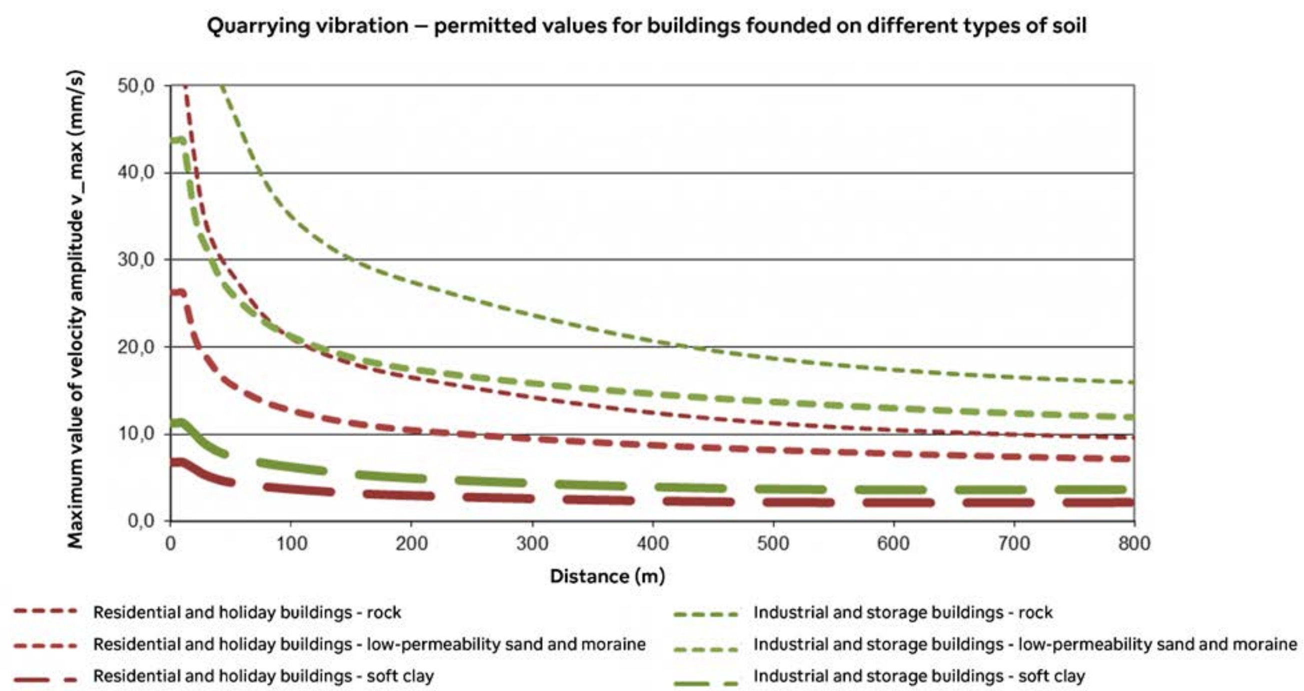


Figure 9-14. Velocity amplitudes values attributable to blasting and permitted for residential and holiday buildings as well as industrial and storage buildings on soft clay/sand or moraine with low permeability/ buildings with foundations on rock (RIL 2010).

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.

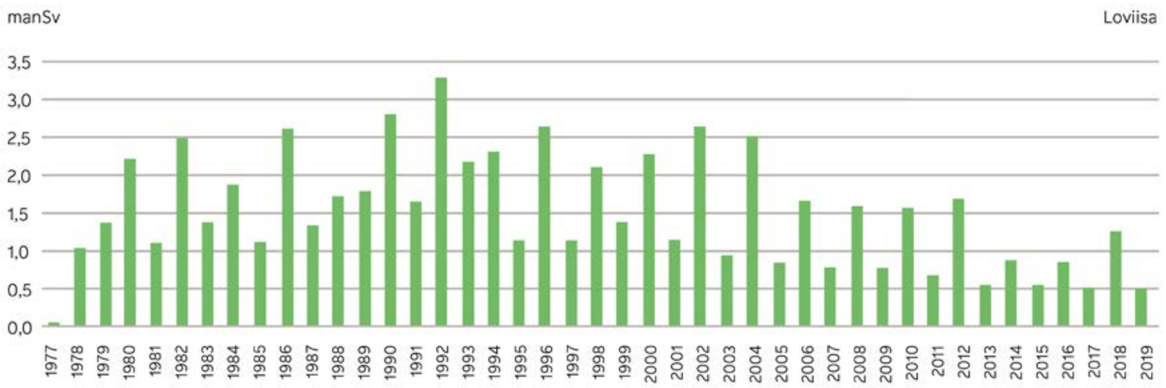


Figure 9-15. The collective (aggregate) radiation doses of Loviisa nuclear power plant's workers in 1977–2019. (STUK Guide 2021b)

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.

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

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 9-21. 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).

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. .

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 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

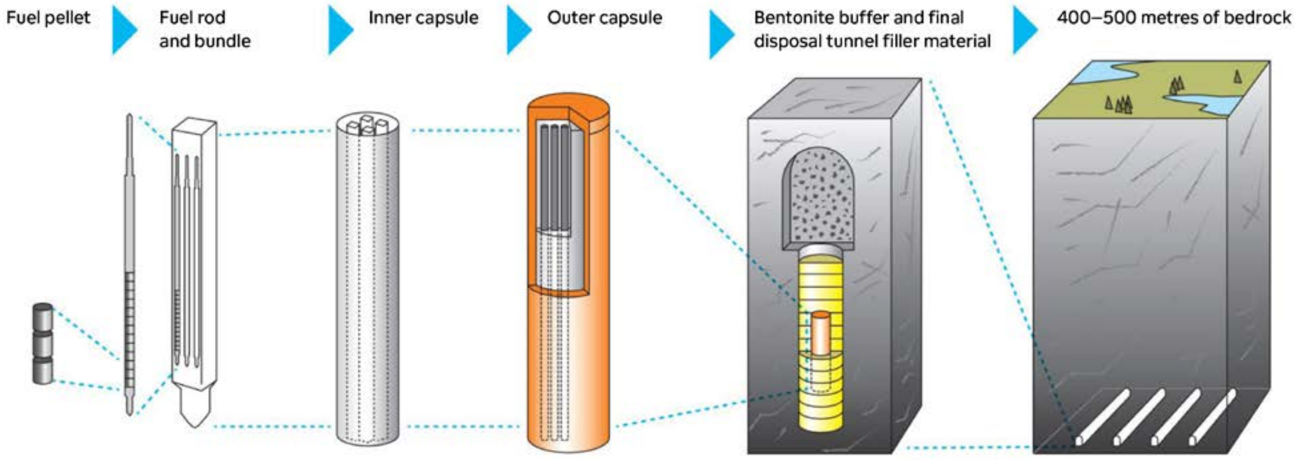


Figure 9-16. The safety of the final disposal of spent fuel is based on the multi-barrier principle, in which several release barriers securing each other ensure long-term safety. Photo: Posiva Oy

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

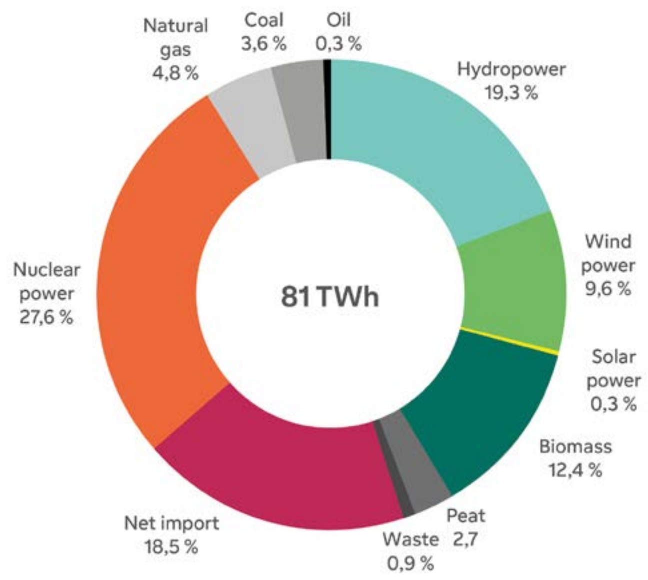


Figure 9-17. Electricity production by energy source and net import of electricity in 2020. (Finnish Energy 2021)

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.*

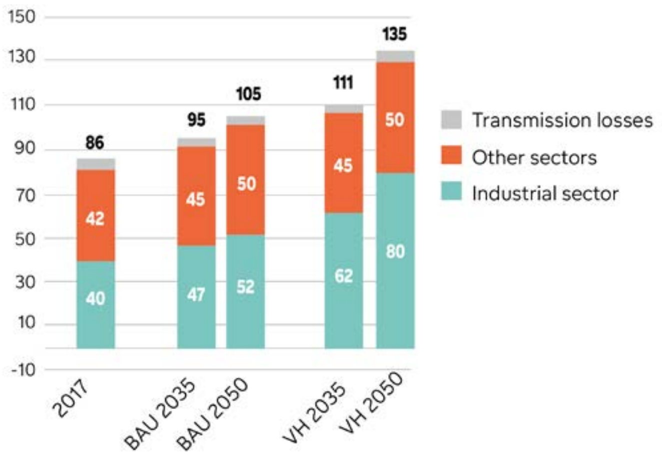


Figure 9-18. The electricity demand of the industrial and other sectors in the scenarios of the background review of the energy industry's roadmap. Photo: Ministry of Economic Affairs and Employment 2020a.

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.

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).

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.

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**

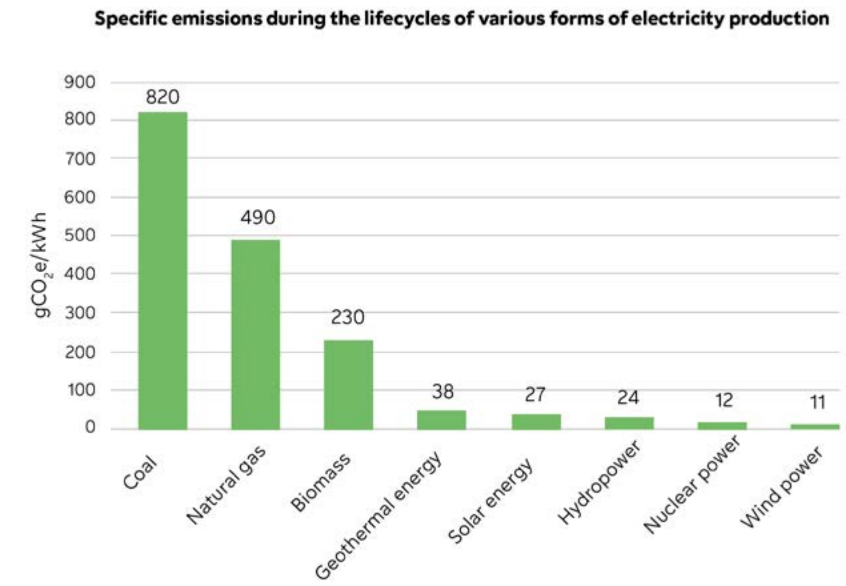


Figure 9-19. Comparison of the specific emissions during the lifecycles of different forms of energy production. (Bruckner et al. 2014)

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.

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.

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

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.

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].

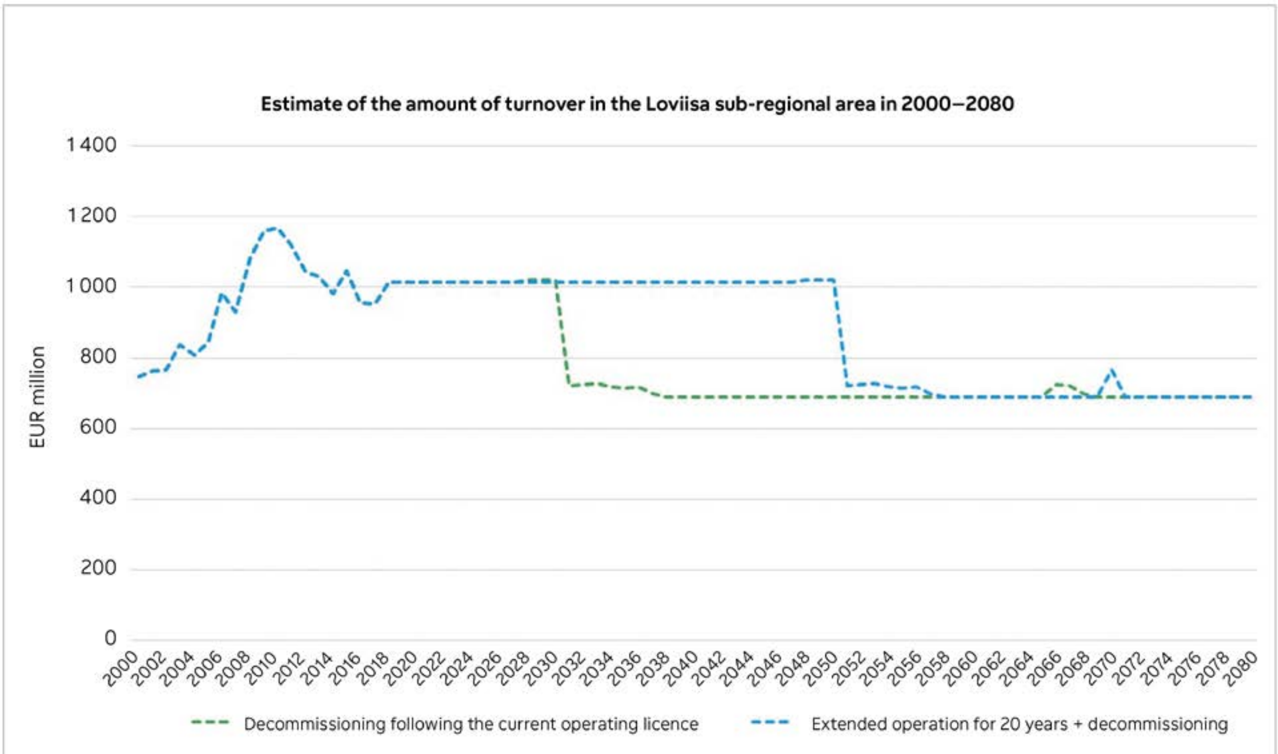


Figure 9-20. Estimate on the amount of turnover in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on turnover was assumed to be 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.

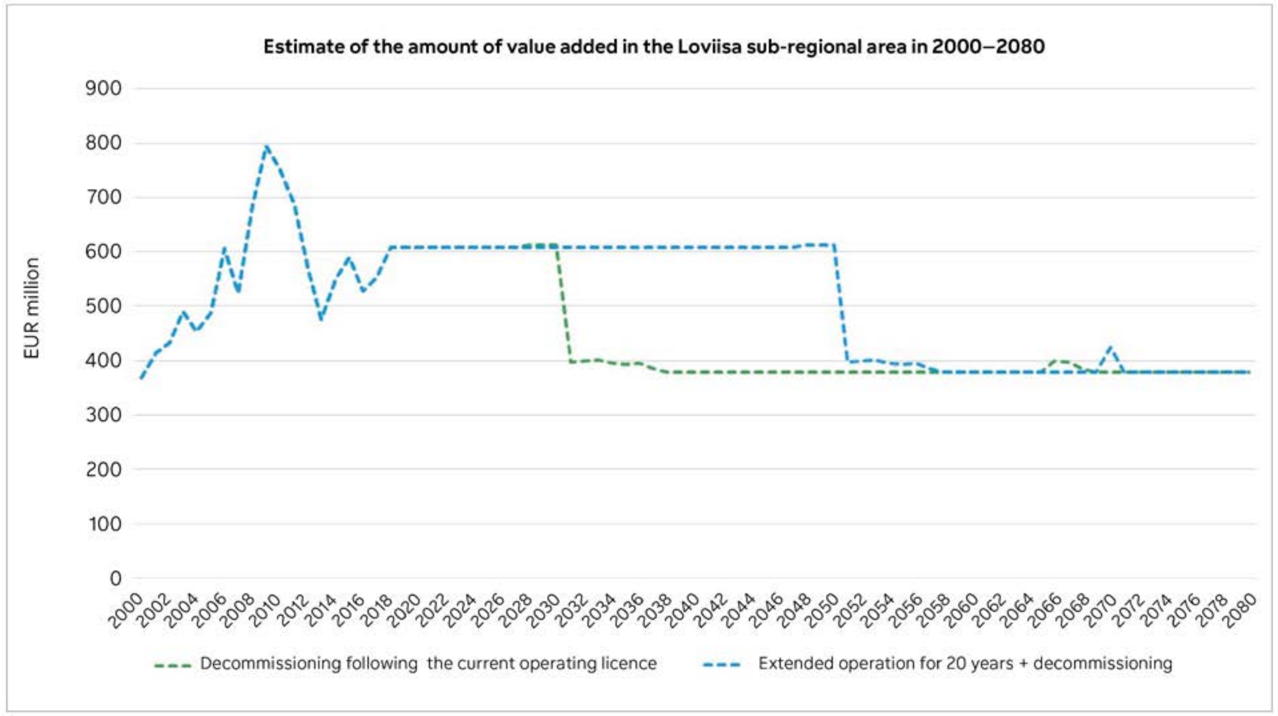


Figure 9-21. Estimate on the amount of value added in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on the value added was assumed 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.

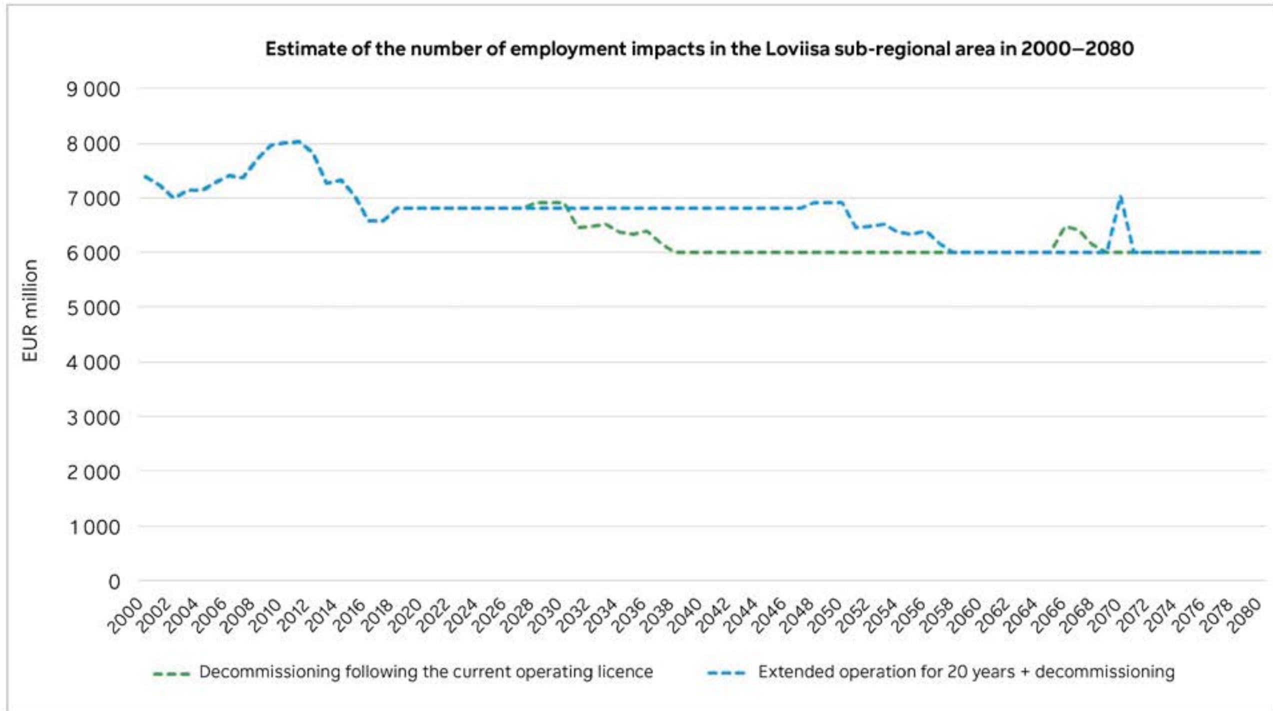


Figure 9-22. Estimate on the amount of labour needed in the Loviisa sub-regional area in 2000–2080. The period between 2000 and 2018 is based on the realised amount reported by Statistics Finland. The impact that the extended operation of Loviisa nuclear power plant would have on the need for labour 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 m³ (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

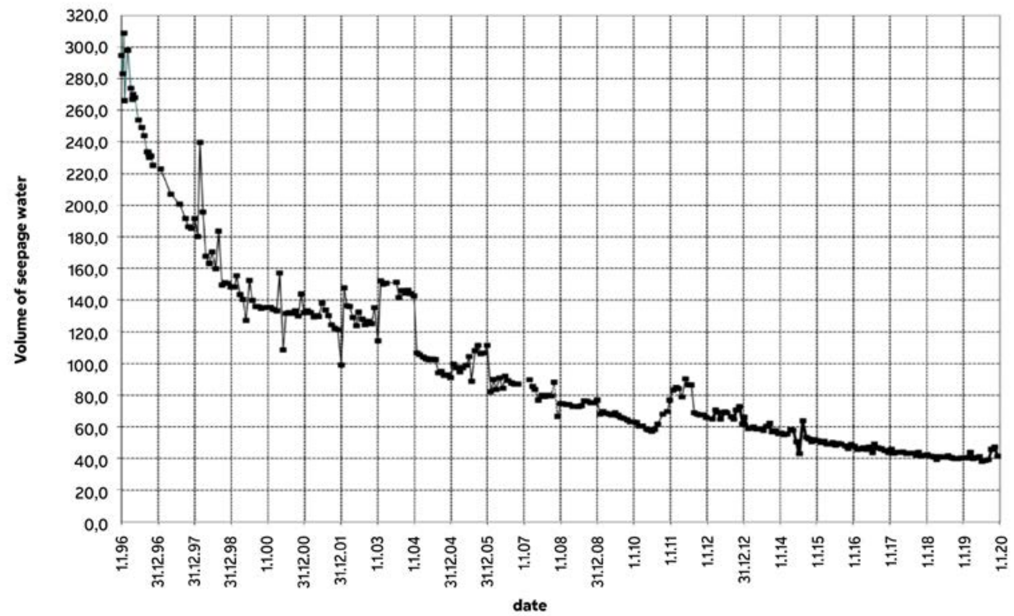


Figure 9-23. The final disposal facility's volume of seepage water (source: Fortum Power and Heat Oy).

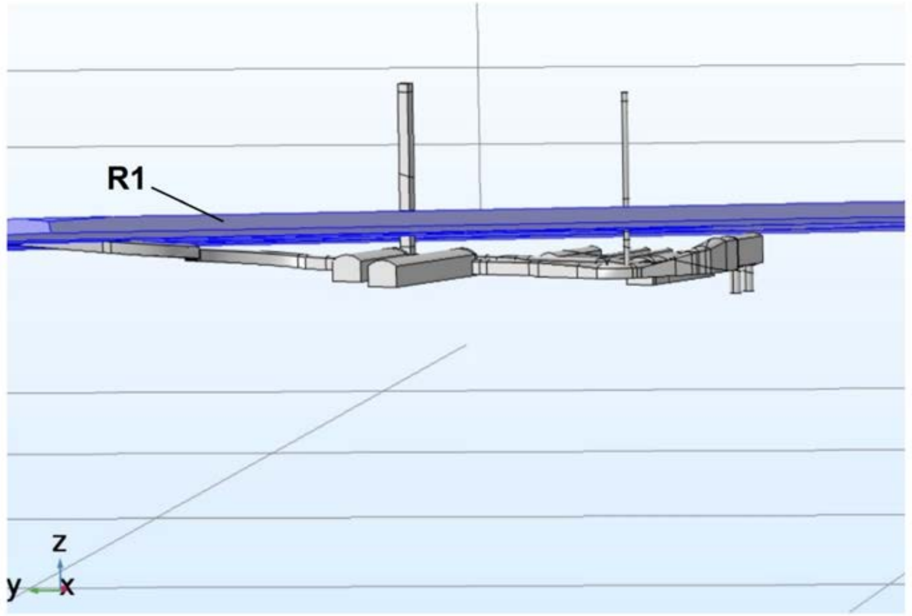


Figure 9-24. The location of the bedrock's zone of fragmented rock R1 (the horizontal zone above the final disposal facility which intersects with the shafts and the access tunnel) according to Hästholmen's groundwater model drawn up for the 2018 long-term safety case.

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

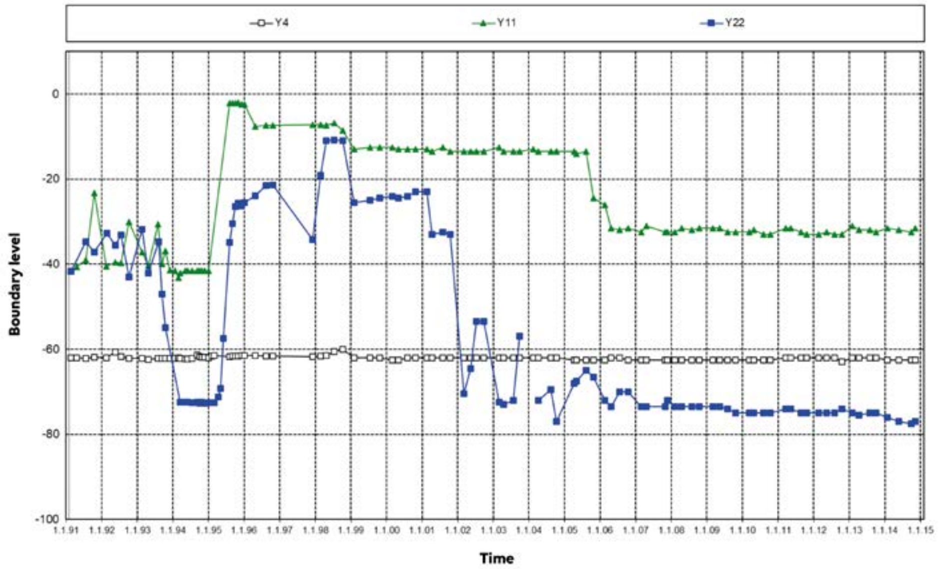


Figure 9-25. Measurement results of the boundary level of fresh and saline water in holes Y4, Y11 and Y22.

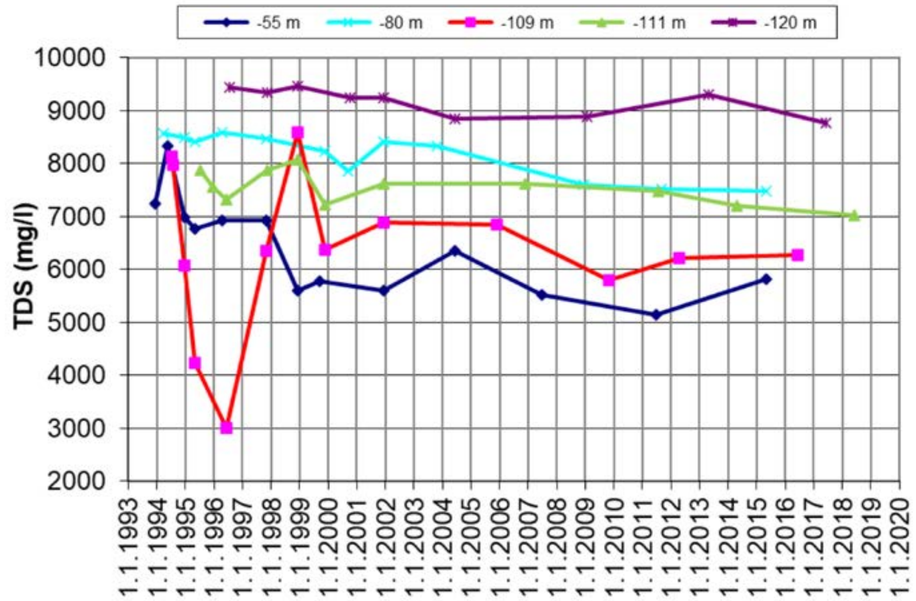


Figure 9-26. The total concentration of dissolved solids (TDS) in the groundwater at groundwater stations located at different depths.

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.

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

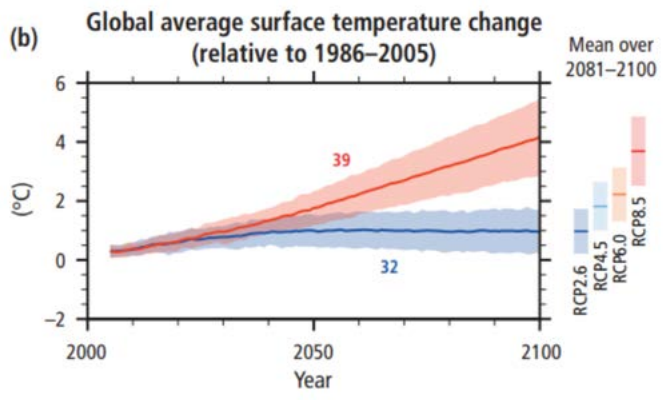


Figure 9-27. Time series of the change in global mean temperature in the RCP2.6 and RCP8.5 greenhouse gas emission scenarios between 2006 and 2100 compared to the period between 1986 and 2005. The figures in the time series describe the number of the CMIP5 models used for the calculation of the means 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).

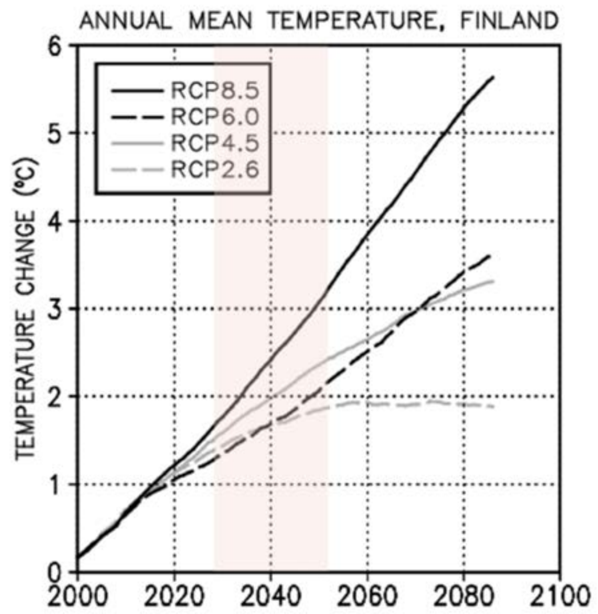


Figure 9-28. Increase in the annual mean temperature in Finland according to different greenhouse gas emission scenarios between 2000 and 2085 compared to the period between 1981 and 2010 (Ruosteenoja et al. 2016). The shading added to the figure represents the period reviewed in the EIA.

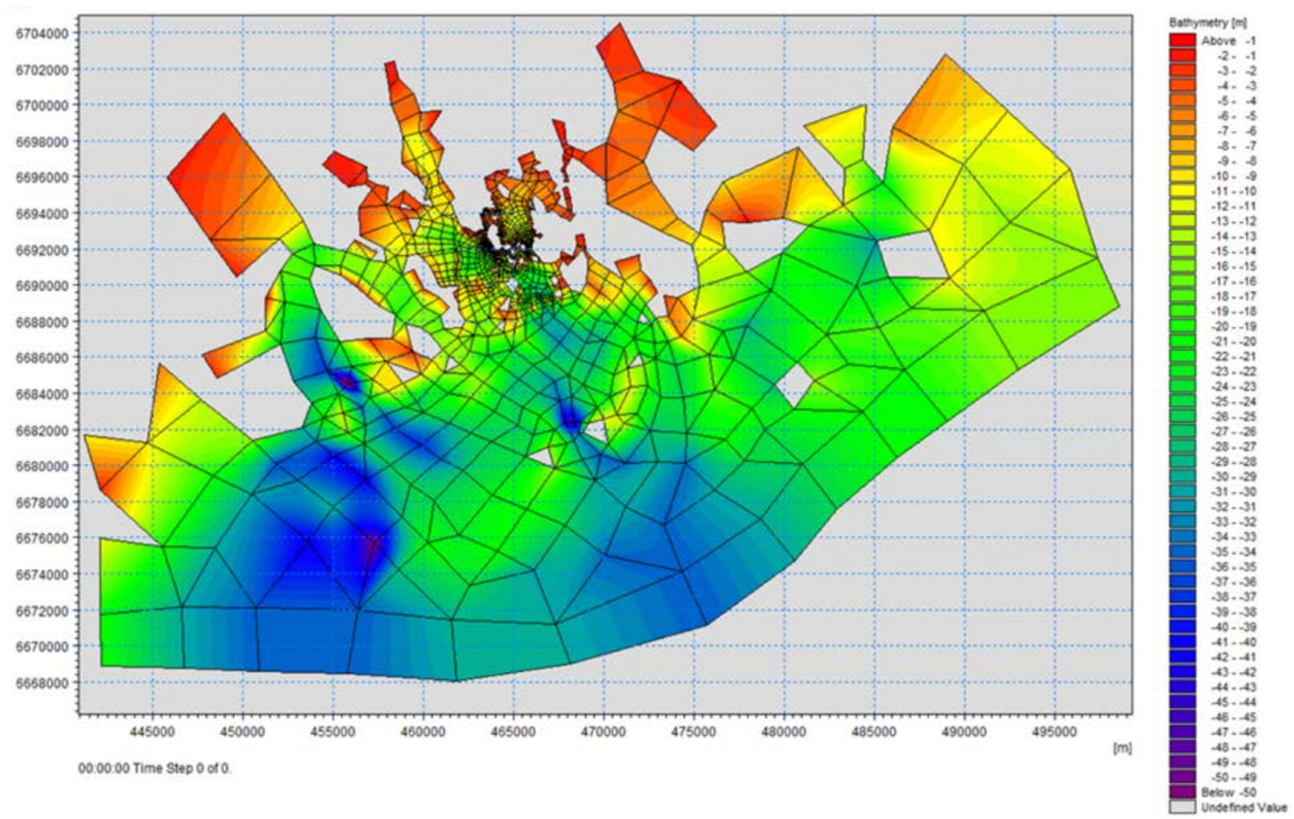


Figure 9-29. The model's computational mesh and the area's depth profile. The density of the computational mesh is at its greatest near the power plant at Hästholmsfjärden and Hudöfjärden. The model's computational mesh is described in detail in the modelling report (Lahti 2021).

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

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).

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.

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 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

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.*

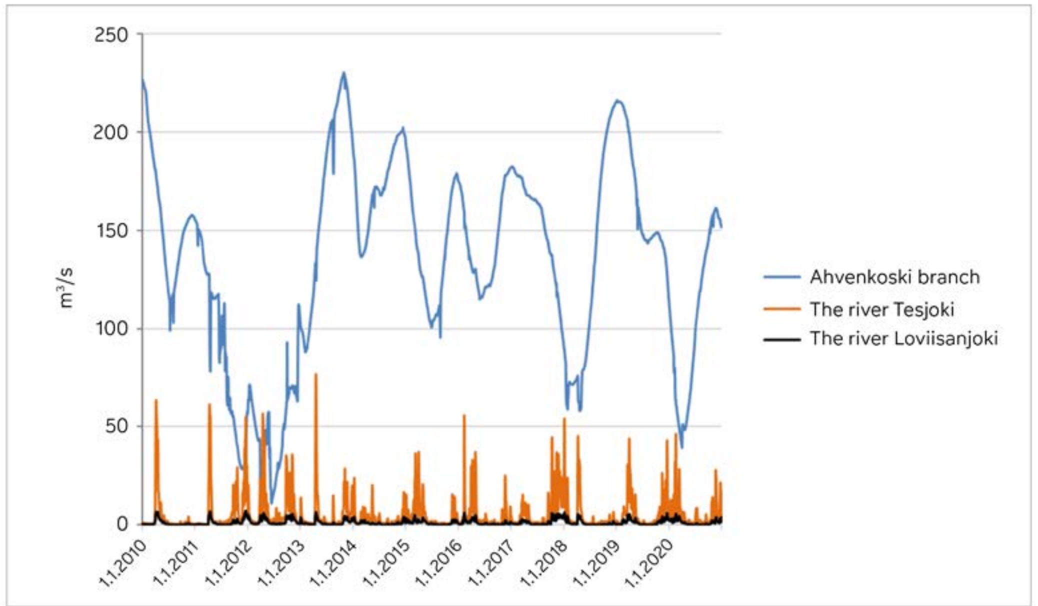


Figure 9-31. Variation in the discharges of the river Kymijoki's Ahvenkoski branch as well as in the discharges of the rivers Tesjoki and Loviisanjoki in 2010–2020 (VEMALA, data retrieved on 5 February 2021).

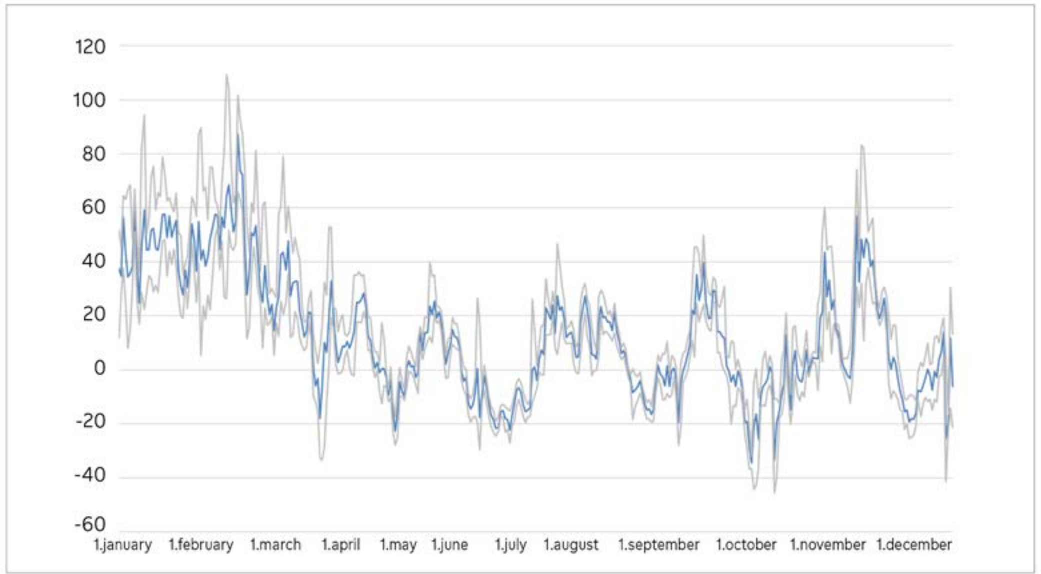


Figure 9-32. Daily sea level averages and the (daily) range of variation in Emäsalo, Porvoo relative to the theoretical mean water level (Finnish Meteorological Institute 2021).

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

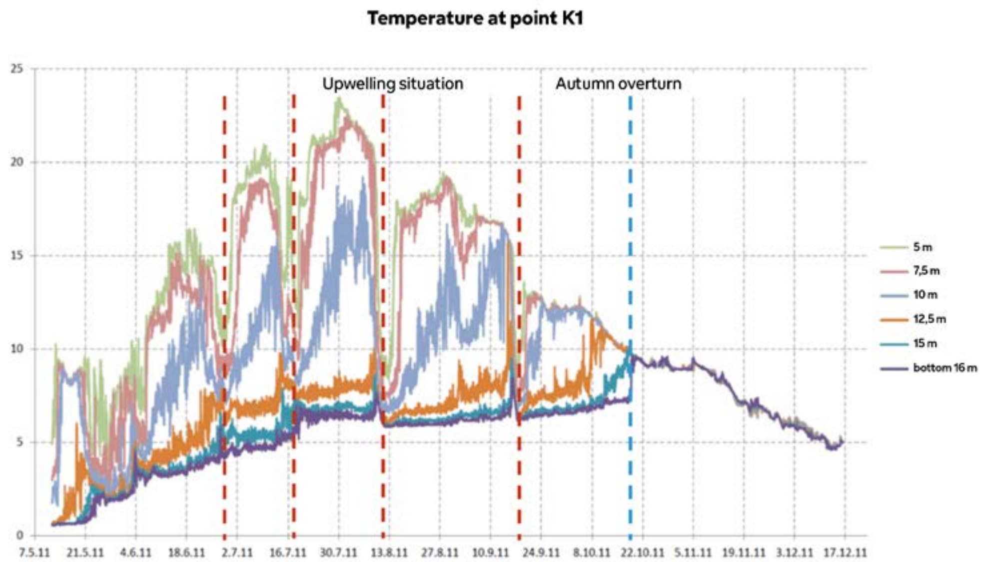


Figure 9-33. Development of seawater temperature at Hudöfjärden's point K1 in May–December of the 2011 measuring campaign. The upwelling situations are indicated by the broken red line. The temperature differences between the water layers levelled off in late October (Lindfors et al. 2012).

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

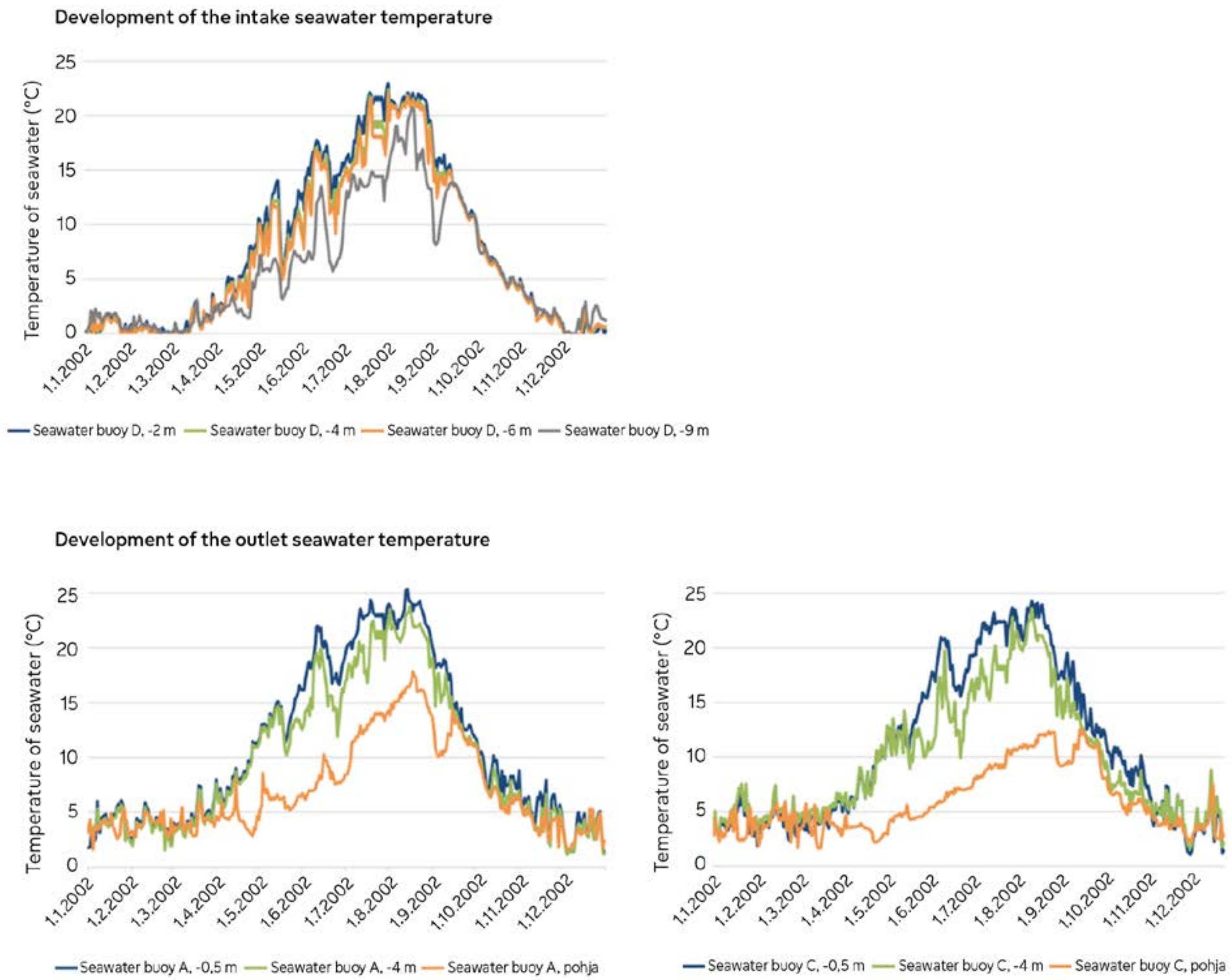


Figure 9-34. The annual development of seawater temperature at the continuous data buoys in 2002 on the cooling water's intake side at Hudöfjärden (topmost image) and discharge side, at data buoys A (image on the left) and C (image on the right) in Hästholmsfjärden. The locations of the buoys are shown 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.

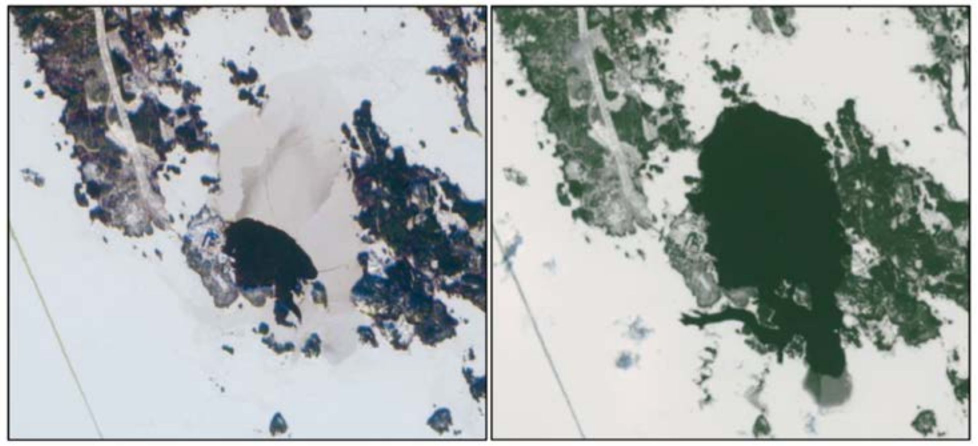


Figure 9-36. Variation in the size of the area of meltwater in the power plant's sea area in the winter of 2018. The satellite image on the left was taken in late February (27 February 2018), when the area of meltwater was at its smallest. The image on the right was taken in early April (3 April 2018); 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.

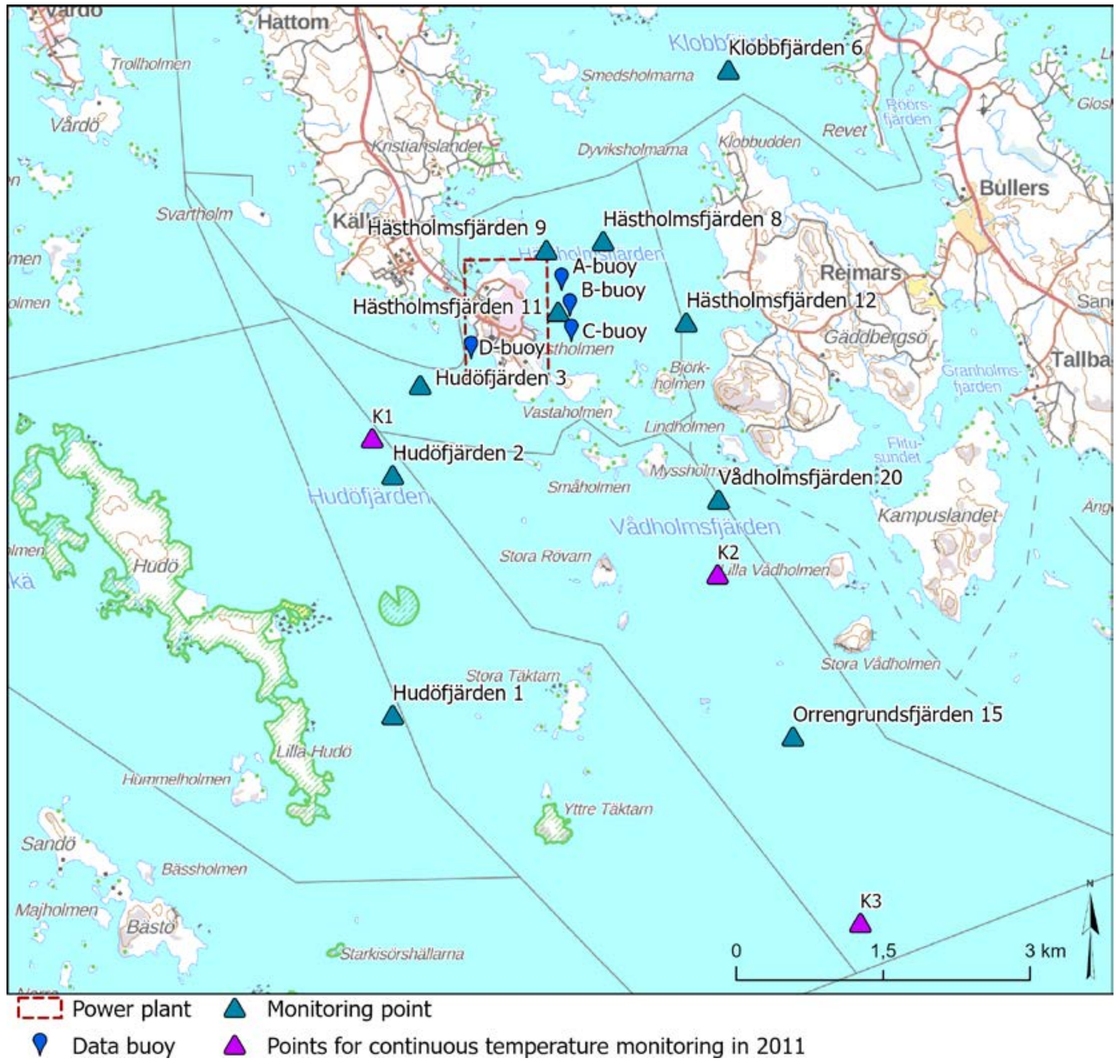


Figure 9-37. Monitoring points for the required monitoring of the quality of seawater in the sea area near Loviisa power plant (source: National Land Survey of Finland 2019, Anttila-Huhtinen & Raunio 2018).

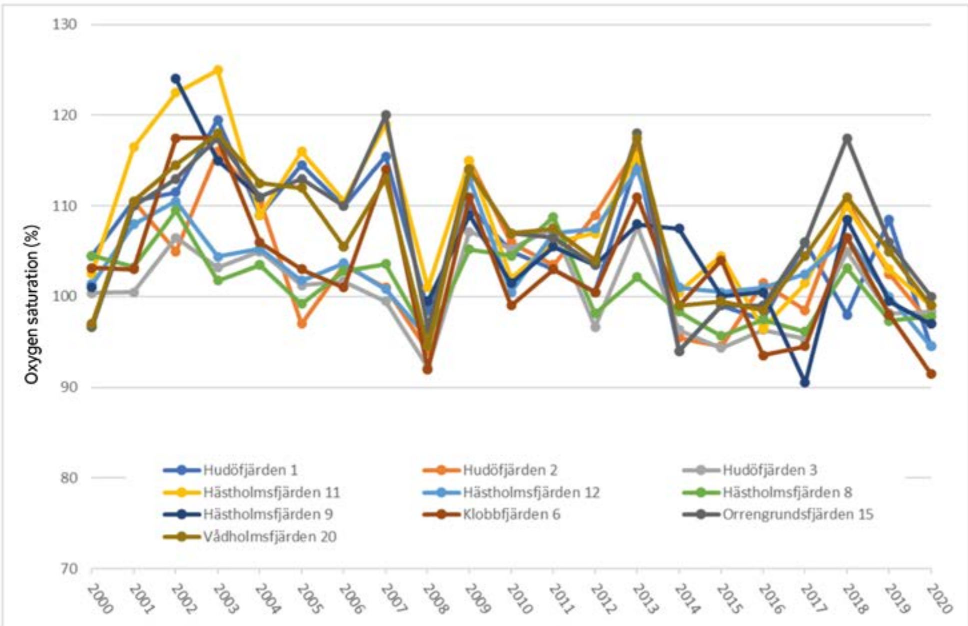


Figure 9-38. Average oxygen saturation in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

9.16.3.5 Quality of seawater

The water quality of the sea area adjacent to Loviisa power plant has been monitored for decades. The power plant's required monitoring includes the monitoring of water quality at various depths. The points for monitoring the quality of seawater are shown in Figure 9-37. The figure also shows the locations of the continuous temperature data buoys A–D and the continuous monitoring points K1–K3 related to the monitoring of seawater temperature, carried out during the ice-free season in 2011.

Loviisa power plant's discharges of radioactive substances into the sea are described in Chapters 4.12.2 and 9.8.3.2. The present state of the environment in terms of radiation is described in Chapter 9.8.3.

The oxygenation conditions during the surface layer's (0–1 metre) growing season (May–October) have been generally good at the monitoring points for water quality (Figure 9-38). Oxygen saturation has ranged from 70% to 130% during the growing season. Oxygen supersaturation resulting from the accelerated production of phytoplankton, a typical phenomenon in eutrophic waters, has been observed at all monitoring points in the surface layer. The oxygenation conditions of the hypolimnion have generally been poorer than that of the surface water during the growing season, due to the water's temperature stratification, among other things. No distinct trend in the oxygenation conditions was observed in the 2000–2020 period (Figure 9-39) (Anttila-Huhtinen & Raunio 2018). The regional fluctuation, in contrast, is clearly

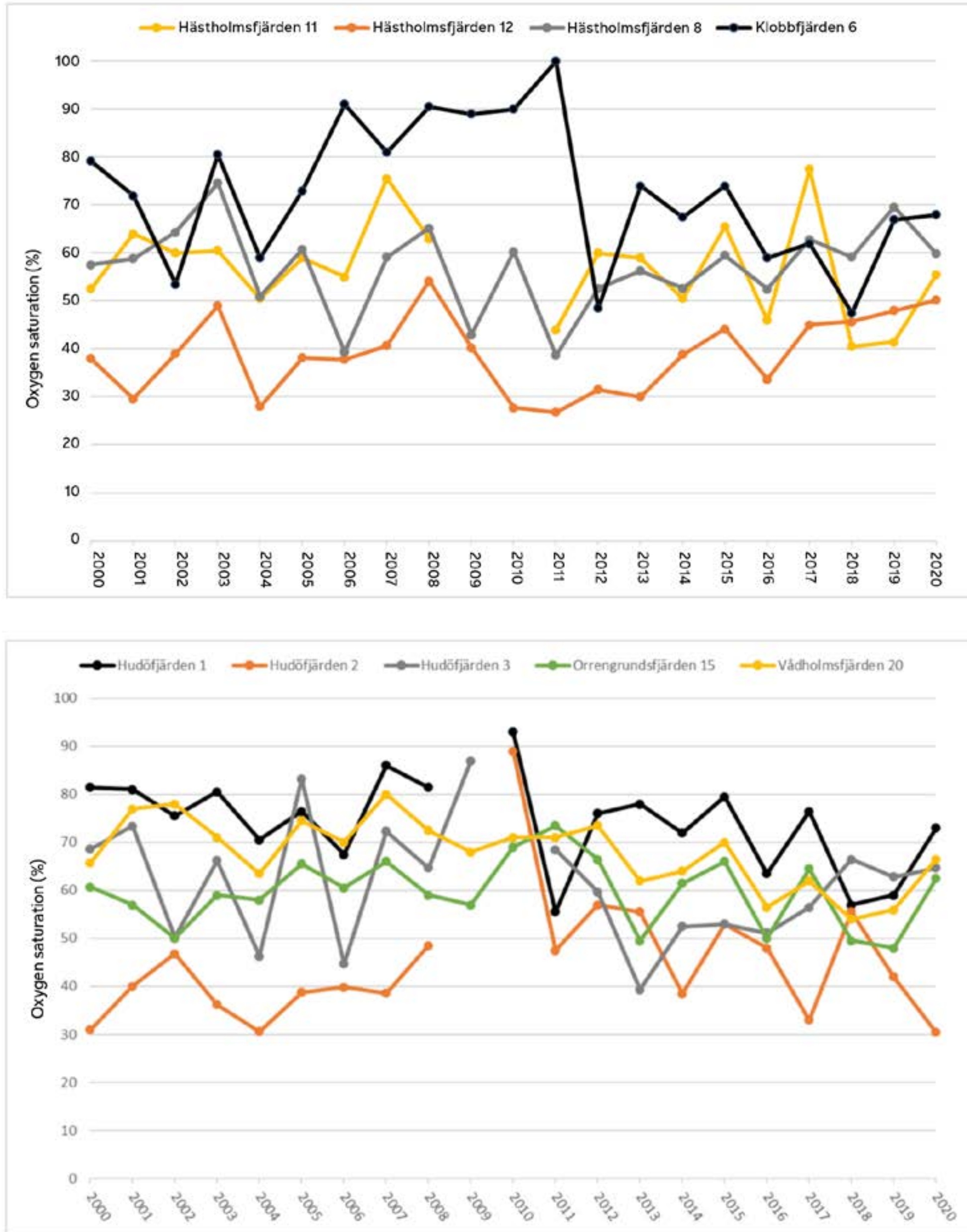


Figure 9-39. Average oxygen saturation in seawater's water layer close to the bottom (average in May–October) in the Loviisa sea area in 2000–2020. The top figure concerns the Hästholmsfjärden and Klobbfjärden area, while the lower figure concerns the Hudöfjärden area as well as Vådholmsfjärden and Orrengrundsfjärden (Open data, Hertta database, 11 February 2021).

greater than in the surface layer. Anoxic conditions have been detected in the hypolimnion in recent years, primarily in the deeps of Hästholmsfjärden and occasionally in the thermocline, but hypoxia has also occurred on the Hudöfjärden side. According to the data on water quality, the hypolimnion's oxygenation conditions have been weak in the deeps of Hästholmsfjärden since the 1970s, before the power plant's commissioning, while the oxygenation conditions in the thermocline weakened in the 1990s (Open data, Hertta database, 24 March 2021).

Based on the average nutrient content in the growing season (May–October), the surface water of the sea area near Hästholmen has been slightly eutrophic or eutrophic. The growing season's average total phosphorus content in 2000–2020 varied in the surface layer at the monitoring points for water quality between 12–41 µg/l (Open data, Hertta database, 11 February 2021) (Figure 9-40). No actual trend has been observable in the fluctuation of phosphorus content during the 2000s. The surface water's average total nitrogen content has ranged between 250–475 µg/l (Figure 9-41). The total nitrogen content dropped significantly in 2009, after which the content has increased slightly, nevertheless remaining at the same level, on average, as in 2000–2008.

The nutrient content in the hypolimnion near the bottom has typically been higher than in the surface water (Figure 9-42 and Figure 9-40). The hypolimnion's bad oxygenation or anoxic conditions, resulting in nutrients from the sediment dissolving into the water, has repeatedly caused total phosphorus and nitrogen content in the Hästholmsfjärden deeps (Hästholmsfjärden 12) that is higher than in other points. In May–October of 2000–2020, the phosphorus content in the hypolimnion close to the bottom was 200 µg/l, on average, while the total nitrogen content was 613 µg/l. The same phenomenon was observable at the Hudöfjärden 2 monitoring point. At the other points, the average phosphorus content in the hypolimnion varied on either side of 50 µg/l, while the nitrogen content was in the region of 375–434 µg/l. The content may nevertheless rise considerably from time to time as a result of the hypoxia.

Visibility depth has been measured in the Loviisa sea area since the 1970s. Visibility depth describes the depth which is visible from the surface of the water. Visibility depth is reduced by particulate matter in the water (including phytoplankton algae and clay-based turbidity carried by river waters) or strong wind, for example, which mixes particulate matter from the sediment into the water. Eutrophication is a significant factor reducing depth visibility in waterways.

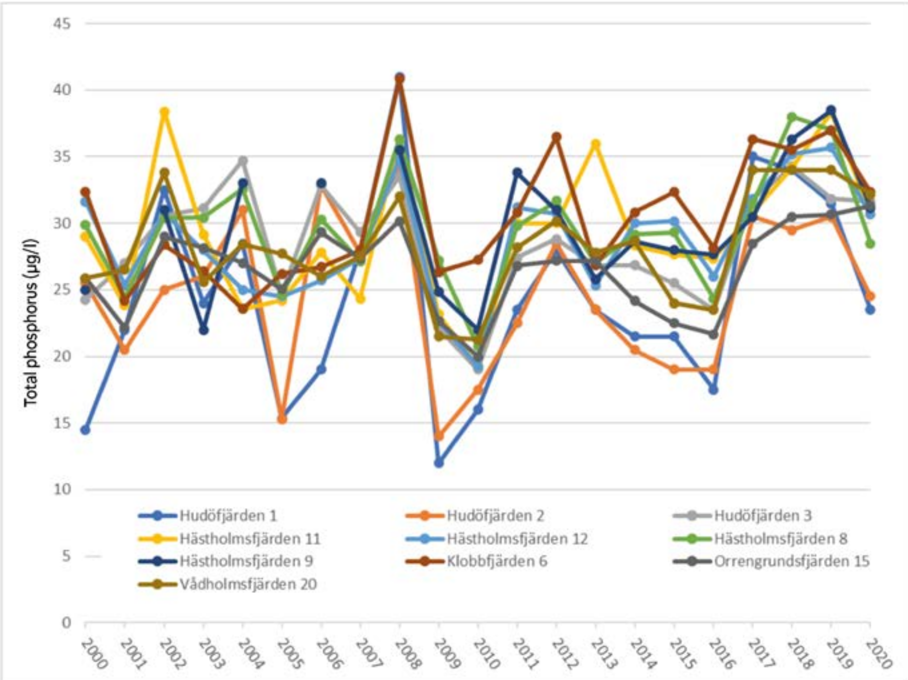


Figure 9-40. Total phosphorus content in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

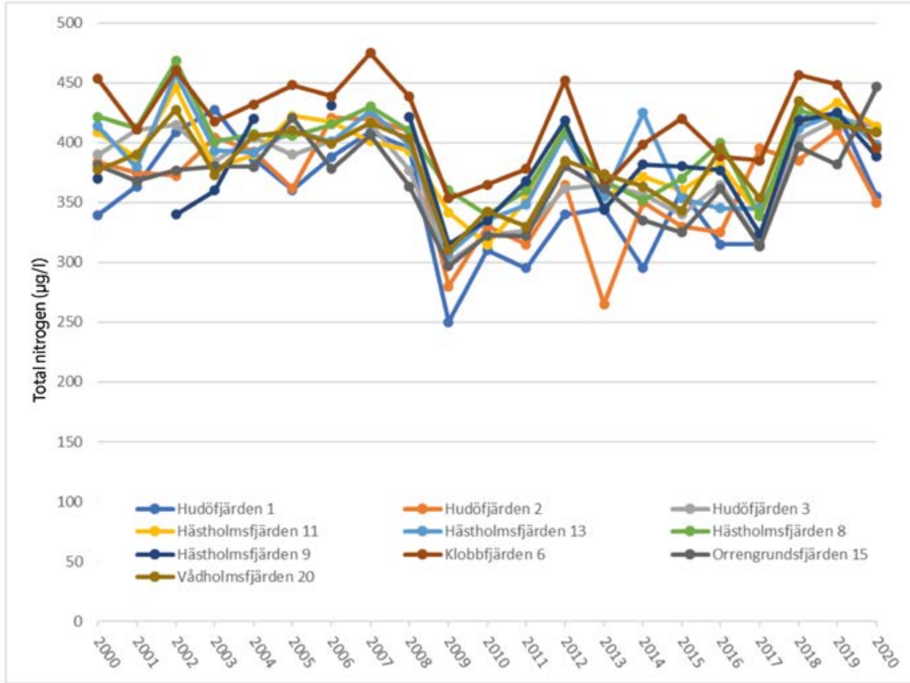


Figure 9-41. Total nitrogen content in the surface layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

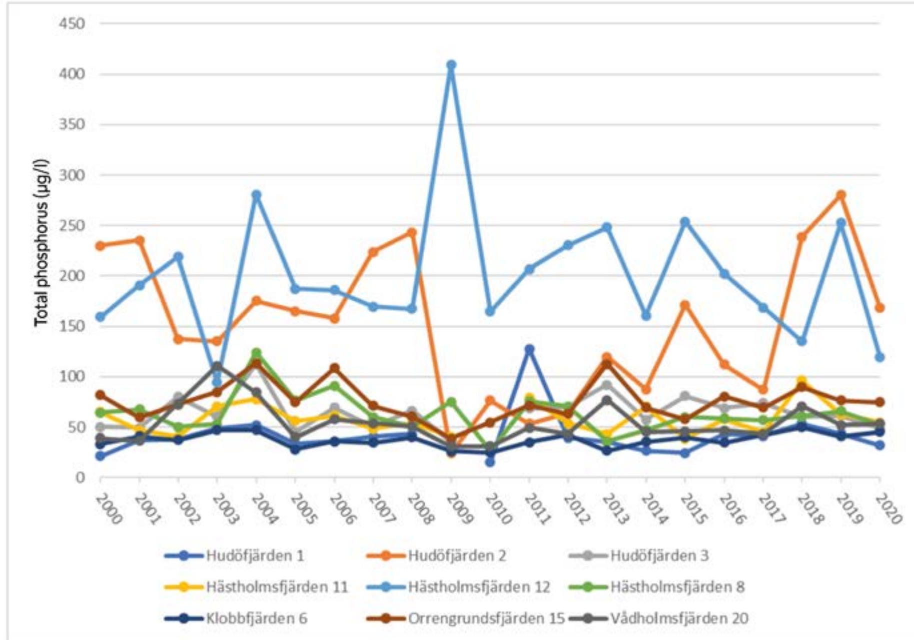


Figure 9-42. Total phosphorus content in the hypolimnion layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

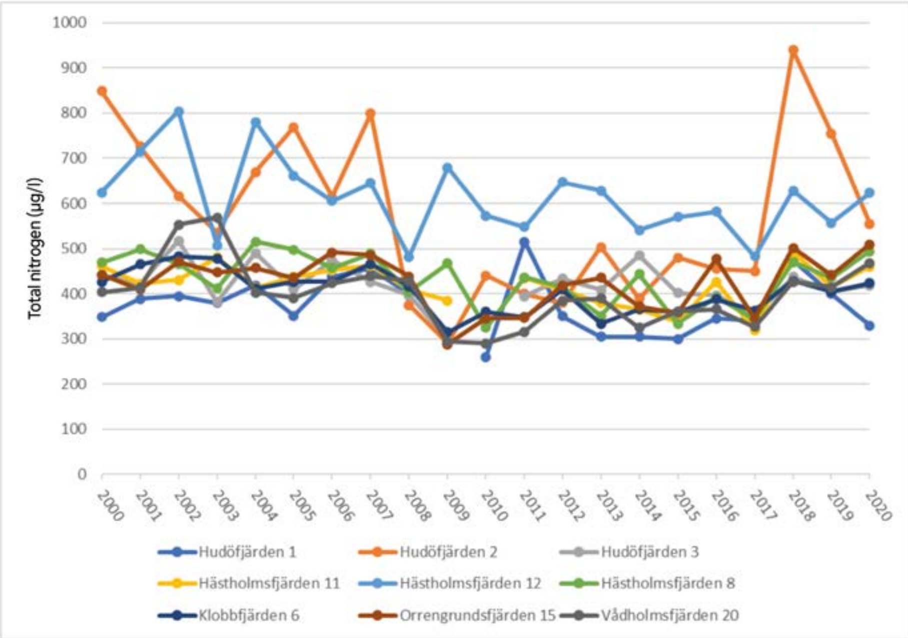


Figure 9-43. Total nitrogen content in the hypolimnion layer of seawater (average in May–October) in the Loviisa sea area in 2000–2020 (Open data, Hertta database, 11 February 2021).

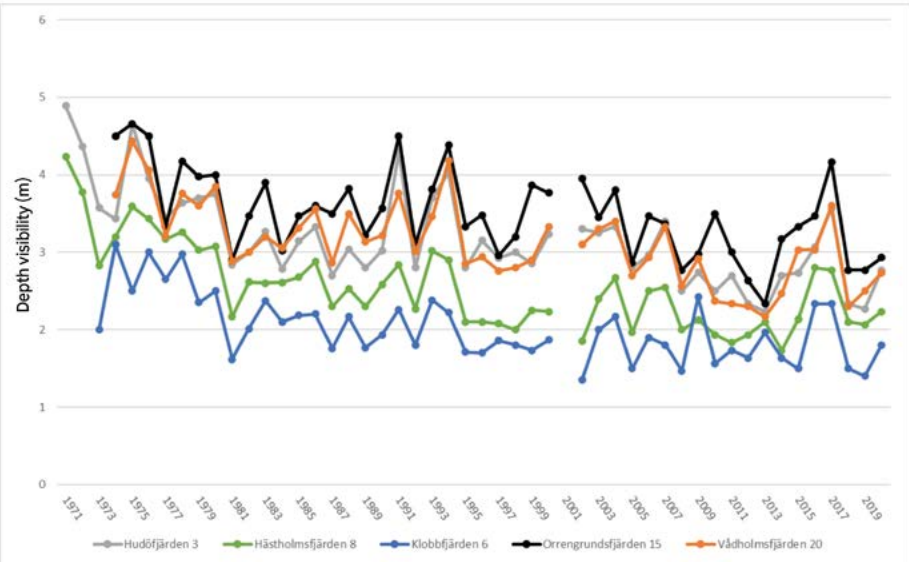


Figure 9-44. Depth visibility (m) in Hästholmen's nearby sea area in high summer, June–August (Open data, Hertta database, 12 February 2021).

Based on the monitoring of water quality, depth visibility in the sea areas close to Hästholmen has decreased (Figure 9-44). In Klobbfjärden and Hästholmsfjärden, depth visibility has been smaller than in the surrounding sea areas since the 1970s, and a declining trend has been apparent in the entire nearby sea area from the beginning of the observation until the 2000s. The reduction in depth visibility is a consequence of the Gulf of Finland's general eutrophication trend, but local factors also contribute. Klobbfjärden's lower depth visibility is explained by the river water input, rich in solids and nutrients, arriving via Jomalsund from the river Tesjoki (Figure 9-35). In recent years, the declining trend in depth visibility seems to have levelled off.

9.16.3.6 Phytoplankton

Phytoplankton algae are small single-cell organisms forming, as primary producers, the base of food webs in the marine ecosystem. The phytoplankton community is regulated by several different physico-chemical factors, including light, temperature, nutrient content and relations, as well as biotic factors, which include the grazing of zooplankton and competition over nutrients. The Gulf of Finland's phytoplankton community has a clear seasonal succession, which comprises a spring bloom, a summer minimum, a late-summer maximum and sometimes a smaller autumn bloom.

In the power plant's nearby sea area, the phytoplankton species and biomass, as well as the phytoplankton's seasonal succession (development), have been typical of the coastal waters in the Gulf of Finland. In the winter, the amount of light and the mixing conditions of the sea area limit the growth of phytoplankton, even though enough nutrients are available for algal production. Primary production is at its greatest during phytoplankton's spring bloom, and its strength varies regionally and from one year to the next, being the greatest in the Gulf of Finland (Fleming and Kaitala 2006). In the 2017 monitoring, typical algae groups of the spring bloom in the power plant's nearby sea area consisted of the taxa most abundant in May – dinoflagellates (with the large *Peridiniella catenata* being the dominant species) and diatoms (Hakanen 2018).

In the summer, phytoplanktons use mainly recycled nutrients, given that the thermocline prevents nutrients from moving from the deeper layers of water to the productive surface layer with abundant light, and that the content of soluble nutrients in the surface layer is low. Dominant groups of algae in the summer typically include filiform cyanobacteria (i.e. blue-green algae), pyrrophyta as well as small autotrophic flagellates and nanoflagellates. The amount of blue-green algae in the power plant's nearby sea area has varied from one year to the next, and blue-green algae's share of the community is at its greatest in late summer (Hakanen 2018). The most abundant species of blue-green algae in the 2017 monitoring was the non-toxic filiform Aphanizomenon (Hakanen 2018). In the Gulf of Finland, eutrophication has led to the average strengthening of mass occurrences of blue-green algae in late summer, although the regional and temporal variation in the strength of the occurrences, and the variation between different years in this regard, is great (Bruun et al. 2010). The dominant algae in the autumnal phytoplankton community are the large cold water diatoms found in the Loviisa sea area (Hakanen 2018).

Only fragmented data is available on the annual averages of the chlorophyll a concentrations, which describe the amount of algae in the water, from the initial years of monitoring. Chlorophyll a concentrations have grown compared to the initial years of the monitoring, which indicates an increase in the amount of algae (Table 9-51). The most complete monitoring data is available from monitoring points Hästholmsfjärden 8 and Hudöfjärden 3. At these points, the average chlorophyll concentration pointed to a declining

Table 9-51. Annual averages of chlorophyll a concentrations during different periods as of 1970. The data from the initial years are fragmented, and the sample size (n) was very small (Open data, Hertta database, 17 February 2021).

Piste	1970-1980	n	1981-1990	n	1991-2000	n	2001-2010	n	2011-2020	n
Hudöfjärden 1	—		—		—		22.5	2	—	
Hudöfjärden 2	0.2	1	7.3	8	3.1	1	17.3	2	—	
Hudöfjärden 3	—		—		12.03	12	10.9	72	8.3	62
Hästholmsfjärden 11	3.8	1	14.8	1	—		8.6	17	7.9	61
Hästholmsfjärden 12	3.7	1	7.9	16	7.7	1	8.7	19	9.1	62
Hästholmsfjärden 8	2.9	5	—		12.8	11	10.9	72	9.1	56
Hästholmsfjärden 9	—		12.8	1	—		9.4	25	9.1	60
Klobbfjärden 6	—		—		—		11.6	19	9.9	61
Orrengrundsfjärden 15	—		—		—		7.3	19	7.9	61
Vådholmsfjärden 20	—		—		—		7.5	19	9	61

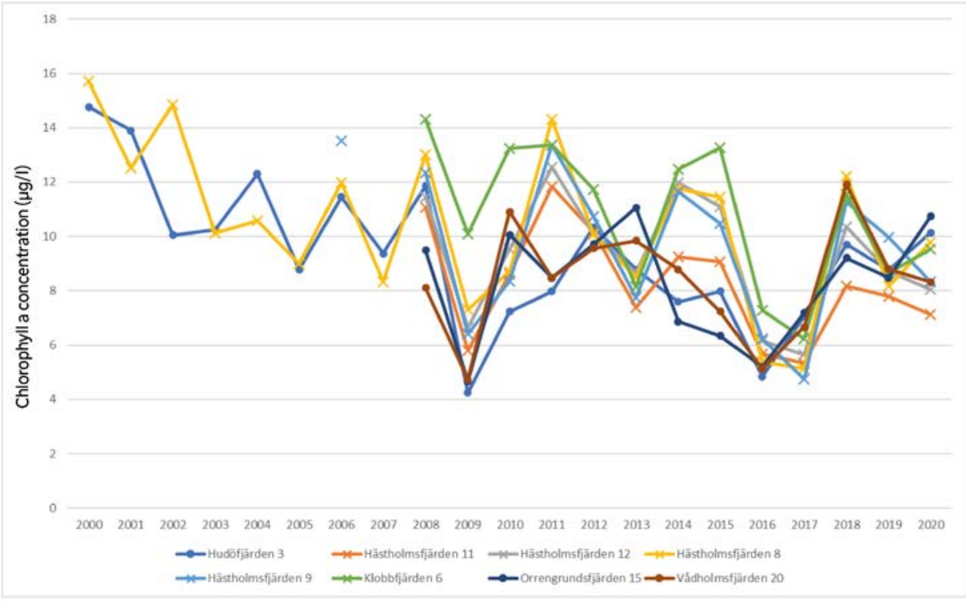


Figure 9-45. Surface layer's station-specific average chlorophyll a concentration (µg/l) during the growing season (May–October) in the Loviisa sea area in 2000–2020 (Anttila-Huhtinen & Raunio 2018).

trend (a decrease in the amount of algae) in the 2000s, up to 2009 (Figure 9-45) (Anttila-Huhtinen & Raunio 2018). The same trend was also observed at the points added to the monitoring in 2008 (Anttila-Huhtinen & Raunio 2018). The chlorophyll concentration then rose again, and the variation from one year to the next has been great. The highest concentrations were observed in 2011 and 2014. In the present state, the chlorophyll concentrations reflect mainly a eutrophic waterway. In the cooling water's discharge location at Hästholmsfjärden, the thermal load caused by the power plant has contributed to an acceleration of eutrophication.

The changes that have taken place in the status of the Gulf of Finland are also reflected in the state of the power plant's nearby sea area. In the Gulf of Finland, the amounts of algae grew until the early 2000s due to eutrophication. The amounts of algae there began to grow again in the late 2010s. This was indirectly related to the major Baltic inflows of the 2010s, which pushed hypoxic water rich in phosphorus from the Baltic Proper (the Gotland Basin) into the Gulf of Finland. For example, the impact of the major Baltic inflows in 2014–2016 was visible in the 2018 results of the Loviisa waterway monitoring as an increase in the chlorophyll a concentration and primary production (Anttila-Huhtinen & Raunio 2019).

Regular monitoring data on the total biomass of phytoplankton are available starting from 2008 (Open data, Phytoplankton register, 15 February 2021). The most extensive data are derived from the monitoring points Hudöfjärden 3 and Hästholmsfjärden 8. The biomasses are considerably greater than the biomass in 1967, which was calculated on the basis of only a single sample in July and is of indicative nature only (Figure 9-46). The changes are probably a result of the general eutrophication in the Gulf of Finland. The average amount of biomass in 2014–2020 was 0.9-1.7 mg/l. The biomass has begun to decline since 2011.

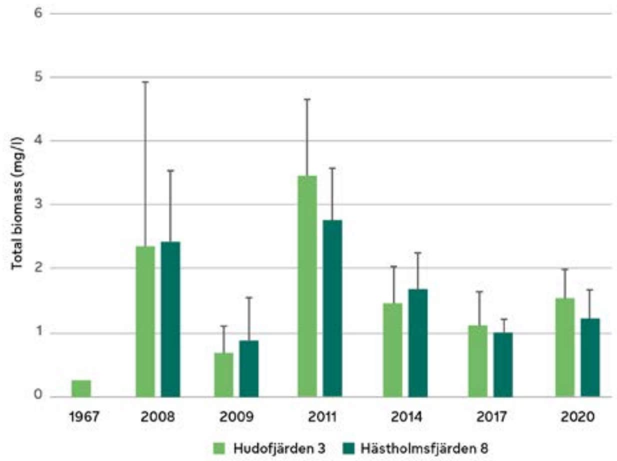


Figure 9-46. Phytoplankton's total biomass in Hudöfjärden and in Hästholmsfjärden. Only one measurement is available in terms of 1967, from July. In terms of other years, the sample size is 2–6 (Open data, Phytoplankton register, 15 February 2021).

The measurement data on the primary production of phytoplankton in the Loviisa sea area are exceptional in terms of their time span, with the earliest results being from 1967; the production of phytoplankton seems to have declined since 1997 (Anttila-Huhtinen & Raunio 2018). During this monitoring, the amount of primary production increased both at the discharge and intake locations of the cooling

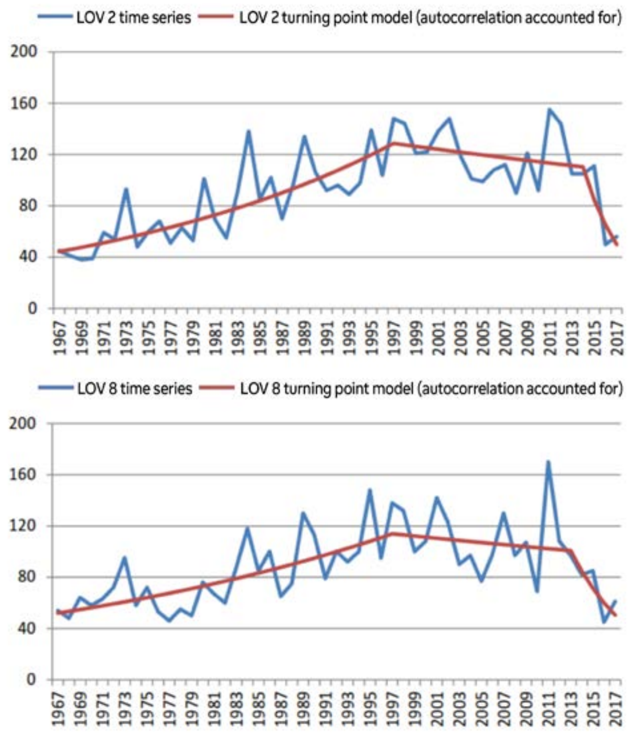


Figure 9-47. Primary production per unit area (mg C/m2d) in the cooling waters' impact area at Hästholmfjärden (station LOV 2, upper figure) and in the reference area at Hudöfjärden (station LOV 8, lower figure) in 1967–2017 (Anttila-Huhtinen & Raunio 2018).

water until the mid-1990s. The increase is connected to the general increase in the Gulf of Finland's nutrient content and the general eutrophication trend in the Gulf of Finland. The eutrophication trend has nevertheless been stronger in Hästholmsfjärden (station 2, Hästholmsfjärden 8) than in the nearby reference area in Hudöfjärden (station 8, Hudofjärden 3). For its part, this points towards the impact of the power plant's cooling water (Anttila-Huhtinen & Raunio 2018). In the 2000s, the primary production increased to a level clearly indicative of a eutrophic waterway. However, based on the turning point model adapted for the data, the eutrophication trend seems to have taken a downward turn (Figure 9-47). While the variation between different years is great, the turning point model suggests that the changes in the amount of primary production took place in 1997 and in 2013–2014. The declining trend first began in 1997, but gained further strength in 2013–2014. The low primary production figures of 2016 and 2017, in particular, strengthened the declining trend.

9.16.3.7 Aquatic vegetation

Aquatic vegetation has been monitored in the sea areas near Loviisa power plant since 1971. The seabed on the shores of the island of Hästholmen is mostly rocky and usually drops off steeply close to shore, which is why the aquatic vegetation zones are generally narrow (Ilus 2019). In 2017, a total of 12 aquatic plant species belonging to vascular plants and macroalgae were found in the areas being monitored. The species were customary to the area, and included hornwort, spiked water-milfoil, spiny naiad, perfoliate pondweed, fennel pondweed, *Fucus radicans* brown alga, *Cladophora glomerata* macroalga, *Ectocarpus siliculosus* brown alga, bladder wrack, and sea lettuce (Monivesi Oy 2018).

No significant change in the abundance of aquatic plants has been observed in Hästholmsfjärden and Hudöfjärden between the years 2008, 2011, 2014 and 2017. Between 1977 and 2017, aquatic vegetation in Hästholmsfjärden and Hudöfjärden changed in such a way that aquatic plants sensitive to physico-chemical inputs (nutrients, temperature, depth visibility) declined in both sea areas since 1980, whereas some vascular plants and filamentous algae have benefited from the warmer water. The change in Hästholmsfjärden has been greater than the change in Hudöfjärden. Annual filamentous algae, in particular, have benefited from the longer growing season. The thermal effect is especially visible in the greater occurrence of aquatic plants – from the surface of the water down to a depth of 1.5 metres – in the monitoring lines of the Hästholmsfjärden area (the impact area of the power plant's cooling water) (Monivesi Oy 2018). The increase in the coastal vegetation and the eutrophication of the shore areas can be seen at a distance of approximately one kilometre from the cooling water intake.

9.16.3.8 Benthic fauna

The benthic fauna populations in the sea area surrounding Loviisa power plant were first studied in 1966, when the quantity of species was deemed fairly low. The quantity of species in the Gulf of Finland is limited by the salinity of the brackish water, which is too low for marine species and too high for freshwater species. Benthic fauna monitoring of a more regular nature in Loviisa power plant's nearby sea area began in 1973. There have been considerable changes in the condition of the seabed of the area and in the benthic fauna over the last 40 odd years.

The state of the seabed and benthic fauna in the eastern Gulf of Finland has long been weak due to the bad oxygenation conditions. Since the 1980s, the state of the seabed has weakened particularly steeply in the deeper areas. After the major Baltic inflows in the first half of the 1990s, benthic fauna communities declined dramatically, particularly in the deeps of the Gulf of Finland (Jaale & Norkko 2008). Loviisa power plant's monitoring area has separate pools, set apart by low thresholds, in which the exchange of water close to the bottom is poor. The power plant's thermal load also exacerbates the weak oxygenation conditions, because the increased temperatures further impair the oxygenation conditions on the seabed through both degradation activity and increased primary production (Anttila-Huhtinen & Raunio 2018). The deterioration has been visible as the strong decline of the Baltic macoma and *Monoporeia affinis* – benthic fauna typical of the eastern Baltic Sea – and very few, if any, findings of these species have been made in the deepest stations of Loviisa power plant's impact monitoring.

Changes in the benthic fauna in the 2000s have not been equally significant. Based on an extensive survey of the benthic fauna conducted in 2017 (Anttila-Huhtinen & Raunio 2018, Monivesi Oy 2018), the benthic fauna in the shallow mud floors of Klobbfjärden and Hästholmsfjärden consisted of the Oligochaeta of a eutrophic seabed and chirominid larvae. However, at the sample station close to the power plant's discharge location, the benthic fauna has been more diverse than at the other stations throughout the 2000s (Figure 9-48). This is probably due to the area's better exchange of water and the coarser material of the seabed. The thermal effect of the cooling water may also favour the occurrence of some alien species. One such alien species is the New Zealand mud snail *(Potamopyrgus antipodarum)*. Its abundant occurrence at station 5b, close to the discharge location, began in the 1990s and continued into the 2000s, up until 2008 (Figure 9-48).

The condition of the seabed in the deeper zones – the profundal zones in which the amount of light no longer enables the growth of green plants – of Hästholmsfjärden (station 3) and Hudöfjärden (station 8), Vådholmsfjärden (station 4) and Orrengrundsfjärden (station 7) has been largely bad in the 2000s (Figure 9-49 and Figure 9-50). Even so, the condition of the seabed in Vådholmsfjärden (station 4) has been better over the last three years of research than during previous years (Figure 9-50). The *Marenzelleria* worm has become more widespread in recent years at the outer sample stations in Vådholmsfärden and Orrengrundsfjärden (Figure 9-50).

According to the Benthic Biotic Indices (BBI), which describe the benthic fauna communities on the soft coastal seabed, the state of the Klobbfjärden body of water's seabed has been largely bad in the 2000s, when as recently as the 1970s and 1980s, it was poor (Anttila-Huhtinen & Raunio 2018). Further out in the sea area, in the Loviisa–Porvoo body of water, the state of the seabed has been more varied, but improved from poor to moderate over the 2013–2017 period (Anttila-Huhtinen & Raunio 2018). The BBI assumes that the diversity of species and the share of sensitive species in a benthic fauna community decrease as the environmental stress grows (Perus et al. 2007). The BBI is based on quantitative samples and is calculated from the benthic fauna community's composition of species and the values set for the sensitivity of the species. Given that the BBI was originally developed for the Kvarken area and is therefore not necessarily well suited for the Gulf of Finland and the species there, the status classes pursuant to the BBI values should be treated with some caution. Among other things, the index fails to recognise the freshwater chirominid and oligochaetes, typical of the Gulf of Finland's coastal archipelago, at the

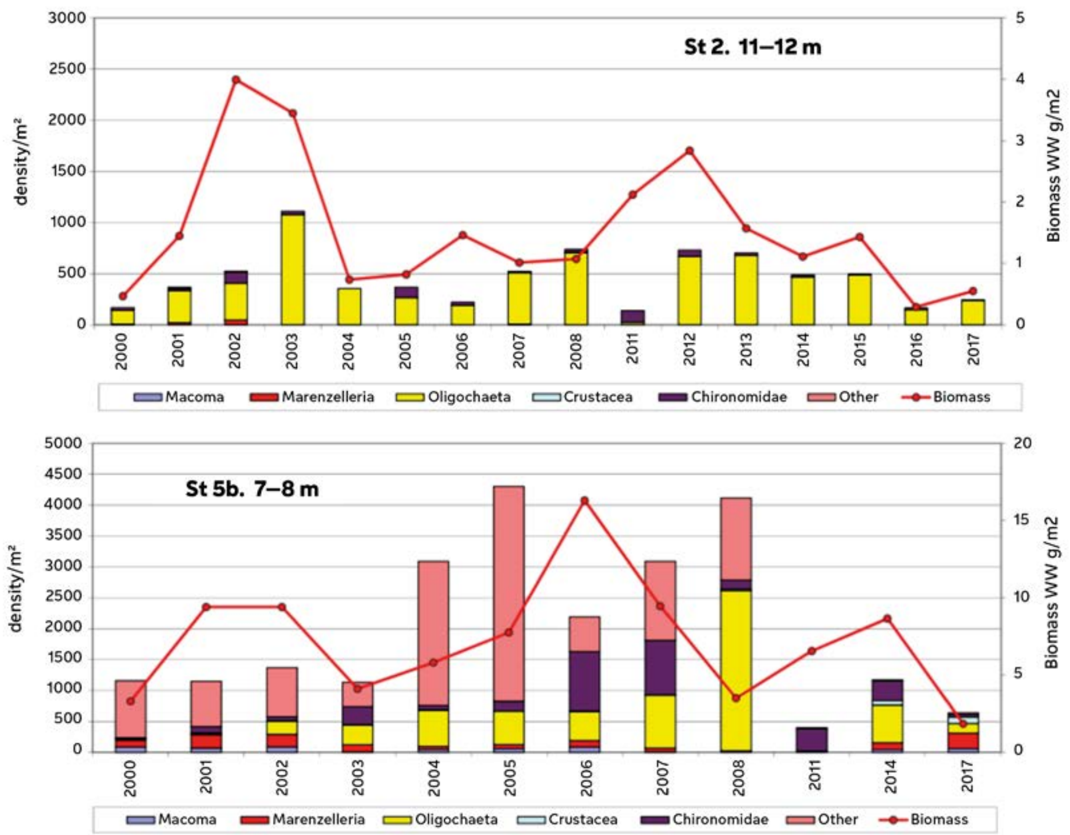


Figure 9-48. Population densities and biomasses of benthic fauna groups in the 2000s at Hästholmsfjärden (stations 2 and 5b), Loviisa. The group "Others" includes the number of New Zealand mud snails. The scales of the figures' Y axes are not identical (Anttila-Huhtinen & Raunio 2018).

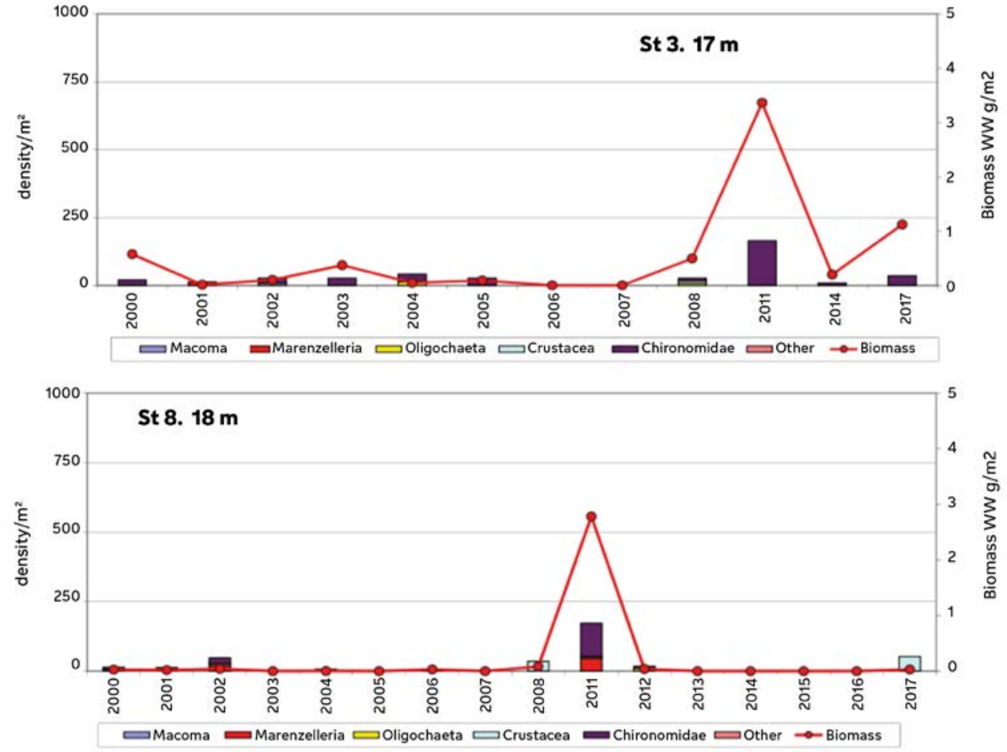


Figure 9-49. Population densities and biomasses of benthic fauna groups in the 2000s in Hästholmsfjärden's profundal zone (station 3) and Hudöfjärden (station 8). The scale of years in the figures is not identical (Anttila-Huhtinen & Raunio 2018).

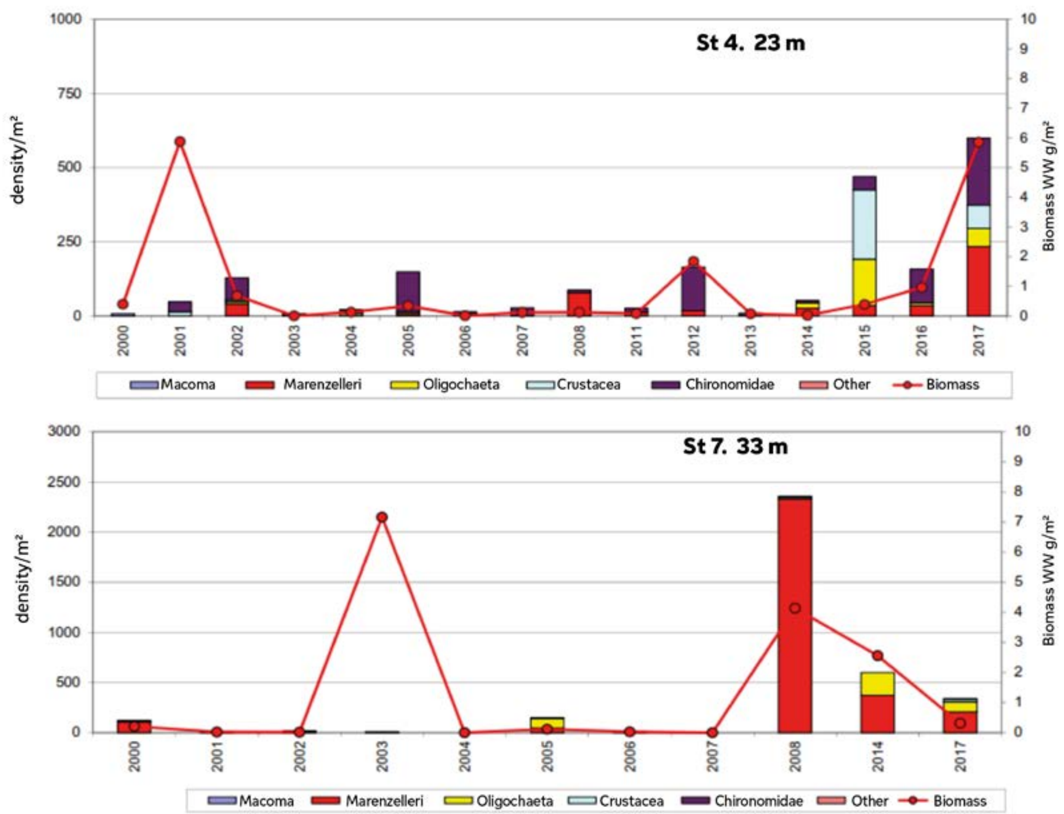


Figure 9-50. Population densities and biomasses of benthic fauna groups in the 2000s in Vådholmsfjärden (station 4) and Orrengrundfjärden (station 7), Loviisa. The scale of years in the figures is not identical (Anttila-Huhtinen & Raunio 2018).

species level, meaning that the occurrence of more demanding species remains unaccounted for. In addition, the index gives the *Marenzelleria* worm the same sensitivity value as the Baltic macoma, even though *Marenzelleria* can live in poor and hypoxic conditions (Anttila-Huhtinen 2018).

The benthic fauna in the littoral zone exhibits variation from one year to the next (Anttila-Huhtinen & Raunio 2018). In 2017, the share of insects was much higher than in the 2014 study, when the community was more marine. The most abundant group of benthic fauna at all sample points in the littoral zone in 2014 and 2017 was crustaceans (including amphipoda of the genus Gammarus). At the sample station closest to the shore, important groups in the benthic fauna consisted of mussels and insects, including chironomid larvae, in addition to crustaceans. The most abundant species of insects was the Caenis horaria mayfly, and among mussels, the small Macoma baltica clams. Further offshore, the share of insects declined and the share of gastropods and oligochaetes increased correspondingly.

The benthic fauna samples covered by the monitoring have also included the larvae of Macroplea pubipennis. Three species of Macroplea beetles are found in Finland. Of these species, Macroplea pubipennis has been categorised as near threatened (NT) in Finland (Hyvärinen et al. 2019). The species of Macroplea beetles cannot be identified during their larval stage, due to which the occurrence of Macroplea pubipennis southwest of Fallholmen, Hudöfjärden, and in the monitored areas in Myssholmen's littoral zone, cannot be ruled out. Macroplea pubipennis is a species listed in Annex II to the Habitats Directive and a species for which Finland is internationally responsible.

Non-native species, or species which do not occur in the monitored area naturally, but have been introduced there inadvertently by human activity, have also spread to the sea area near Loviisa. Given that they often do not have natural predators or competitors, non-native species may reproduce and spread rapidly in their new environment and take up space from other species. In 2017, a total of nine non-native species was detected in the benthic fauna

Table 9-52. Non-native species observed in benthic fauna monitoring and general information on these species (Anttila-Huhtinen & Raunio 2018, Invasive Alien Species Portal 18 February 2021).

Non-native species	English name/group	General information on the species
Marenzelleria	worms, annelids, polychaetes	Soft seabed. Tolerant of hypoxia. First found in the Gulf of Finland in 1990. A dominant species in the outer monitoring stations of the research area. Range covers the entire Baltic Sea.
Paranais frici	oligochaeta	Soft seabed.
Potamopyrgus antipodarum	New Zealand mud snail	Soft seabed/littoral. Spread to the Finnish coast in the 1920s. Has so far not been observed to pose a risk to the ecosystem of the Baltic Sea.
Murchisonella	a marine gastropod mollusc	Littoral. First observed in Hamina in 2013 and in 2014, found in Loviisa. A formal description of the species is yet to be published.
Amphibalanus improvisus	bay barnacle	Hard seabed/littoral. Arrived in the Baltic Sea in the 1840s. Since its spread, has shaped the biotic community of the coasts as a result of competition for space and food. Prevents bladder wrack and mussels, among others, from attaching to surfaces. Causes biofouling.
Cordylophora caspia	brackish hydroid	Hard seabed. Arrived in the Baltic Sea in the 1800s. *Cordylophora* caspia is a warm-water species which can overwinter in cold climates with the help of resting phases. The species may compete for space and food with blue mussels and other species attaching themselves to hard surfaces. Causes biofouling.
Mytilopsis leucophaeta	dark false mussel	Hard seabed/littoral. Currently found only in the surroundings of Loviisa and Olkiluoto power plants. Found in Loviisa in 2003; abundant in Hästholmsfjärden. Competes for habitat and food with other organisms attaching themselves to bases. Causes biofouling.
Gammarus tigrinus	crustaceans	Hard seabeds. First observed in Finland in the area of the Port of Hamina in 2003. Has displaced original species in some places in the Baltic Sea; is an aggressive competitor.
Paleomon elegans	grass prawn	Hard seabed. First found in Finland in 2003. May have displaced original species in some places in the Baltic Sea; is a good competitor.

studies conducted in the joint monitoring of the sea area off Loviisa (Table 9-52). Most of the non-native species were found in the littoral zone. Non-native species found in the area include barnacles (Balanus improvisus), brackish hydroid (Cordylophora caspia) and the dark false mussel (Mytilopsis leucophaeta). The dark false mussel is a species that benefits from the thermal effect. In Finland, it has been found in the nearby sea areas of Loviisa and Olkiluoto nuclear power plants (Invasive Alien Species Portal, 7 April 2021), and only in the monitored areas located within the impact area of the cooling water. The aforementioned three species also cause what is referred to as biofouling, which entails the biological contamination of various underwater surfaces (Anttila-Huhtinen & Raunio 2018).

Among organisms involved in fouling, dark false mussels cause the most problems in the cooling water systems of Loviisa power plant, which is why the power plant has engaged in monitoring and studies of the nearby sea areas in relation to the dark false mussel since 2005. The number of organisms in the seawater systems is also regularly monitored at Loviisa power plant in connection with periodic inspections, and growths which have become too large are removed during annual outages, for example.

9.16.3.9 Sediments

The layers of soil on the seabed near Loviisa power plant consist mainly of moraine or rough soil types, gravel and sand, with clay and silt sand of varying thickness layered on top in places.

The quality of the sediment was studied in the western sea area of Hästholmen, at the intake side of the cooling water, in 2019 (Lindfors et al. 2020). In the report, sediments are categorised in accordance with dredging and stacking guidelines (Ministry of the Environment 2015) (Figure 9-51). The quality of sediment in terms of radioactive substances is described in Chapter 9.8.3.4.

Based on the results, the metal content of normalised sediment samples was of level 1–1A (clean/no impact on stacking suitability). The dioxin and furan contents exceed level 2 (primarily unsuitable for stacking) in eight out of the eleven samples analysed, and all the samples analysed exceeded level 1C (stackable in a "good" stacking area). The content of tributyltin (TBT), which belongs to organotin compounds, and the analysed polyaromatic hydrocarbons (PAH compounds) in the sediments were slightly elevated, but for the most part, the values were at level 1A or lower, and only in isolated cases was the content at level 1B.

Elevated dioxin and furan contents are typical of river basins in the eastern Baltic Sea and the river Kymijoki, due to the area's industrial history. Harmful dioxins and furans are generated inadvertently in various industrial processes, including waste incineration and chemical production. Correspondingly, compounds containing TBT were formerly used in the primers of vessels, for example, to prevent organisms from attaching themselves to the hulls, and in agriculture, as an anti-mildew agent for seeds (Lindfors et al. 2020).

9.16.3.10 Lappomträsket lake

Lappomträsket lake, from which the raw water needed by the power plant is taken, is located roughly five kilometres north of the power plant (Figure 9-30). The lake's water level was lowered decades ago to dry out additional arable land, but later in the 1970s, it was raised again due to the water supply needs of Imatran Voima, now Fortum (Ramboll Finland Oy 2012a). Pike fry are transplanted in the lake, oxidised by Fortum, every year.

The inflow of Lappomträsket lake is in the region of 2.3 million m^3 a year. Water for the power plant's needs is pumped at an average rate of 20–30 m^3 per hour, and the annual need has been roughly 200,000 m^3 a year. Fortum uses less than 10% of the inflow. According to the regulation permit, the regulation's upper limit is 3.25 m, and the lower limit is 2.3 m (N60). According to the permit conditions, water may be taken from the lake at a rate of 180 m^3 per hour on a

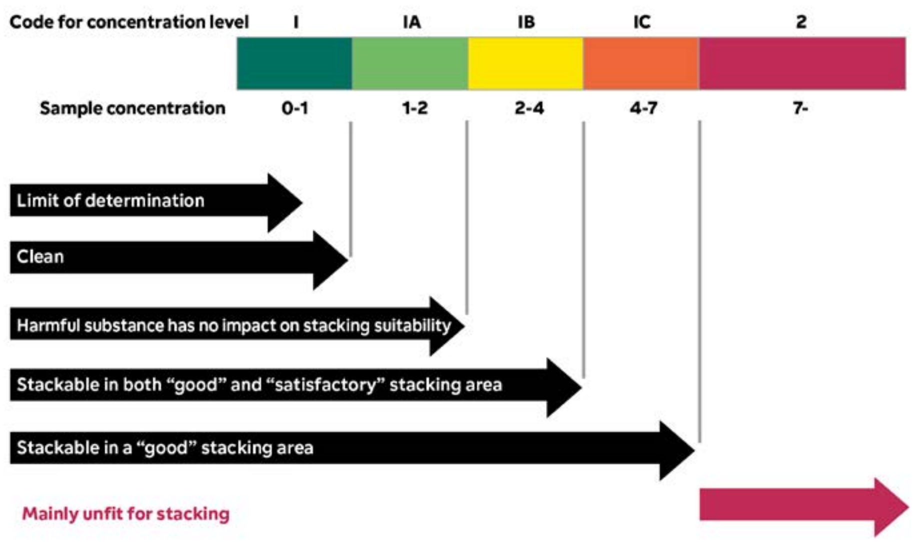


Figure 9-51. Quality grading of normalised sediment (Ministry of the Environment).

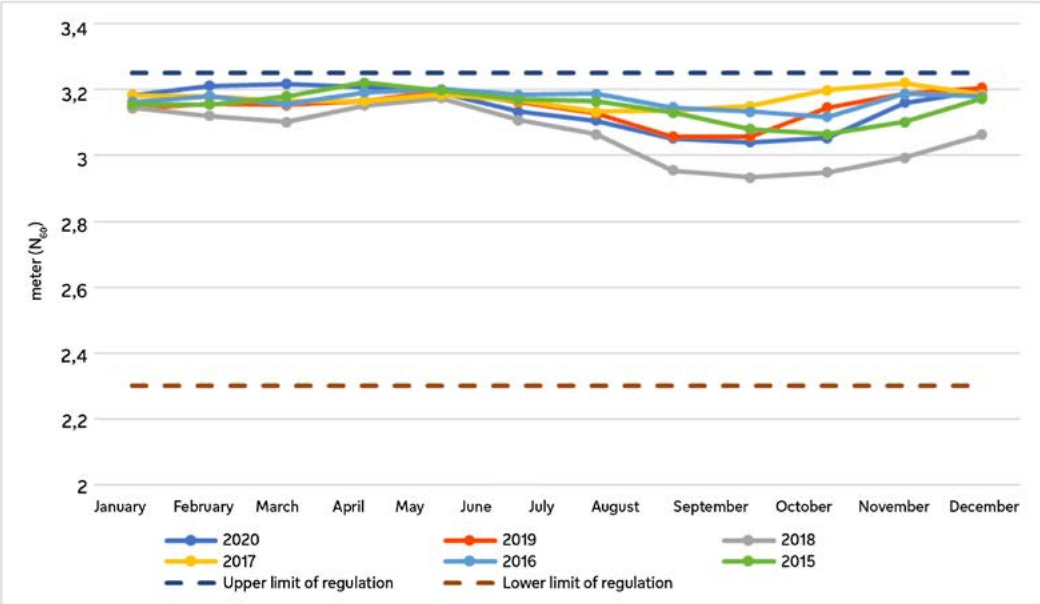


Figure 9-52. Lappomträsket lake's water level as monthly averages in 2015–2020 as well as the upper and lower limit of regulation.

short-term basis and at a maximum rate of 150 m³ per hour over every three months. In 2015–2020, the water level as monthly averages has been fairly stable and remained close to the upper limit of the regulation (Figure 9-52). Variation from one year to the next has also been minor, and there has been no need to empty the lake close to the lower limit. The drainage ditch of Lappomträsket lake has a dam south of Långstrandintie through which water can be run to the bay of Lappomviken when necessary.

According to the data in the watershed model, the phosphorus input entering the lake is fairly minor, 128 kg per year (Watershed model, 18 February 2021). Nor has any internal input been detected in the lake (Niiranen & Hagman 2012). The data on the water quality of Lappomträsket lake from 2011–2018 (Open data, Hertta database, 15 February 2021) have been collected in Table 9-53.

The oxygen content and oxygen saturation of Lappomträsket lake have remained at an at least satisfactory level. The oxidising carried out in the lake has improved the oxygenation conditions. The lake water has been neutral and its alkalinity – or ability to resist pH changes – has been at a good level. The colour standard number of Lappomträsket lake is typical for humic waters. The total phosphorus content and chlorophyll a concentration are typical of mildly eutrophic waters. The total nitrogen content is characteristic of humic waters. The turbidity of the water describes mildly turbid water. As a shallow lake, Lappomträsket is susceptible to sediment resuspension (mixing of sediment into water) (Niiranen & Hagman 2012). On the whole, the quality of the water is good.

The vegetation of Lappomträsket lake consists of common reed and common club-rush, both of which are helophytes. In front of these is a dense accumulation of broad-leaved pond weed, yellow water lily and water lily (Niiranen & Hagman 2012). Elodeids are represented by perfoliate pondweed and water moss. The broadleaved pond weeds form large growths, as do the yellow water lilies and water lilies. No data has been recorded on the lake's benthic fauna community (Open data, Hertta database, 26 March 2021). There have also been drifting turf rafts in the lake, which are thought to have been formed in the shallow peaty shore areas when the lake's surface was raised in the 1970s (Niiranen & Hagman 2012). The vegetation in the shallow shores of Lappomträsket lake is rooted in the littoral zone's organic soil. Currents have carried the rafts detached from the littoral zone by ice in the winter for short distances around the lake. The impacts of regulation are indeed usually the most visible in the littoral zone.

9.16.3.11 Water resources management and marine strategy

The Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy) aims to improve the quality of surface

Table 9-53. Lappomträsket lake's average water quality in 2011–2018. The samples were taken between January and March as well as in July–August.

July–August			January–March		
	Unit	**Average**	**n**	**Average**	**n**
Oxygen saturation rate	saturation (%)	88	4	67	4
Oxygen, soluble	mg/l	7.6	4	9.3	4
pH		7.1	3	6.6	4
Alkalinity	mmol/l	0.2	3	0.3	4
Total phosphorus	µg/l	18.7	3	13.7	4
Total nitrogen	µg/l	653	3	757	4
Turbidity	FNU	2.0	3	3.0	4
Electrical conductivity	mS/m	7.3	3	8.5	3
Colour number	mg/l Pt	62	3	96	3
Chlorophyll a	µg/l	6.2	2	—	—

waters so as to attain a good status in all surface waters and groundwaters. The targeted schedule for the attainment of good ecological potential and chemical status was 2015. The attainment of the objective can be postponed until 2027. Among other things, the goals of the Water Framework Directive involve the prevention and reduction of contamination, the promotion of sustainable water use, environmental protection and the improvement of aquatic ecosystems. In practice, the Water Framework Directive covers the littoral zone in sea areas up to one nautical mile from the boundary of a territorial sea.

Finland's Marine Strategy implements the EU's marine policy and the corresponding Marine Strategy Framework Directive (Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy) at the national level. Finland's marine strategy area extends from the shoreline to the outer limit of the exclusive economic zone and is divided over six Baltic Sea basins in line with HELCOM's agreed basin division. The sea area of Loviisa is located within the Gulf of Finland's sea area.

In Finland, the directives have been implemented with the Act on the Organisation of River Basin Management and the Marine Strategy (1299/2004), the Government Decree on Water Resources Management (1040/2006) and the Government Decree on Water Resources Management Regions (1303/2004). The Finnish government approved the water resources management plans for 2016–2021 in December 2015. The water resources management plans include information on the status of the water environment, the pressures to which the environment is subject, the monitoring of the environment's status, and the measures which have been carried out to attain the goals in terms of the status of surface waters. The coastal waters in the Gulf of Finland are subject to the valid water resources management plan for 2016–2021, concerning the water resources management region of the river Kymijoki-the Gulf of Finland, and the proposal for a water resources management plan for 2022–2027 (Karonen et al. 2015, Mäntykoski et al. 2020).

The Programme of Measures for the attainment of a good status of the environment in sea areas was approved by the government in December 2015 (Laamanen 2016). The programme contains a summary of the status of the marine environment (the qualitative descriptors of the sea's good status) and the human-derived pressures on the marine environment. It also includes details on the measures to be carried out to promote the good status of the marine environment.

Finland's water resources management plans and marine strategy are updated every six years. The plans for 2022–2027 have been drawn up, and the hearings on them ended on 14 May 2021. The water resources management plans and the Programme of Measures will be submitted to the government for approval at the end of 2021.

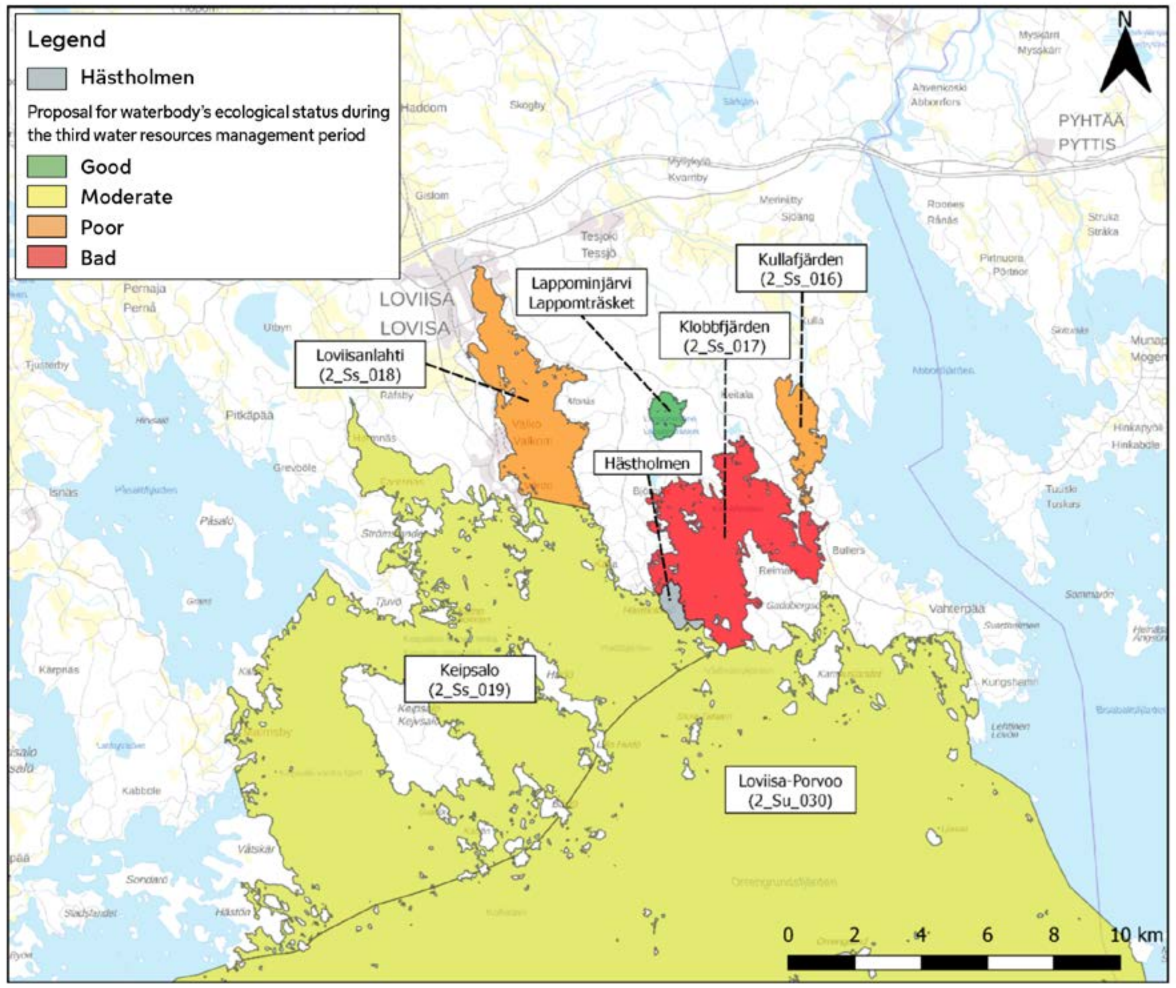


Figure 9-53. A map of the ecological status of surface waters in the bodies of water close to Hästholmen according to the preliminary categorisation of the third planning period of water resources management (SYKE).

A preliminary assessment (the third planning period of water resources management) of the ecological and chemical status of Finland's surface waters has been published (Figure 9-53). According to the assessment, eutrophication is still the biggest problem. The status of the Gulf of Finland's coastal waters has partly improved and is mostly moderate or poor. Nevertheless, the nutrient input continues to be too big and has led to eutrophication, algae blooms and anoxia in the water layer close to the bottom, which has also maintained the internal phosphorus input (Mäntykoski et al. 2020).

The following tables detail the categorisation of the ecological and chemical status of surface waters in Loviisa power plant's nearby sea area and in Lappomträsket lake during the second period of water resources management as well as the preliminary categorisation of the third planning period (Table 9-54 and Table 9-55). The bodies of water in the sea area fall under the surface water type Gulf of Finland's coastal archipelago (Ss) or Gulf of Finland's outer archipelago (Su). Lappomträsket lake is of the surface water type shallow humic lakes (Mh).

None of the sea area's bodies of water in Table 9-54 attained a good status within the original deadline. The grounds for extending the deadline included technical unreasonableness and the superiority of natural conditions. The objective during the third water resources management period is the good status of bodies of water by 2027 (Open data, Hertta database, 3 March 2021).

The area of the **Klobbfjärden** body of water is 15.7 km². Small improvements have occurred in the individual quality factors of the ecological status. Of the biological quality factors, the status of benthic fauna has improved to poor in the preliminary categorisation of the third planning period of the water resources management, and the category of physico-chemical improved from bad to poor. Based on the additional physico-chemical variables (there are no category limits for the variables in question), most of the water column suffers from oxygen depletion or hypoxia every year. In the preliminary status assessment of the third planning period, the ecological status has remained the same as during the previous water resources management periods (Open data, Hertta database, 3 March 2021).

The area of the **Loviisanlahti** body of water is 11.3 km². No significant changes have taken place in the status. Of individual quality factors, total nitrogen has improved from poor to moderate, but there are no changes in the ecological status assessment.

Table 9-54. The ecological and chemical status of the bodies of water surrounding Loviisa power plant during the second planning period of water resources management and a preliminary assessment of the status of the third planning period. Numerical values have been given in terms of the biological and physico-chemical variables. The categorisation data have been retrieved from the Open data Hertta database.

Body of water		Biological quality factors					Physico-chemical quality factors				Hydro-morphological change	Ecological status	Chemical status
		Chloro-phyll a	Phyto-plankton total biomass	Benthic fauna	Bladder wrack minimum sheltered/ open	Biological Category, total	Total phosphorus	Total nitrogen	Depth visibilit	Physico-chemical category, total			
	Water resources management period	µg/l	mg/l	BBI	m		µg/l	µg/l	m				
Klobbfjärden 2_Ss_017	2nd period	10.5	—	0.07	—	Bad	28.7	401.4	2.1	Bad[1]	Good	Bad	Good
	3rd period	9.39	—	0.19	—	Bad	28.6	379.1	2.2	Poor[2]	Good	Bad	Less than good
Loviisanlahti 2_Ss_018	2nd period	13.4	—	—	—	Poor	38.4	486.1	1.3	Poor	Poor	Poor	Good
	3rd period	7.62	—	—	—	Poor	39.6	415.4	1.51	Poor	Poor	Poor	Less than good
Keipsalo 2_Ss_019	2nd period	7.9	—	0.06	2.5/2.8	Poor	26.9	389.4	2.6	Moderate	Excellent	Poor	Good
	3rd period	5.86	—	0.58	1.9/2.6	Moderate	27.8	355,1	2.86	Moderate	Excellent	Moderate	Less than good
Loviisa-Porvoo 2_Su_030	2nd period	6.2	1.1	0.23	3.5/3	Poor	24.4	371.6	3	Moderate	Excellent	Poor	Good
	3rd period	5.73	0.83	0.45	3.4/3.3	Moderate	23.2	339.4	3.4	Moderate	Excellent	Moderate	Less than good

Ecological status	Excellent	Good	Moderate	Poor	Bad
Chemical status	Good	Less than good			

[1] Significant observed oxygen problems
[2] Oxygen problems

Table 9-55. The ecological and chemical status of the Lappomträsket lake body of water during the second planning period of water resources management and a preliminary assessment of the status of the third planning period. Numerical values have been given in terms of the biological and physico-chemical variables. The categorisation data are narrow. The categorisation data have been retrieved from the Open data Hertta database.

Quality factor	Unit	Lappomträsket lake 81V026.1.004_001					
		2nd period			3rd period		
		Numerical value	Ecological status	Chemical status	Numerical value	Ecological status	Chemical status
Chlorophyll a	µg/l	5.6	Good	Less than good	6.2	Good	Less than good
Phytoplankton total biomass	mg/l	3.39			3.17		
Percentage of harmful algae	%	4.38			0		
TPI		0.66			-0.66		
Biological category, total		Good			Good		
Total phosphorus	µg/l	15			24		
Total nitrogen	µg/l	660			740		
Physico-chemical category, total		Excellent			Good		

Ecological status	Excellent	Good	Moderate	Poor	Bad
Chemical status	Good	Less than good			

The ecological status of the **Keipsalo** and **Loviisa-Porvoo** bodies of water has improved from poor to moderate. The improved status is the result of an improvement in the status of the biological quality factors (chlorophyll a and benthic fauna) compared to the earlier categorisation. The area of the Keipsalo body of water is 98.5 km^2 and that of the Loviisa-Porvoo body of water 1,050 km^2.

The category of the physico-chemical quality factors of the **Lappomträsket lake** body of water has declined from excellent to good, but the change is so minor that there has been no change in the ecological status. The chemical status has remained less than good; it is influenced particularly by the quality norm of mercury being exceeded in perch. The mercury derives primarily from atmospheric deposition, which ends up in the waterways as a result of leaching.

The **chemical status** of surface waters has remained largely unchanged, but the strict environmental quality norm of polybrominated diphenyl ethers (PBDE), used as flame retardants, results in a less-than-good chemical status in all of Finland's surface waters. The chemical status has therefore also declined to less than good in the bodies of water within the Loviisa sea area.

In the marine strategy, the current status of the marine environment is assessed in relation to the qualitative descriptors of a good status, of which there are 11 in all. Condensation waters, i.e. cooling waters, are mentioned in connection with two qualitative descriptors of the current status: "permanent changes in hydrographic conditions do not have an adverse impact on marine ecosystems" and "conducting energy into the sea, including underwater noise, is not of a level that would have an adverse effect on the marine environment (energy and underwater noise)". In terms of the qualitative descriptor describing hydrographic conditions, the Programme of Measures states that "the condensation waters of power plants raise the temperature of water locally, which strengthens eutrophication in discharge locations and creates conditions for changes in the species of organisms. New non-native species are often found in the impact areas of condensation waters. These impacts are largely local." In terms of the qualitative descriptor related to the conduction of energy into the sea, it is stated that the impacts are local and extend to a distance of a few kilometres from power plants (Laamanen ed. 2016)

The proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027 states the following: "Heat is conducted into the sea as a by-product of electricity production in the condensation waters of power plants or within the cooling waters of various processes in the industrial sector. The impacts are usually local and extend to a distance of a few kilometres from the power plant. The impact of the thermal load is so local that it is not found to have an impact on the status of the sea" (Laamanen et al. 2020).

The following table shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4). Table 9-56 shows the sensitivity of the affected aspect and some factors determining sensitivity (Chapter 9.1.4).

9.16.4 Environmental impact of extended operation

Impact formation

In extended operation, the operations would continue to be similar to what they currently are. The most significant impact would be attributable to the thermal load on the sea area, which results from the conduction of cooling water there. No changes to the annual level are expected.

The potential impacts of the thermal load are attributable, among other things, to changes in the temperature and stratification conditions of the water close to the discharge location and the longer growing season. The temperature stratification weakens the mixing between the surface and hypolimnion layers as well as the exchange of oxygen and nutrients occurring between the layers. The higher temperature of the seawater may also accelerate the metabolism and growth of the aquatic organisms, increasing the production of organic matter. This being the case, the thermal effect may also contribute to the eutrophication trend, provided that other factors, such as the availability of nutrients or light, do not limit primary production. In addition, the elevated temperature of the seawater accelerates the microbiological degradation of organic matter, meaning that the oxygen consumption may increase hypoxia in the water layer close to the bottom. Hypoxia or anoxia intensify the internal input, which is manifested as high nutrient concentrations in the hypolimnion and is a factor increasing eutrophication. Hypoxia furthermore weakens the living conditions of benthic fauna. In addition to the aforementioned, the potential consequences of eutrophication include the growing abundance of phytoplankton and aquatic vegetation as well as structural changes in the water ecosystem.

Sea areas in which the water temperature remains higher than the natural temperature throughout the year may function as areas receiving non-native species, in which the spread and adaptation of a new species are easier than in sea areas not impacted by the thermal effect.

The impacts on Lappomträsket lake's raw water source are attributable to variations in the water level. Alternative ways to obtain raw water have been reviewed in terms of raw water sourcing.

Table 9-56. Sensitivity of affected aspect: surface waters.

Sensitivity of affected aspect: surface waters	
General factors impacting the sensitivity of surface waters include factors related to the area's value, such as conservation values and the occurrence of protected or sensitive species or underwater natural habitats. The area's resilience is impacted by the environmental factors of the impact area, including the size of the catchment area, the volume of the water area, and the current and mixing conditions. The risk of a deterioration in the ecological or chemical status of a body of water is also considered a criterion increasing sensitivity.	
Moderate	There are no special or sensitive aspects within the immediate vicinity of the **sea area's** impact area which would be impacted by the quality of water and any changes to it, but the near threatened Macroplea pubipennis may be found in the area. The water exchange of the principal affected aspect, the Hästholmsfjärden sea area, is limited by fairly narrow and shallow straits, which weakens the mixing conditions in the cooling water's discharge area. Further offshore, the mixing conditions are more favourable. The ecological status of the bodies of water within the impact area has not attained a good category, although small improvements compared to earlier water resources management periods have been observable. This is considered a factor increasing sensitivity. **Lappomträsket lake** is small in terms of its volume and shallow, which increases the lake's sensitivity. The lake is regulated for the needs of Fortum's raw water intake. The objective for the lake's ecological status has been attained.

9.16.4.1 Results of the cooling water modelling

The thermal load's impact on the sea area's temperatures and water quality was assessed by modelling the dispersal of the cooling water (see Chapter 9.16.2.2 and Appendix 4). The impact of climate change was accounted for in the modelling concerning the ice-free season (summer situation) (Chapter 9.16.2.2). The impacts of the thermal load are also described in the section on the present state in Chapter 9.16.3.3. In terms of the impacts of the thermal load, it should be noted that the impact is not an aggregating (accumulating) variable, given that heat transfers to the atmosphere continuously during the ice-free season, and that the warmed cooling water mixes with the cooler seawater. The seawater's surface temperature impacts the transfer of heat so that as the water evaporates into the atmosphere, the higher the surface temperature is, the more heat is transferred (An et al. 2017). Heat transfer from the surface via convection likewise increases. This limits the temperature increase resulting from intensified stratification and the maximum temperatures themselves on the surface of the water.

According to the cooling water modelling, the thermal impact of the ice-free season is at its greatest in the immediate vicinity of the discharge location and decreases when moving further away. The average increase in the temperature of the seawater (Figure 9-54) would be roughly similar to its current level. In Hästholmsfjärden, at buoys A, B and C, close

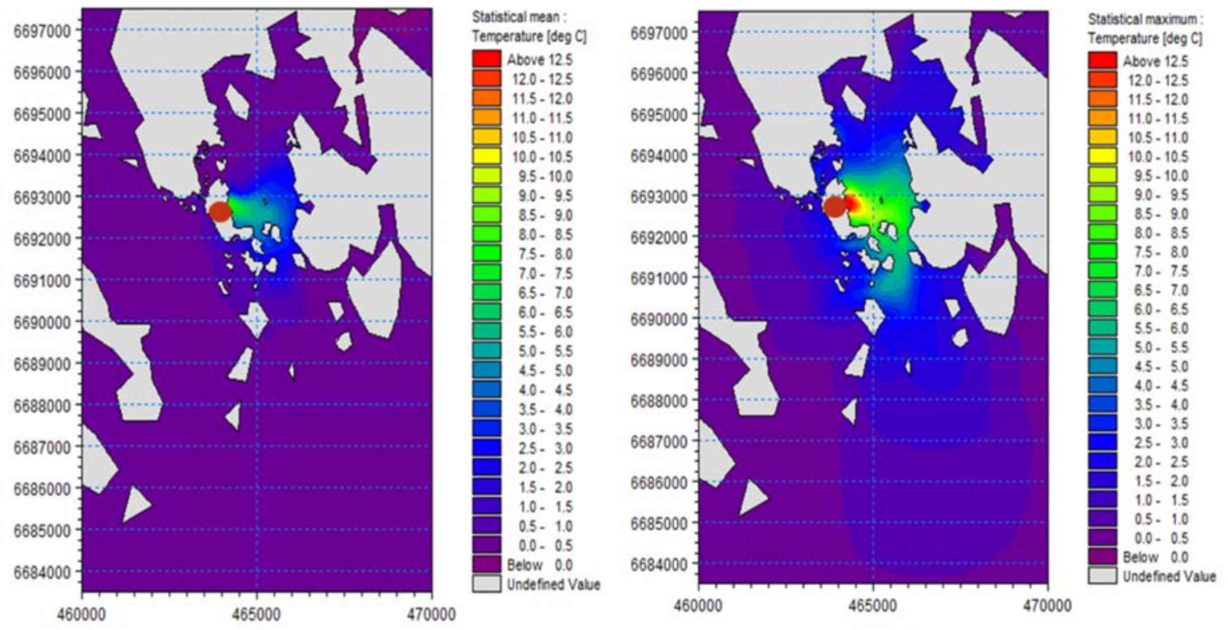


Figure 9-54. Difference image of the temperature increase caused by the power plant's operation in summer (difference: power plant in operation – power plant decommissioned). The image on the left shows the average, and the image on the right the maximum. Hästholmen's location is indicated with a red dot (Lahti 2021; Appendix 4).

to the cooling water's discharge location (see Figure 9-37 for the location of the buoys), the surface temperature of seawater is 1–11 °C warmer than in situations when the power plant is not in operation (Figure 9-54). The range of variation in the surface temperatures is largely explained by changes in the wind conditions, which impact the transport of the cooling water. In Hästholmsfjärden, close to the bottom, the temperature increase occurs gradually over the summer and is approximately 2–3 °C in August.

As can be seen from the images depicting the dispersal, the average surface temperature of the seawater in the immediate vicinity of the discharge location can be around 25–27 °C during a warmer than average summer, and roughly 30 °C in a maximum situation (Figure 9-54 and Figure 9-55). However, the surface temperature rapidly drops when moving further away, given that the surface water is mixed with the rest of the water column horizontally and vertically, and heat is also transferred into the atmosphere. The average surface temperature increases by roughly 2 °C in southern Hästholmsfjärden. In western and northern Hästholmsfjärden, the estimated impact no longer exceeds parts of a degree due to the slow flow of water into these areas. Based on the modelling results, surface water temperature may nevertheless occasionally rise in some of these areas due to the thermal effect of the cooling water, with the maximum increase being 2 °C. When calculated for the Klobbfjärden body of water, the average rise in surface temperature is approximately 1 °C (Lahti 2021; Appendix 4).

Based on the cross-sectional views, the warm water stratifies in the surface layer of the seawater (Figure 9-56), being bounded mainly to the topmost five-metre layer of water in the southern part of Hästholmsfjärden (Lahti 2021; Appendix 4).

In Hudofjärden, at point K1, the temperature is, on average, approximately 0.1–0.9 °C higher than in a situation in which there is no thermal effect attributable to cooling water. The thermal effect in Hudöfjärden is minor and usually limited to the northeastern sea area, close to Hästholmen (Figure 9-54 and Figure 9-55). However, under some weather conditions, the surface temperature can occasionally rise by a maximum of 2 °C in the parts of Hudöfjärden close to Hästholmen.

In Vådholmsfjärden, at point K2 in front of the straits from Hästholmsfjärden, the surface temperature of the seawater can be 0–4.5 °C higher than in a situation where there is no

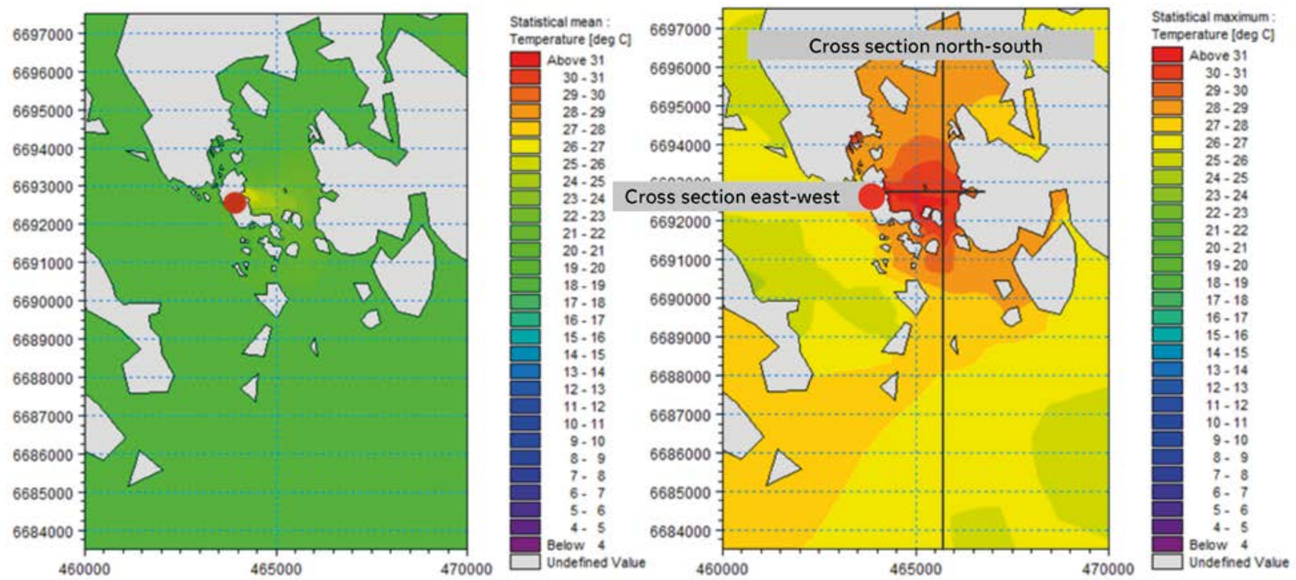


Figure 9-55. Temperature of seawater in the surface layer in the summer, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west direction and in the north-south direction are indicated in the image on the right (see following image). Hästholmen's location is indicated with a red dot (Lahti 2021).

thermal effect attributable to cooling water. Based on the images depicting the dispersal, the most intense thermal effect is focused on the surface layer and limited to the northern part of Vådholmsfjärden, in front of the straits leading there from Hästholmsfjärden (Figure 9-54 and Figure 9-55), where the average increase in temperature is around 2 °C (Figure 9-54). In the southern part of Vådholmsfjärden, the maximum temperature increase is around one degree centigrade. Deeper down, the impact is smaller (Lahti 2021; Appendix 4).

At observation point K3 in Orrengrundsfjärden, the thermal effect on the surface layer is very small. In a small area in the northwestern part of Orrengrundsfjärden, the effect is close to 0.5 °C, the maximum being approximately 1.5 °C at the part leading to Vådholmsfjärden (Figure 9-54) (Lahti 2021; Appendix 4).

According to the modelling, during the ice season in Hästholmsfjärden, at data buoys A, B and C, close to the discharge location (see Figure 9-37 for the location of the

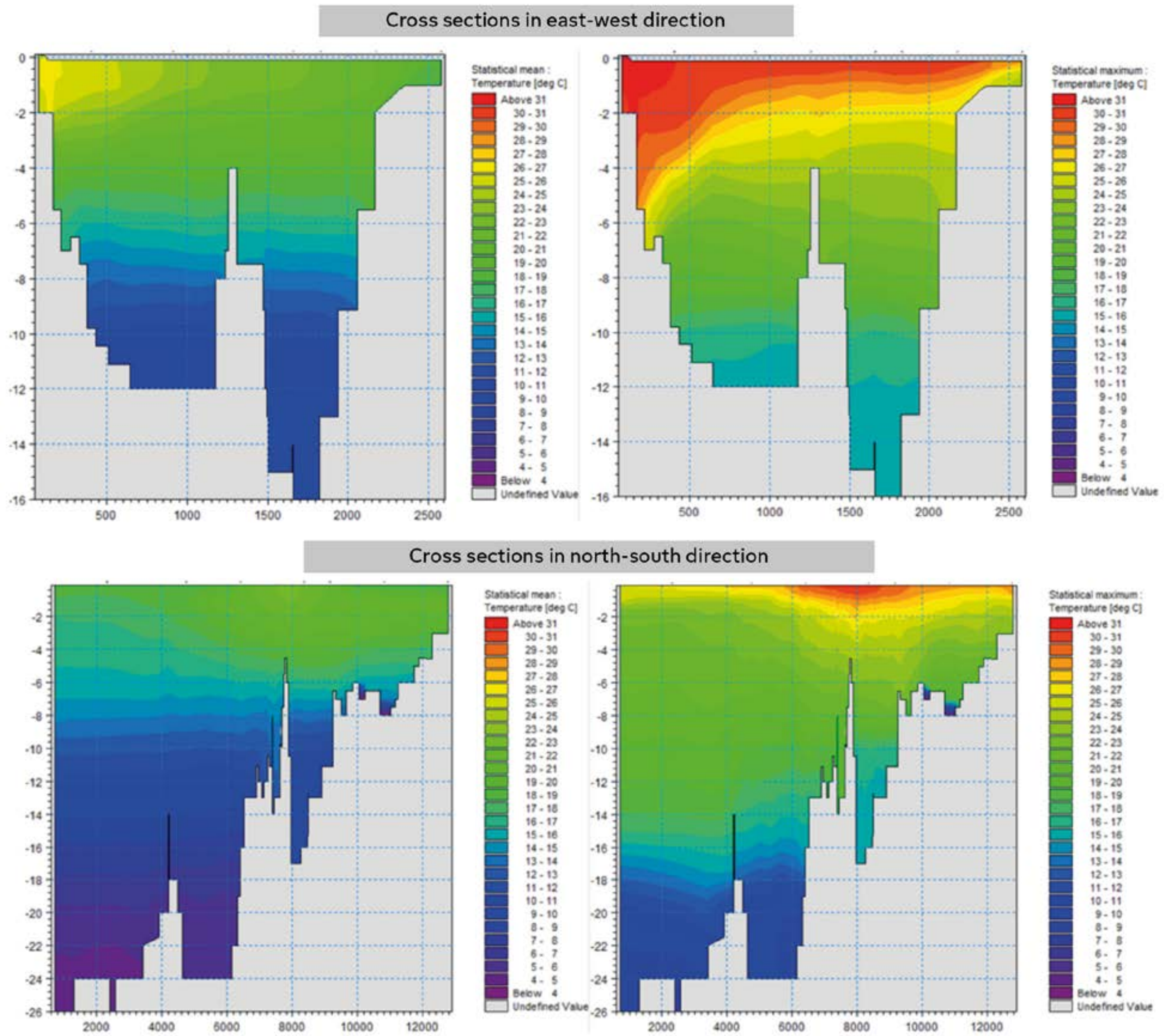


Figure 9-56. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the summer, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the discharge of the cooling water is in the upper left-hand corner of the image.

buoys), the temperature of the seawater is around 5–16 °C, 5–9 °C and 3–5 °C higher at a depth of one metre, four metres and near the bottom, respectively, compared to a situation in which the power plant is not in operation (Lahti 2021; Appendix 4). As can be seen from the images depicting the dispersal, the greatest thermal effect in the winter focuses on the area of Hästholmsfjärden, close to the surface layer (Figure 9-57 and Figure 9-58).

A temperature increase of roughly 0–3 °C attributable to the recirculation of warm cooling water can be detected at point K1 in Hudöfjärden when the power plant is in operation. This increase is primarily confined to a depth of 4–5 m (Lahti 2021).

In Vådholmsfjärden, the temperature increase is focused on the northern part of Vådholmsfjärden, in front of the straits leading there from Hästholmsfjärden (Figure 9-57 and Figure 9-58), where a thermal effect can be seen to varying degrees at all depths at point K2. The thermal effect is at its greatest at a depth of approximately five metres, being around 5 °C higher than in a situation in which the power plant is not in operation. The temperature increase is at its smallest close to the surface (Lahti 2021). In Orrengrundsfjärden, the thermal effect is minor, ranging between 0 and 0.8 °C, and focusing at depths below five metres.

9.16.4.2 Impacts on the sea area's temperature and stratification conditions

The thermal effect on the sea area (57,000 TJ per year, on average) attributable to the conduction of the cooling water used by the power plant would remain of the same annual magnitude as its current level. The impacts would not last beyond 2050 or so, following the expiration of the current operating licences.

During the ice-free season, the thermal effect is local, and mainly observable in Hästholmsfjärden and occasionally in front of the straits between Hästholmsfjärden and Vådholmsfjärden, in the surface layer of the northern part of Vådholmsfjärden. The temperature increase caused by the cooling water would remain unchanged, because no changes are expected to occur in the permit conditions for the temperature and flow of cooling water conducted from the plant to the sea. However, due to the impact of climate change, the probability of warmer than average summers is likely to grow. The selection of an exceptionally warm modelling year therefore offers an opportunity to assess the development in the temperature conditions of seawater in the future, as the climate warms.

The surface temperatures that form during a warmer than average year are slightly higher than the average and maximum temperatures of the ice-free seasons (June–September) in 2010–2020 (Table 9-50). The summer temperatures of 2011 are likely to be fairly typical of the climate conditions in 2030–2050, or at least significantly more common than at the beginning of the 2010s. The modelling results of the review period therefore provide an idea of the seawater temperatures during the middle of this century. A rise in surface temperatures may also have an impact on the discharge of cooling water in the future. According to Loviisa power plant's environmental permit, the hourly average temperature of the cooling water conducted to the sea may not exceed 34 °C. In other words, when the temperature of the cooling water taken from the sea rises to a degree where the power plant's power must be limited for the temperature of the discharged cooling water to remain below 34 °C, the relative share of the power plant's thermal effect will also reduce.

According to the assessment based on the modelling, the temperature and stratification conditions during the ice-free season would remain largely unchanged from their current levels. In the present state, the seawater's temperature and stratification conditions in the discharge side are significantly shaped by the thermal effect of the cooling water, but the effect is primarily confined within the area of Hästholmsfjärden, in which the thermal effect has intensified the vertical temperature stratification (Chapter 9.16.3.3).

During the ice season, the thermal effect would remain unchanged from its current level, and the extended operation would not result in a significant change. In terms of the present state, it should be noted that particularly the temperature and stratification conditions of Hästholmsfjärden clearly depart from the natural conditions. The thermal load's impact on the nearby sea area is the easiest to detect in wintry conditions, when the warm cooling water keeps the sea area close to the discharge location free of ice.

As the section concerning the present state describes (Chapter 9.16.3.4), climate change is expected to reduce the area of the Baltic Sea's ice cover and shorten the ice winter (Climate Guide 2021). The variation between winters is nevertheless expected to remain a natural feature of ice conditions. The ice cover is effective in preventing the thermal energy from transferring to the atmosphere, once the cooling water has sunk more deeply and passed beneath the ice. During mild winters, when the area covered by ice is small or there is no ice at all, the thermal effect of the cooling water will be proportionately smaller, and the warm water will not disperse to as large an area as described above. On the other hand, the thermal effect of the cooling water and the impact of climate change may result in a mild combined impact in the future, due to which the area covered by the ice may reduce slightly, and the ice may become thinner than its present level, disrupting movement on the ice, for example.

The impact of the thermal effect is local, mainly confined within the area of Hästholmsfjärden and partly maintaining the temperature and stratification conditions in the nearby sea area of Hästholmen. The impact further out in the sea area is minor. The temperature increase caused by the thermal load would be of the same magnitude as in the present

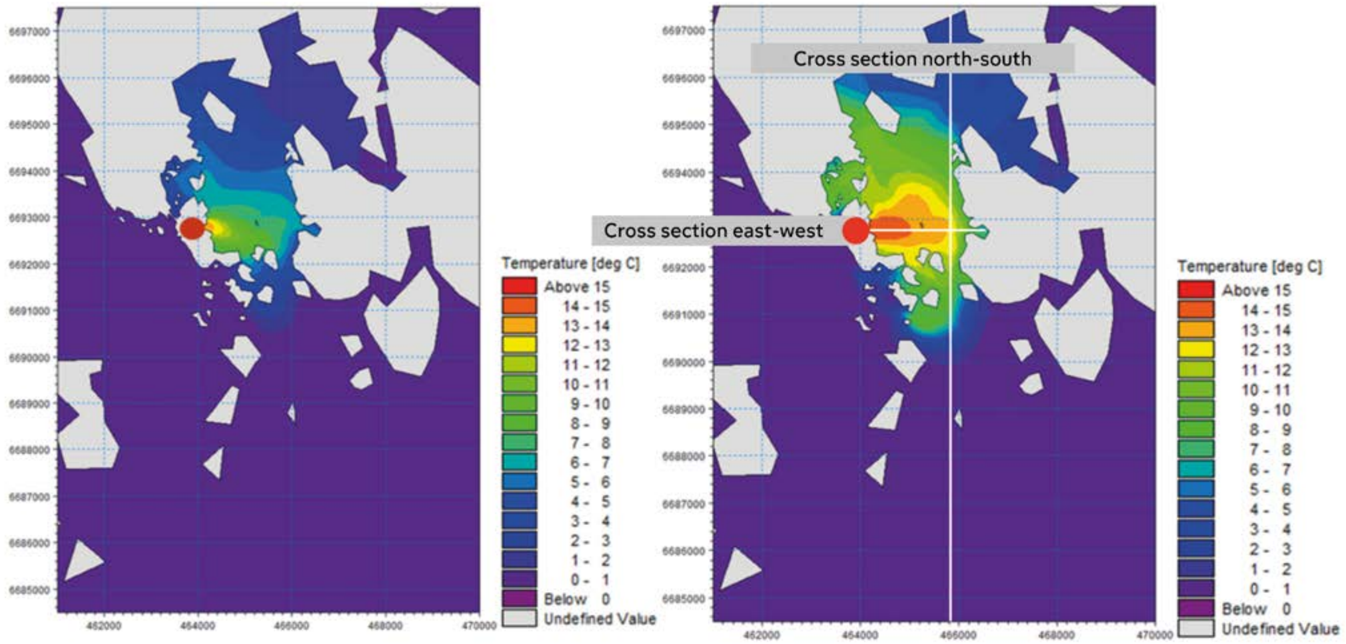


Figure 9-57. Temperature of seawater in the surface layer in the winter, when the power plant is in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west and north-south directions are indicated in the image on the right (see following images). Hästholmen's location is indicated with a red dot (Lahti 2021).

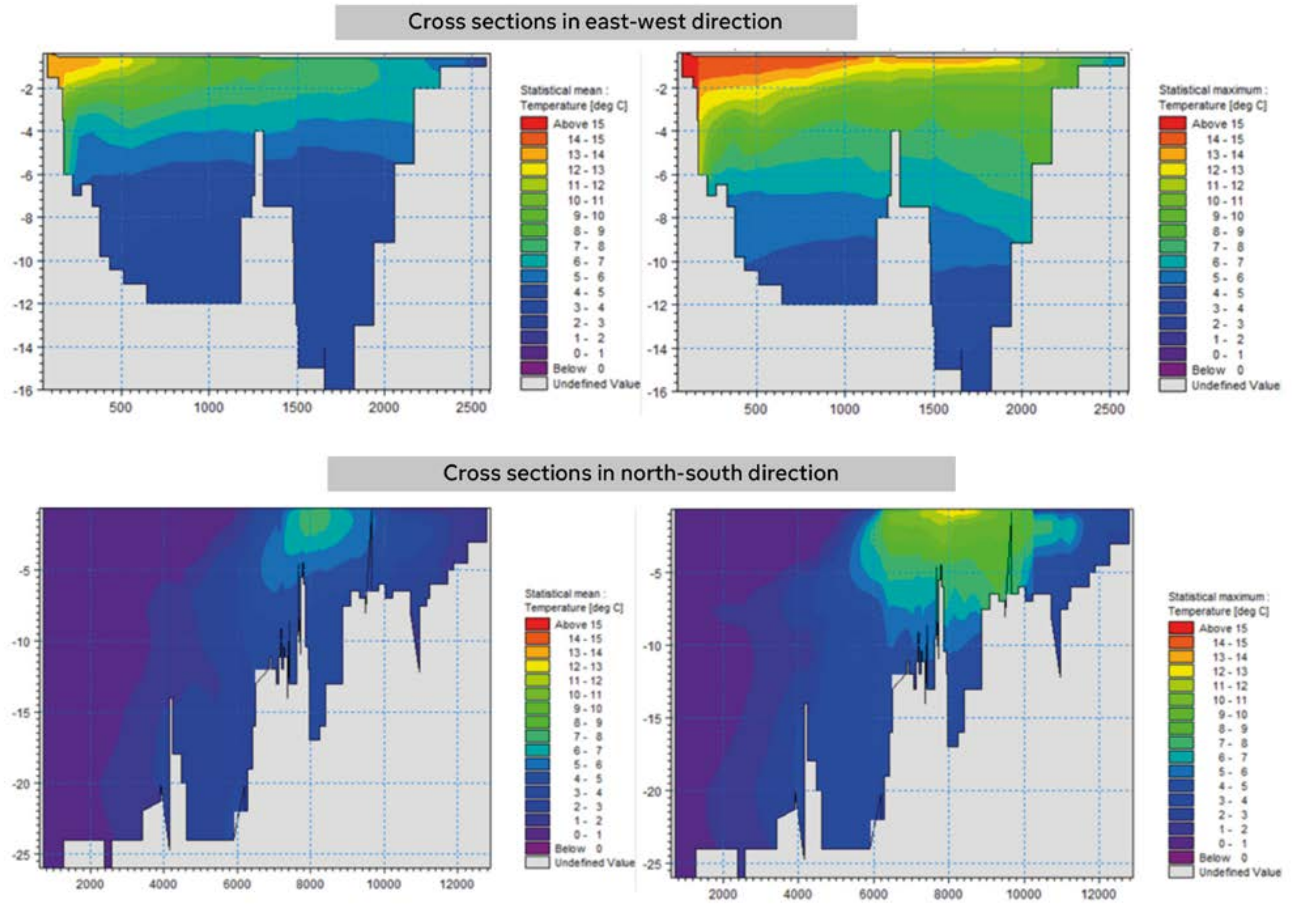


Figure 9-58. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the winter, when the power plant is in operation. The images on the left show the average, and the images on the right the maximum, situation. In the east-west cross section, the discharge of the cooling water is in the upper left-hand corner of the image.

state, but an increase in the number of warmer-than-average years may translate in the coming decades into a slight increase of the seawater's surface temperature compared to the present state. An increase in the number of mild winters may impair the sea area's use in the winter to a minor degree, due to the weaker ice cover. In extended operation, the thermal load would maintain atypical temperature and stratification conditions that would be more intense than the natural ones in Hästholmsfjärden. These would continue for some 20 years following the expiration of the current operating licences, until around 2050 at the latest. Based on this, the magnitude of the change compared to the present state was deemed moderate and negative in Hästholmsfjärden, and at most minor and negative in the other nearby sea areas.

9.16.4.3 Impacts on the quality of water

The impacts on the temperatures and stratification of the sea area described above also have an impact on the water quality. The Gulf of Finland's general eutrophication trend is visible in the sea areas near Loviisa power plant, where distinguishing the thermal effect from the general eutrophication is challenging. Based on the long-term monitoring of the nearby sea area of Loviisa, it is known that the warmed seawater has contributed to a strengthening of eutrophication attributable to an excessive nutrient input within the thermal effect's impact area, especially in Hästholmsfjärden. Climate change increases the mean annual temperature, which is expected to increase the diffuse source input of nutrients. The impact assessment must therefore account for the impact that climate change will have on the development of the nutrient pollution.

In the case of extended operation, the power plant's wastewater discharges would remain unchanged. The impact of radioactive emissions is assessed in Chapter 9.8. In terms of nutrient pollution, Loviisa power plant's share of the sea area's other point source pollution and diffuse pollution would continue to remain very low (Chapter 9.16.3.2). Currently, the sanitary wastewaters are treated in the power plant area's wastewater treatment plant and conducted to Hudöfjärden. In the case of extended operation, the continued use of the power plant area's wastewater treatment plant 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 conducted to the town of Loviisa's (Loviisan Vesiliikelaitos) Vårdö wastewater treatment plant, in which case the impact would still focus on Hudöfjärden, but on a different location within it. The potential change would not have an impact on the input which, in the power plant's case, is extremely low in relation to the other input sources. The input's impact on the sea area's water quality is expected to be extremely small.

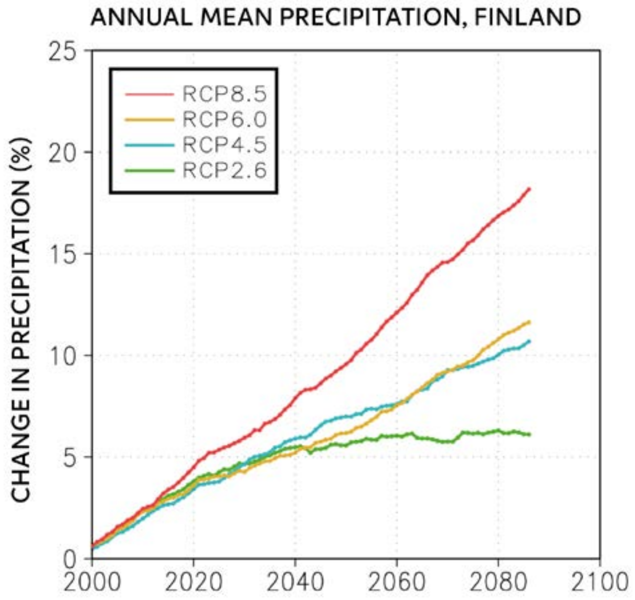


Figure 9-59. Change in annual precipitation in Finland in 2000–2085 compared to the average of 1981–2010 (as percentages). The changes are averages of the results of 28 global climate models presented separately for four greenhouse gas scenarios (RCP8.5: very high emissions; RCP6.0: comparatively high emissions; RCP4.5: comparatively low emissions; and RCP2.6: very low emissions) (Climate Guide 2021, Ruosteenoja et al. 2016).

Climate change is expected to increase the nutrient pollution of waterways in general and thereby eutrophication, given that the lack of snow on fields is likely to increase the leaching of nutrients – phosphorus and nitrogen – into waterways in the winter (Mäntykoski et al. 2020). This is the result of increased precipitation and increasingly strong rainstorms as the climate warms (Climate Guide 2021, Ruosteenoja et al. 2016) (Figure 9-59). An increase in run-offs and rainstorms is also likely to increase nutrient pollution in forests, since a significant part of the nutrients of forested land leach into waterways during floods. The coastal regions of southern and southwestern Finland are expected to experience the greatest impact of the increased input (Mäntykoski et al. 2020).

The watershed model assesses various input scenarios in relation to different RCP scenarios (see Chapter 9.16.2.2 for descriptions of the RCP models) and the agricultural sector's water protection measures. In the period 2021–2050, the total phosphorus input in the Gulf of Finland is expected to grow slightly (by approximately 1.5–72 t per year) compared to 2010–2019 in climate scenarios in which current water resource management measures would be in use. "Current measures" refers to agriculture continuing as at present, and other input sources remaining at the current level. Were the agricultural measures applied in full, the input is expected to decline (depending on the climate scenario, the decrease would be in the range of 50–134 t per year). In addition to applying gypsum to agricultural fields, "agricultural measures" refers to the adoption of focused fertilisation, a maximum quantity of wintertime plant cover, catch crops, structural liming/fibre treatment and slurry placement, while the cultivation areas and yields of various crops would remain similar to their current levels. In the watershed model scenario, the attainment of the targeted input of phosphorus with current measures is unlikely, but with the full-scale adoption of the agricultural measures, the targeted input could be attained (VEMALA, data retrieved 3 March 2021).

According to the watershed model, the Gulf of Finland's nitrogen input would appear to decrease in the 2021–2050 period in the scenario in which the agricultural measures are in full-scale use (a decrease of approximately 400–1,570 t a year). With the current measures, the input would grow slightly in the RCP scenarios RCP4.5 (intermediate climate change scenario) and RCP8.5 (strong climate change scenario) (VEMALA, data retrieved 3 March 2021).

The phosphorus and nitrogen inputs off shore of Loviisa are likely to remain around the current level for the 2021–2050 period in climate scenarios in which the current measures are in use. If the agricultural measures are applied in full, the input is likely to decline (VEMALA, data retrieved 3 March 2021).

Climate change and the resulting warming of the Baltic Sea could also have other impacts on the marine ecosystem. Changes in the severity of winter affect the mixing of water in the winter and thereby the spring conditions. In ice-free winters, significant amounts of the phosphorus in a halocline in the Baltic Proper and in the Gulf of Finland may mix with the water column above during winter storms. Strong blue-green algae blooms may emerge if there are calm and warm periods during the following summer, as was the case in 2014 and 2018. This stock of nutrients, mainly located in the deep water of the Baltic Proper, will also slow down any improvement in the status of the Gulf of Finland, even if the external nutrient pollution is cut, given that the Gulf of Finland's sea area falls under the sphere of influence of the anoxic waters in the Baltic Proper. Any upwelling events caused by wind also transport nutrient-rich water into the surface water which, under favourable conditions, intensifies algal blooms. A decrease in the number of revitalising major Baltic inflows, combined with a high level of primary production and the consequential abundant sedimentation of organic matter, has led to a situation in which there was more hypoxic water across the entire Baltic Sea in 2018–2020 than ever before during the measurement history (Laamanen et al. 2020).

Based on the monitoring, the changes that have taken place in the status of the Gulf of Finland are also reflected in the state of the power plant's nearby sea area. For example, the impact of the major Baltic inflows in 2014–2016 was visible in the 2018 results of the Loviisa waterway monitoring as an increase in the chlorophyll a concentration and primary production (Anttila-Huhtinen & Raunio 2019).

In extended operation, the quality of water in Loviisa power plant's nearby sea area is expected to remain close to the present state (see Chapter 9.16.3.5). However, the long-term projections of the nutrient pollution involve uncertainties attributable to the uncertainty related to the materialisation of climate change scenarios and particularly to the extent to which and how fast the measures reducing agricultural pollution will be implemented in the catchment area of the Loviisa coast. What is especially significant with respect to the status of the Klobbfjärden body of water is the long-term development of the input carried by the river Tesjoki. As was stated in terms of the thermal load (Chapter 9.16.4.1), an increase in the number of warm summers in the long term as a result of climate change, coupled with the thermal load of the cooling water, may increase the thermal effect in the sea area to a minor degree. According to the modelling, the impact would be most significant in Hästholmsfjärden. Should nutrient pollution simultaneously increase, Hästholmsfjärden's water quality would be subject to a combined impact, given that the thermal effect is known to contribute to a strengthening of the eutrophication trend resulting from excessive nutrient pollution. The impact on the water quality would probably be manifested as a slightly rising trend in nutrient pollution in long time series. The oxygenation conditions in the hypolimnion of Hästholmsfjärden's deeper areas would continue to be weak, enabling the potential occasional continuation of the internal input of phosphorus.

On the other hand, if all the agricultural measures are adopted, nutrient pollution would probably reduce, and eventually result in the decline of nutrient concentration in the sea area and a decrease in the production level, which would reduce the oxygen-consuming effect of organic matter in the water layer close to the bottom, thereby improving the oxygen conditions. This scenario is expected to have a positive impact in the Klobbfjärden body of water. Potential changes in the quality of water are reflected in the food web with a delay. These impacts are discussed in the following chapters.

In extended operation, the impacts would not continue beyond the 2050s, but the changes compared to the present state are expected to be minor. The materialisation of the climate and input scenarios introduces uncertainty to the assessment. The magnitude of the change in the water quality compared to the present state is deemed, in extended operation and accounting for the precautionary principle, minor and negative in Hästholmsfjärden (in the Klobbfjärden body of water). In the other sea areas, the water quality is determined primarily on the basis of the long-term development of the nutrient pollution and the general development in the status of the Gulf of Finland, and the water quality is not expected to be impacted.

9.16.4.4 Impacts on phytoplankton and aquatic vegetation

The impacts on phytoplankton and the aquatic vegetation are indirect and partly attributable to a potential change in the quality of water. Based on the water quality assessment, the impacts are expected to remain more or less similar to their current levels (see Chapter 9.16.3.6 and 9.16.3.7). Based on the long time series, eutrophication has been slightly stronger in the area of Hästholmsfjärden than in the other sea areas close to the power plant. Several annual filamentous algae and vascular plants, among others, have benefited from the warmed water and longer growing season, whereas some aquatic plants sensitive to the deterioration of water quality have declined (see Chapter 9.16.3.7). The strongest eutrophication is seen at a roughly 1 km radius of the cooling water's discharge location (Ilus 2009).

Ice winters are projected to shorten from both ends over the long term as a result of climate change, but the freezing period will change more than the date on which the ice melts (Climate Guide 2021). In the present state, ice winters in sea areas near Hästholmen have been varying, ranging from nearly ice-free winters to more severe ones. This variation is expected to continue over the long term, and the combined impact of the thermal effect of the cooling water and climate change is not expected to impact the length of the growing season in the power plant's nearby sea area compared to the present state.

A possible minor weakening of water quality in Hästholmsfjärden (see Chapter 9.16.4.2) may increase the production of phytoplankton and aquatic vegetation to a minor degree, which would be manifested as a slight increase in the chlorophyll a concentration and primary production as well as in the aquatic vegetation becoming more abundant. Ilus (2009) has suggested that changes in primary production at Hästholmsfjärden are best explained by the water's temperature, followed by the depth visibility and total phosphorus. The blue-green algae binding nitrogen from the atmosphere can furthermore benefit from potential warming, because their optimal temperature is slightly higher than that of other groups of species. Nor is the production of the algae groups in question as dependent on the water's nutrient concentration, as many other groups of species are. The long-term development depends partly on the materialisation of climate change scenarios and measures that reduce inputs, and the input carried to the sea area may also decline in the long term if the agricultural measures are adopted on a wide scale. This is expected to have positive impacts, given that the declining amount of nutrients will reduce the production of phytoplankton and prevent aquatic vegetation from becoming more abundant. In this scenario, the impacts would be manifested as a decline in the production level (a reduction of primary production and in the chlorophyll a concentration as well as in the biomass of filamentous algae). The impact assessment concerning primary production and the phytoplankton community nevertheless involves uncertainty, given that the complex interactive relationships of the food web – including the regulation of the consumers (zooplankton, fish) – could not be accounted for in this assessment.

Due to the uncertainties, a detailed assessment of the impacts on phytoplankton and aquatic vegetation is difficult. In the case of extended operation, the impact on the aquatic vegetation and phytoplankton is expected to be local and primarily confined to the Hästholmsfjärden sea area in the Klobbfjärden body of water. In the rest of Loviisa's nearby sea area, the impacts are determined on the basis of the long-term development of the nutrient pollution and the general development in the status of the Gulf of Finland.

The magnitude of the change concerning phytoplankton and the aquatic vegetation is deemed, compared to the present state and accounting for the precautionary principle, minor and negative in Hästholmsfjärden, given that the impacts will not continue beyond the 2050s in extended operation. The other sea areas are not expected to be impacted.

9.16.4.5 Impacts on benthic fauna

The impacts on the benthic fauna are indirect and attributable to the sea area's temperature and stratification dynamics as well as a potential change in water quality (Chapters 9.16.4.1 and 9.16.3.8). Based on the monitoring, the power plant's thermal effects are local and impact mainly Hästholmsfjärden's benthic fauna, the status of which has been, alongside the rest of the nearby sea area, largely poor during the 2000s. The most significant factors on the discharge side are expected to consist of the stratification conditions departing from their normal levels, which weakens the aeration of the hypolimnion, and the oxygen consumption resulting from eutrophication, which has resulted in hypoxia in the deeper seabed. The seabed has also been in poor condition on the intake side of the cooling water, meaning that the status of the benthic fauna has also been impacted by the Gulf of Finland's general eutrophication.

In the sea area further offshore, the status of the seabed has been impacted more by the development of the general status of the Gulf of Finland, which was visible as a strong decline in the benthic fauna communities of the deeps following the major Baltic inflows of the early 1990s, for example. In the sea area further offshore, the status of the benthic fauna seems to have improved slightly in recent years.

Based on the quality of water, no significant changes are to be expected in the long term. The aforementioned combined impact of nutrient pollution and the thermal effect, the materialisation of which involves uncertainty, may impair the oxygen conditions locally to some extent. This is attributable to an increase in the production level, which increases the amount of oxygen-consuming organic matter sinking to the bottom. On the other hand, the impacts may also be positive and depend on the materialisation of the climate and input scenarios. The potential impact is primarily focused on the deeps in Hästholmsfjärden.

Sea areas in which the water temperature remains higher than the natural temperature throughout the year may function as areas receiving non-native species, in which a new species' spread and adaptation to the new habitat is easier than in sea areas not impacted by the thermal effect. The risk of new spreading is greater in such environments. Based on the monitoring, there are currently nine species defined as non-native in the sea area near Loviisa, of which the bay barnacle, brackish hydroid and dark false mussel cause biofouling by forming growths in Loviisa power plant's seawater systems. Of these three species, the dark false mussel finds the thermal effect particularly beneficial. In terms of non-native species, the status is expected to remain similar to its current level, but projecting the spread of potential new non-native species is difficult. For example, according to HELCOM's assessments, the spread of non-native species has reduced somewhat in 2011–2016 compared to 2000–2010, but remains higher than the goal (State of the Baltic Sea – holistic assessment: non-indigenous species). A total of 12 non-native species, most of which were crustaceans, spread to the Baltic Sea area in 2011–2016. Non-native species in terms of icthyofauna are discussed in Chapter 9.17.

In extended operation, the thermal load would continue for approximately 20 years following the expiration of the current operating licences, at most until circa 2050, and maintain temperature and stratification conditions departing from the natural in the nearby sea areas of Hästholmen. These conditions have also contributed to the status of the benthic fauna in the area. A continuation of the thermal effect will increase the risk of the spread of non-native species. Changes in the benthic fauna are likely to be minor, but due to the long-term nature of the impacts, the magnitude of the change, compared to the present state, is expected to be at most moderate and negative in Hästholmsfjärden and at most minor in Hudöfjärden and Vådholmsfjärden. The other nearby sea areas are not expected to be impacted.

9.16.4.6 Impacts on sediment (harmful substances)

The impact of radioactive emissions is assessed in Chapter 9.8. The process water and wastewater discharges of Loviisa power plant do not impact the quality of the sediment.

The elevated dioxin and furan content found in the sediment are typical of river basins in the eastern Baltic Sea and the river Kymijoki due to the area's industrial history. Harmful dioxins and furans are generated inadvertently in various industrial processes, including waste incineration and chemical production. Correspondingly, compounds containing TBT were formerly used in the primers of vessels, for example, to prevent organisms from attaching themselves to the hulls, and in agriculture, as an anti-mildew agent for seeds (Lindfors et al. 2020).

The water engineering projects in front of the intake location of Loviisa power plant and the nearby sea area, mentioned in the EIA Programme, are no longer being planned, due to which there will be no impact on the sediment.

The quality of the sediment in Loviisa power plant's nearby sea area is not expected to be impacted.

9.16.4.7 Impacts on Lappomträsket lake

According to plans, the power plant's service water will continue to 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 replaced by the procurement of other service water. The plans for the sourcing of service water are presented in Chapter 4.3. If the service water is sourced from elsewhere, the power plant's current raw water supply system and water treatment plant would, for reliability purposes, remain in the power plant's process and domestic water use, and the lake would continue to be regulated.

The status of Lappomträsket lake is currently good and is not expected to be subject to any special pressures. The impacts would remain unchanged in both water supply options. The lake's water level has remained stable and close to the upper level of regulation in recent years. Should the intake of water reduce, the water level will be regulated with a regulating dam. The regulation maintains a greater-than-natural dilution volume, or volume into which the nutrient pollution entering the lake mixes. In addition, the oxidising has improved the lake's oxygenation conditions.

In extended operation, the intake of water would continue for roughly 20 years, until around 2050 at the latest. Neither the water intake nor the water supply option is expected to have an impact on the lake's present state.

9.16.4.8 Impacts on ecological and chemical status as well as on marine strategy

The impacts on the quality of water and the water environment (phytoplankton, aquatic vegetation, benthic fauna) are assessed above. The ecological and chemical status of Klobbfjärden and the outer bodies of water is presented in Chapter 9.16.3.11.

The power plant's cooling water is discharged into the Klobbfjärden body of water. The ecological status of the Klobbfjärden body of water has been deemed bad. The status is partly attributable to the thermal effect of the cooling water, which has intensified the impacts of the eutrophication trend in the body of water. In practice, the thermal effect has no impact on the ecological status of Loviisa sea area's other bodies of water, which are mainly impacted by changes in the general status of the Gulf of Finland. In the vicinity of the discharge location of the cooling water, the quality of water and biological status of the water area are expected to remain similar to what they currently are or to at most weaken slightly as a result of the combined impact of climate change and the thermal effect. The long-term development of the ecological status will also depend on the development of the diffuse source input. In extended operation, the impacts would continue for roughly 20 years, during which the magnitude of the change on the water quality and water environment is expected to vary between minor or moderate and negative in the vicinity of the cooling water's discharge location in the Klobbfjärden body of water (Chapters 9.16.4.2–9.16.4.4).

The assessment of the impacts on the biological and physico-chemical quality factors involves uncertainty, which derives from the length of time reviewed, the uncertainty related to the long-term projections of climate change and

Table 9-57. The changes that occurred in the status of the biological and physico-chemical quality factors between the second and third planning period, and an assessment of how the status of the waterbodies can develop over the long term and how the implementation of the extended operation option would impact the ecological status.

Biological quality factors	Physico-chemical quality factors	Assessment on the potential development directions of the ecological status
Klobbfjärden body of water		
The decrease in the chlorophyll a concentration has been minor. The BBI of the benthic fauna indicates a tolerable status, but has varied a great deal and indicated a bad status in the second period. The biological category has remained bad. To attain a good status, the chlorophyll a concentration, for example, should decrease by approximately 6 µg/l, which is a significant decrease in relation to the changes observed during the water resources management periods (Table 9-54).	The status of total phosphorus and total nitrogen is moderate. The numerical value of phosphorus is close to the boundary of a poor status. The physico-chemical status has improved to poor. Additional physico-chemical variables: hypoxia occurs regularly up to the thermocline.	For its part, the thermal load has shaped the temperature and stratification conditions of the body of water and intensified the eutrophication trend. The status is also influenced by the general development of the Gulf of Finland's status and, more locally, the development of the river Tesjoki's quality of water. The development of the waterbody's status is a sum of many different factors, and in the long term, it is influenced by the materialisation of climate change scenarios and agricultural measures, among other things. It is unlikely that the body of water will attain a good status by 2027, because the responses to the changes are slow. In the long term, approaching the 2050s, the status is not expected to be subject to a significant change, but nor can a minor deterioration of the status be ruled out. Based on the assessment, the categories of benthic fauna and total phosphorus are at risk of deterioration if efforts aiming to curb the diffuse source input fail. On the other hand, if the agricultural measures are adopted on a wide scale in the catchment area of the river Tesjoki, the status of the Klobbfjärden body of water is likely to improve. The materialisation of the climate and input scenarios introduces uncertainty to the assessment. *For its part, the continuation of the thermal effect for approximately 20 years, until around 2050 at the latest, may slow down the waterbody's attainment of a good status.*
Loviisanlahti body of water		
The chlorophyll a concentration has decreased considerably and is approaching a moderate status.	Of the total nutrients, the phosphorus content has increased slightly, but is not at risk of dropping to a bad status. The nitrogen content has declined significantly and is moderate.	The impact of the thermal effect does not extend to the body of water. The power plant's significance as a point source is minor compared to other point source and diffuse source inputs, and a possible change in the conduction of wastewaters is not expected to have an impact on the ecological status of the body of water. The status of the body of water is influenced, above all, by the development of the area's other input. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Keipsalo body of water		
The biological status has improved to moderate as a result of an improvement in the categories of chlorophyll a and the benthic fauna.	Of the quality factors concerning the physico-chemical status, the numerical values of total nitrogen and depth visibility have improved slightly, but the category has remained unchanged.	The ecological status of the body of water has improved to satisfactory. The intake side of the cooling water is located in the body of water, and the cooling water's recirculation, which extends to the north-eastern part of Hudöfjärden and causes a slight increase in temperature, covers only a small section of the waterbody's area. The significance of the nutrient pollution caused by the power plant is minor. Above all, the status of the body of water is influenced by the development of other inputs (including the river Loviisanjoki) and the general development of the Gulf of Finland's status. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisa-Porvoo body of water		
The ecological status of the body of water has improved to moderate.	Of the quality factors concerning the physico-chemical status, the numerical values of total phosphorus, total nitrogen and depth visibility have improved slightly, but the category has remained unchanged.	The ecological status of the body of water has improved to satisfactory. The most intense thermal effect of the cooling water focuses on the surface layer in the northern part of the body of water (in Vådholmsfjärden, in front of the straits of Hästholmsfjärden). The impact area is small compared to the area of the body of water. The status of the body of water is influenced, above all, by the development of other inputs and the general development of the Gulf of Finland's status. *Extended operation would not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Lappomträsket lake body of water		
There have been no changes in the biological category.	The numerical values of the total phosphorus and total nitrogen quality factors have increased slightly, but the categories have not changed. The physico-chemical status was deemed good, whereas in the previous period, it was excellent.	There has been no change in the ecological status. According to plans, the intake of service water will continue as it is now/decrease. The intake of water is not expected to impact the lake's present state (quality of water). *Extended operation would not put the good status at risk.*

diffuse source input, and the food web's complex interactive relations. Table 9-57 presents assessments of the potential development paths of the waterbodies' ecological status. Based on the assessment, the continuation of the thermal effect in the optioncase of extended operation would contribute to maintaining the weakened status of the Klobbfjärden body of water, which is not expected to improve significantly in the long term. Without the thermal effect of the cooling water, the waterbody's ecological status would probably fall under the same category as the other inner bay areas within the Gulf of Finland in the preliminary categorisation of the third planning period of the water resources management.

The proposal on the programme of measures for the Uusimaa water resources management (Ahokas et al. 2020) mentions the planning and implementation of the eutrophied bay's rehabilitation as a measure of the Klobbfjärden body of water. Furthermore, the programme states, in terms of the Klobbfjärden body of water, that measures for the operation, maintenance and increased efficiency of plants will be presented to the industrial sector during the third planning period. The need to intensify the protection of the waters will be assessed in connection with the review of the environmental permits. The measure includes the operation of industrial facilities subject to a licence so that the operating level remains at least at the level of the initial phase of the planning period about to begin (the third planning period of water resources management), meeting the licence regulations.

The proposal concerning the 2022–2027 water resources management plan of the water resources management region of the river Kymijoki-the Gulf of Finland (Mäntykoski et al. 2020) states that, for a justified reason, the attainment of the objective may be delayed beyond 2027, but that all of the measures should be underway by then. The proposal points out that the postponement of the objective can only be justified by the slowness of the change occurring in the natural conditions, waterways and biota.

In the proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027, the impacts of a thermal effect are considered local, and they are not expected to have an impact on the sea's status on a wider scale (Laamanen et al. 2020).

9.16.5 Environmental impact of decommissioning

Impact formation

The power plant will be in operation during the expansion of the L/ILW repository, and the impacts on the surface waters (the most significant of them being the thermal effect of the cooling waters) will remain unchanged, as described in Chapter 9.16.4.

Construction waters will be generated during the L/ILW repository's expansion. These are composed of the water used in the excavation and the waters filtering into the repository. The water conducted to the sea contains soluble nitrogen (ammoniacal nitrogen) derived from explosives and small quantities of solids. The oxidation of the ammoniacal nitrogen may increase the oxygen consumption of the receiving waterway. Soluble nitrogen represents a nutrient which is in a form directly available to phytoplankton, meaning that the nitrogen input may accelerate the production of phytoplankton, particularly in conditions where nutrients are limited (in the summer following the spring bloom of phytoplankton, for example).

Once the power plant's commercial use comes to an end, the need for cooling water and the thermal effect will decrease to a fraction of what the emissions were during the electricity production. As the thermal emission reduces, the impact area's temperature and stratification conditions will return to their natural state. After dismantling phase 1, the volume of the cooling water will remain low, in addition to which the volume of wastewaters will reduce considerably.

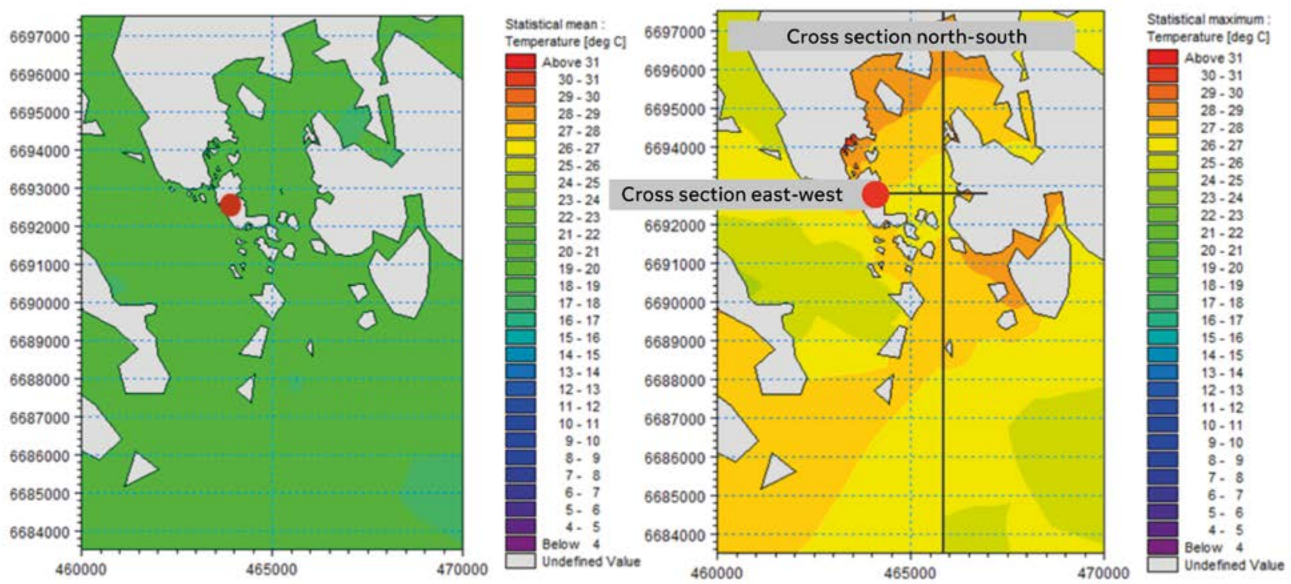


Figure 9-60. Seawater temperature in the surface layer in the summer in a situation where the power plant is not in operation. The image on the left shows the average, and the image on the right the maximum, situation. The locations of the cross sections in the east-west and north-south directions are indicated in the image on the right (see following images). Hästholmen's location is indicated with a red dot (Lahti 2021; Appendix 4).

9.16.5.1 Results of the cooling water modelling

The map images show the result of the modelling of the ice-free season's situation in the warmer than average summer of 2011 without the thermal load and cooling water flow generated by the power plant (Figure 9-60 and Figure 9-61). According to the modelling, the seawater's surface temperature in Hästholmsfjärden is approximately 1–11 °C cooler than in a situation in which the power plant is in operation. In Hudofjärden, it is roughly 0.1–0.9 °C cooler, and in Vådholmsfjärden, approximately 0–4.5 °C cooler.

During the ice-free season, in a summer situation, the thermal effect of the cooling water is not there to intensify the stratification, which is easily visible in the cross-sectional images of the temperature's vertical distribution (Figure 9-61). In other words, while the water column is still stratified in terms of its temperature, which is typical of the summer, the thermocline is no longer as strong as it was when the plant was in operation, meaning that the significance of factors influencing the water column's mixing will grow.

In the winter, once the power plant is no longer in operation, the water column in Hästholmsfjärden will be markedly cooler and of a fairly even temperature (Figure 9-62 and Figure 9-63), which will decrease the intensity of the winter stratification. In the winter, the thermal effect of the cooling water has increased the temperature of the seawater close to the discharge location by approximately 5–16 °C, 5–9 °C and 3–5 °C at a depth of one metre, four metres and near the bottom, respectively. In addition, the water column has also been stratified temperature-wise during the winter.

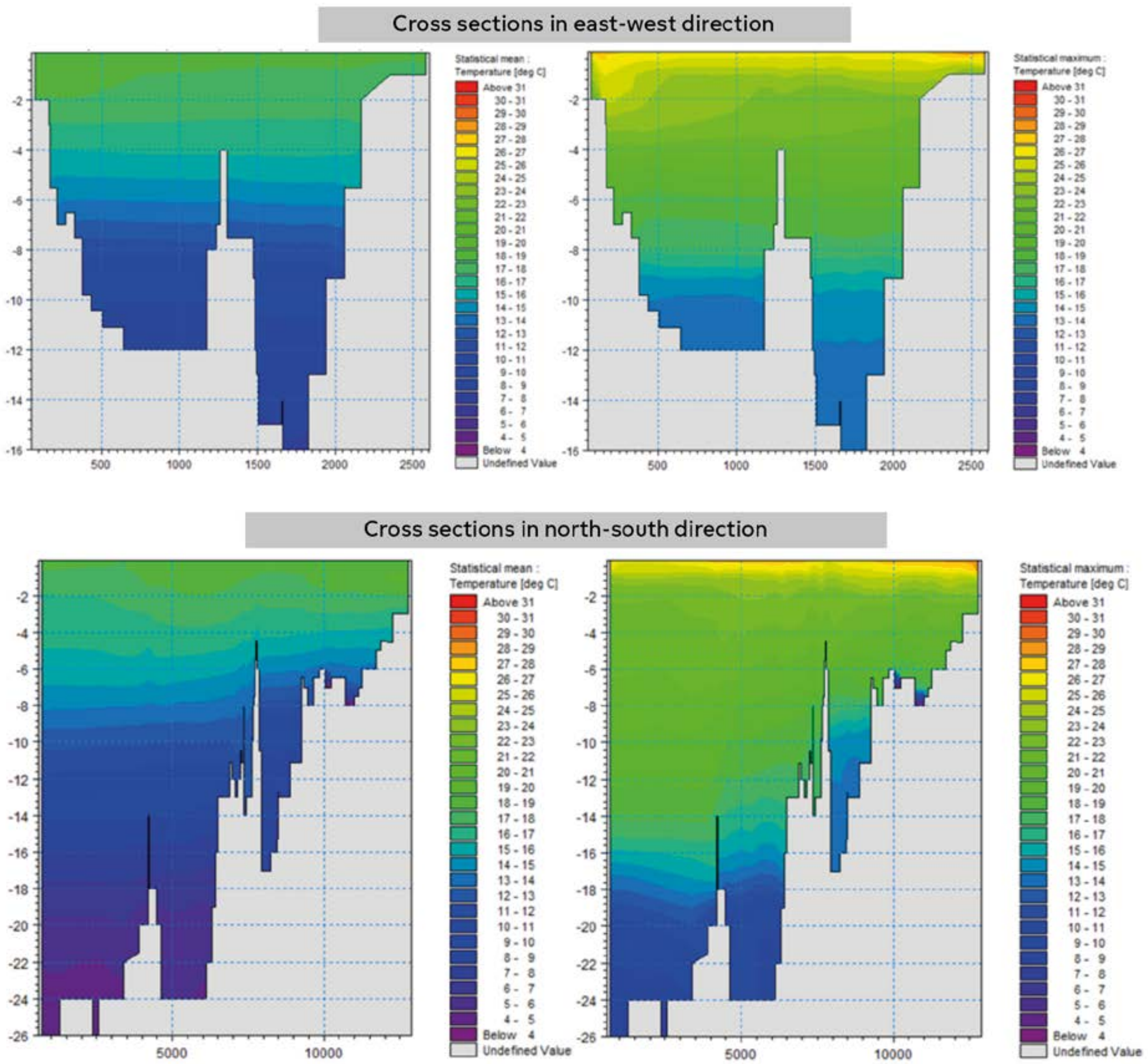


Figure 9-61. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the summer in a situation where the power plant is not in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the eastern side of Hästholmsfjärden is on the image's left-hand side.

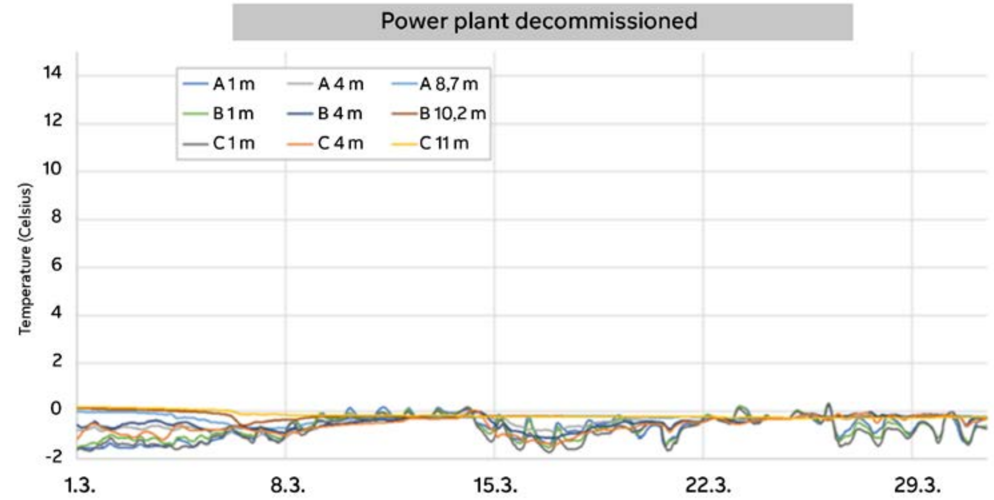


Figure 9-62. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden in the winter and a situation in which the power plant is not in operation.

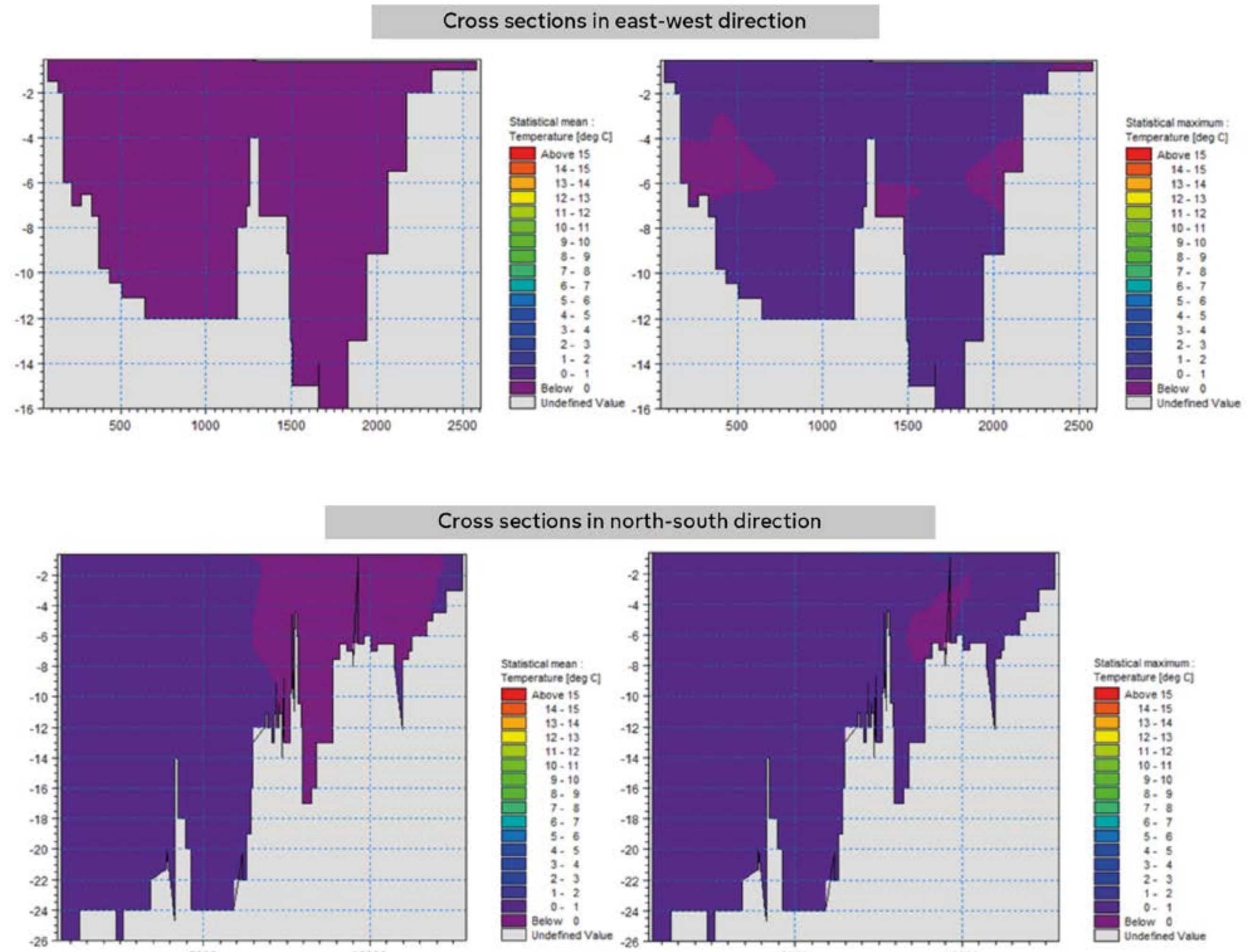


Figure 9-63. The temperature's vertical distribution in the east-west direction (upper image) and in the north-south direction (lower image) in the winter in a modelling situation in which the power plant is no longer in operation. The image on the left shows the average, and the image on the right the maximum, situation. In the east-west cross section, the eastern edge of Hästholmsfjärden is on the image's left-hand side.

9.16.5.2 Impacts on the sea area's temperature and stratification conditions

The impacts of the thermal load are described above, in Chapter 9.16.4.1. In the decommissioning, as the production of electricity halves after 2027 and ends after 2030, the need for cooling water will be reduced to a fraction of its former level. The thermal load generated by cooling water during the independent use of the interim storage for spent nuclear fuel is a mere 0.08% (46.5 TJ a year) of the power plant's current thermal load. The impact that the thermal load of the interim storage has on the sea area's temperature and stratification conditions is negligible.

Once the power plant's thermal load has concluded, the sea area's temperature and stratification conditions will return to correspond to the natural conditions fairly quickly, and the annual development of the seawater's temperature will follow the development of the air temperature. While the water column will still be stratified in terms of its temperature, which is typical of the summer, the thermocline will no longer be as strong as it was when the plant was in operation, meaning that the significance of factors influencing the water column's mixing will grow. In natural conditions, repeated mixing caused by wind also occurs in shallow sea areas during the summer's stratified periods. When the wind is strong, mixing can also occur in the deeper areas of Hästholmsfjärden. The end of the cooling water flow may prolong the water's retention time at Hästholmsfjärden to a slight extent. The retention time estimated for Hästholmsfjärden's (including Klobbfjärden) water prior to the power plant's commissioning was 50–60 days (Launiainen 1975). Once the power plant is no longer in operation, the winter stratification will be minor, and during ice-free winters, for example, Hästholmsfjärden's water column is expected to mix repeatedly due to the impact of wind.

In decommissioning, the thermal effect will reduce to a negligible level after 2027–2030, when the power plant's commercial operation will come to an end. Once the input ends, Hästholmsfjärden's temperature and stratification conditions will return to a natural state. The change will be local and primarily confined to Hästholmsfjärden, in the Klobbfjärden body of water. In other nearby sea areas, the change will remain minor. The magnitude of the change concerning the temperature and stratification conditions compared to the present state is deemed moderate and positive in Hästholmsfjärden and at most minor and positive in other nearby sea areas.

9.16.5.3 Impacts on the quality of water

The most significant change is expected to be the end of the thermal load attributable to the cooling water in Hästholmsfjärden. In addition, Hudöfjärden's water quality will be subject to impacts during the excavation of the L/ILW repository, which is expected to take a total of three years.

The estimate on the total emissions of the excavating over a period of three years is:

- nitrogen 1.9 t
- solids 90 t
- oils and greases 1.5 t

In addition to nitrogen derived from explosives, the L/ILW repository's excavating waters will contain inorganic solids. The waters will be conducted to Hudöfjärden via regulating reservoirs and oil separation. The methods for assessing the input of nitrogen derived from explosives are described in Chapter 9.16.2.3.

The excavation's nitrogen input is distributed over three years and expected to be around 630 kg a year, which corresponds to the daily wastewater input of some 123 people (PE). The nitrogen deriving from the traces of explosives is primarily soluble ammoniacal nitrogen. The annual input comes to only 2% of the sea area's annual point source pollution (Table 9-48). The water conducted to the sea area also contains rock-based inorganic solids, the daily input of which is expected to be around 82 kg. The nitrogen's calculated mixing concentration close to the discharge location (500- x 500-m sea area with an average depth of 5 m) is 1.4 µg/l, while that of the oils and solids is 1.1 µg/l and 0.07 mg/l, respectively. The increases in the concentrations are minor and local. The minor increase in turbidity is focused on the immediate vicinity of the discharge location. The pH values of the site waters are in the same region as those of seawater (the average in Loviisa's sea area being 7.9). The input generated during the construction is not expected to impact the Hudöfjärden sea area's water quality. The impact of the reduction in the nutrient point source pollution caused by Loviisa power plant in Hudöfjärden is also expected to be minor.

The most significant impact on the quality of water will be attributable to the normalisation of the temperature and stratification conditions, and will focus primarily on the area of Hästholmsfjärden in the Klobbfjärden body of water. The change in the physical temperature and stratification conditions will improve Hästholmsfjärden's mixing conditions. In the present state, the oxygenation conditions have been weak in the water close to the bottom, but deteriorated oxygenation conditions have also occurred in the middle of the water column. The water volume suffering from hypoxia is expected to reduce due to the change, which is expected to reduce the internal input in turn. Internal input has occasionally been detected, particularly in Hästholmsfjärden, in the water close to the bottom.

However, it should be noted that the oxygenation conditions in Hästholmsfjärden's deeps were weak as early as in the 1960s, prior to the power plant's commissioning. This is primarily attributable to the poor exchange of water in the bay, resulting from the topography (narrow straits and underwater thresholds). This being the case, the improvement in the deeps' oxygenation conditions may remain minor. The reduction in the internal input is likely to have a slight local impact, reducing nutrient levels and eutrophication, but the impact will appear with a delay. What is clearly more significant in terms of the waterbody's status is the long-term development of the external nutrient pollution (especially from the river Tesjoki). The decrease in temperatures will also have an impact on the level of organisms in the form of slower microbiological degradation. These factors are expected to contribute to a reduction in the hypolimnion's oxygen consumption. In other sea areas close to the power plant, the impacts are expected to be minor.

The magnitude of the change concerning the quality of water compared to the present state is deemed to be at most *moderate and positive* in Hästholmsfjärden. Elsewhere in the sea area, the impact will remain minor.

9.16.5.4 Impacts on phytoplankton and aquatic vegetation

The impacts of the discontinuance of the thermal effect will be attributable to the shortening of the growing season and the slow recovery of the water quality, which is expected to be local. The impacts will extend to the level of organisms, as stated above. The eutrophication trend has occasionally been stronger in Hästholmsfjärden than in Hudöfjärden, which points to, for its part, the thermal effect of the power plant's cooling water (Anttila-Huhtinen & Raunio 2018). The impact has been observable primarily in the aquatic vegetation and, to a small degree, in the primary production. Annual filamentous algae, in particular, have benefited from the longer growing season. The increase in coastal vegetation and the eutrophication of the shore areas has been visible at a radius of approximately one kilometre from the cooling water discharge location.

The impacts on the biological environment are expected to become visible after a delay, given that the sea area's status is impacted by a variety of environmental factors, the most important of them being the development of the external nutrient pollution. As mentioned in Chapter 9.16.5.2, the long-term development of the input involves uncertainty. The impact is expected to be local and primarily confined to the area of Hästholmsfjärden, in the Klobbfjärden body of water, which is expected to remain eutrophic when the thermal effect comes to an end. The biological interactions of the water environment's food web are complex, due to which an assessment of production and community-level changes is difficult. It is nevertheless likely that the change will be manifested as a moderate declining trend in primary production, due to which a declining trend is also expected to be observable in the phytoplankton's biomass and chlorophyll a concentration. In general, it can also be noted that the species which have found the longer growing season particularly beneficial stand to lose some of their competitive advantage. This can be expected to reduce the amounts of annual filamentous algae, for example, to some extent and on a local basis. It is also possible that species sensitive to heat, which have declined in the area, may gradually return there.

The magnitude of the change concerning the phytoplankton and aquatic vegetation compared to the present state is deemed to be at most moderate and positive in Hästholmsfjärden, in the Klobbfjärden body of water. In the other sea areas, the impacts will remain very small.

9.16.5.5 Impacts on benthic fauna

The impacts of the discontinuance of the thermal effect will be attributable to the normalisation of the temperature and stratification conditions, and the slow recovery of the water quality, which is expected to be local. Of special importance in terms of the benthic fauna are the oxygen conditions in the water layer close to the bottom. The status of the benthic fauna living in the deeps of Hästholmsfjärden may gradually improve as the oxygen conditions in the hypolimnion improve. The change is expected to be manifested after a delay and be primarily visible as an increase in the biomass of benthic fauna. No significant changes are expected to take place in the benthic fauna species. The number of species within the sea area's benthic fauna was small as long ago as during the first surveys conducted in the 1960s.

Changes are also expected to occur in the status of Hästholmsfjärden's shallow waters and in the littoral zone's benthic fauna. For example, at the sampling station near the power plant's cooling water discharge location, the benthic fauna population has been more diverse than at the other stations throughout the 2000s, which is probably due to the better water exchange and the coarser materials of the seabed. The thermal effect of the cooling water has favoured the occurrence of some non-native species. Such species include the New Zealand mud snail and the dark false mussel. It is likely that species which have significantly benefited from the thermal effect will lose their competitive advantage and begin to decline. Projections concerning biological interactive relations are challenging, due to which the assessment involves uncertainty. Given that many of the species in question are non-native, the change is deemed positive.

Compared to the present state, the magnitude of the change concerning the benthic fauna is deemed to be at most moderate and positive in Hästholmsfjärden. In the other sea areas, the impacts will remain very small.

9.16.5.6 Impacts on sediment (harmful substances)

The impacts on the sediment are assessed in Chapters 9.8 and 9.16.4.6. The decommissioning is not expected to have impacts on the quality of the sediment.

9.16.5.7 Impacts on Lappomträsket lake

The need for service water varies from one phase to the next during decommissioning. The need for service water will increase temporarily during the excavation and construction of the L/ILW repository, when the power plant is still in operation. Estimates put the total need during excavation at approximately 300,000 m^3. Distributed over the three years of construction, the average pumping need attributable to the excavating of the L/ILW repository is roughly 11.4 m^3 per hour. When the plant is simultaneously in operation, the estimated total need for service water is approximately 31–42 m^3 per hour. The pumped volume of water falls significantly below the volume allowed by the permit conditions (180 m^3 per hour on a short-term basis and at a maximum rate of 150 m^3 per hour over every three months). The minor increase is not expected to have an impact on the present state of Lappomträsket lake.

The volume of domestic water needed during independent operation will decrease to a fraction of its current level. This will be accounted for in the regulation, and when necessary, more water will be run through the dam so that the water level will not rise above the regulation limit.

Deregulation may become topical in the future. The measure requires a permit pursuant to the Water Act; the environmental impact is assessed in connection with the permit process. The planning will typically be carried out by accounting for the various interests as well as the established use of the waterway and the shores. Following the possible deregulation, the obligations of the permit holder (including the obligation to transplant pike) will come to an end. The oxidising carried out by Fortum is also likely to be discontinued, which may have a negative impact on the water quality.

In decommissioning, changes in the intake of water will initially be very small, and the intake will continue in the current manner. A small change in the intake of water is not expected to have an impact on the present state of Lappomträsket lake. The potential end of the regulation would take place far into the future and could result in negative impacts on the quality of water if oxidising is abandoned. In this case, the magnitude of the change concerning the water quality, compared to the present state, is deemed *minor and negative*.

9.16.5.8 Impacts on ecological and chemical status as well as on marine strategy

The impacts on the quality of water and the water environment (phytoplankton, aquatic vegetation, benthic fauna) are assessed above. The ecological and chemical status of Klobbfjärden and the outer bodies of water is presented in Chapter 9.16.3.11.

In decommissioning, the cooling water's thermal effect on the Klobbfjärden body of water will decrease to a fraction of what it was once the commercial operation of the power plant concludes, and it will end completely after the phase of independent operation. As a result of the change, the body of water's temperature and stratification conditions will return to their natural state. The change was deemed to have a minor/moderate and positive local impact on the water quality and water environment, primarily focused on Hästholmsfjärden, in the Klobbfjärden body of water (Chapters 9.16.5.2–9.16.5.5).

The assessment concerning the impact on the biological and physico-chemical quality factors involves uncertainty, which is derived from the complexity of the food web's biological interactions. The potential development paths of the waterbodies' ecological status in the case of decommissioning are assessed in Table 9-58. Changes that have taken place in the status of the biological and physico-chemical quality factors are shown in Tables 9-54 and 9-57.

The targeted schedule in water resources management for the attainment of good ecological potential and chemical status in surface waters was 2015. The attainment of the objective can be postponed until 2027. In the case of decommissioning, it is unlikely that the Klobbfjärden body of water will attain a good status by 2027, given that the improvement of the status will occur with a delay and that the long-term development of the external nutrient input is a significant factor alongside the thermal effect.

In the proposal for the programme of measures for the development and implementation of the marine strategy in Finland 2022–2027, the impacts of a thermal effect are considered local, and the impacts, or their end, are not expected to impact the sea's status on a wider scale (Laamanen et al. 2020).

9.16.6 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 have an impact on surface waters.

Table 9-58. Assessment of the potential impact that decommissioning would have on the ecological status. Changes that have taken place in the status of the biological and physico-chemical quality factors are presented above in Tables 9-54 and 9-57.

Body of water	Assessment on the potential development directions of the ecological status
Klobbfjärden body of water	The ecological status is bad. As the thermal effect comes to an end, the temperature and stratification conditions, as well as the length of the growing season, will normalise. The change will improve the mixing conditions of the layers in Hästholmsfjärden's water column, which is expected to improve the oxygenation conditions of the hypolimnion and reduce the internal input of nutrients. The change is likely to have local significance in reducing nutrient levels and eutrophication, but the impacts will become apparent only after a delay. Based on the assessment, the total phosphorus and total nitrogen content may decrease slightly at the local level; when combined with the shorter growing season, the change is likely to manifest as a decrease in primary production, for example, which may be visible as a decreasing biomass and chlorophyll a concentration. The impact on the benthic fauna is expected to be delayed and visible primarily as an increase in the biomass of benthic fauna in the deeps. The status of the body of water is nevertheless influenced, above all, by the development of the external input (the river Tesjoki). The status of the body of water is expected to gradually return to a status corresponding to that of the other inner bays in the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisanlahti body of water	The ecological status is poor. The impacts of the project's thermal effect have not extended to the body of water. The impact of the end of the power plant's wastewater load was deemed negligible. The status of the body of water is influenced, above all, by the development of the area's other external inputs and the general development in the status of the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Keipsalo body of water	The ecological status is moderate. The impacts of cooling water have been minor in the body of water. The impact of the end of the power plant's wastewater load was deemed negligible. The status of the body of water is influenced, above all, by the development of the other external inputs and the general development in the status of the Gulf of Finland. *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Loviisa-Porvoo body of water	*The ecological status is satisfactory. The most intense thermal effect of the cooling water is focused on the front of Hästholmsfjärden's straits, and the impact area is small compared to the waterbody's area. The thermal effect is therefore not expected to have an impact on the body of water's status. The status of the body of water is influenced, above all, by the development of other inputs and the general development of the Gulf of Finland's status.* *Decommissioning will not weaken the category of the quality factors or prevent the body of water from attaining a good status.*
Lappomträsket lake body of water	The ecological status is good. The regulation and the attendant obligations will continue until deregulation is sought. Once Fortum's obligations, far into the future, potentially come to an end, a discontinuation of the oxidising may impair the water quality. The magnitude of the change concerning the present state is at most minor and negative. *Decommissioning will not weaken the category of the quality factors or put the retention of a good status at risk.*

9.16.7 Significance of impacts

Table 9-59 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

9.16.8 Mitigation of adverse impacts

The most significant impact is attributable to the thermal effect of the cooling water, which has contributed to the eutrophication of the Klobbfjärden body of water. Currently, increases in the temperature of the cooling water and its maximum temperature are limited in the power plant's environmental permit.

Loviisa power plant has improved its efficiency, which has had a minor impact on the thermal load. The efficiency can still be improved slightly in connection with the replacement of old equipment.

As part of Option VE1extended operation, 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 preliminary investigations, it could be assumed that by decreasing the temperature of the abstracted cooling water, it would be possible to reduce the temperature of the discharged cooling water, although this would not affect the thermal load being conducted to the sea. Based on the techno-economic investigations carried out, the water engineering projects were nevertheless removed from the environmental impact assessment procedure. The matter will continue to be studied, separate from the EIA Report, in Fortum's research project, which aims to find the most cost-effective technical solutions for reducing the temperature of the abstracted cooling water with the help of modelling.

In terms of the Klobbfjärden body of water, the reduction of the diffuse source input, a significant portion of which derives from the river Tesjoki, plays a key role. The most effective measures include the agricultural measures to be carried out in the river's catchment area, such as the application of gypsum in agricultural fields. Fortum could participate in investigations aiming to reduce the impacts on the Klobbfjärden body of water attributable to other activities and the planning of corrective measures.

9.16.9 Uncertainties

The cooling water's impact on the temperature and stratification conditions of the sea area was assessed on the basis of hydraulic modelling. Modelling results typically include uncertainties that are derived from the fact that the model simplifies the physical phenomena which have an effect on the dispersion of the modelled variable to some extent (in this case, temperature). The uncertainty is reduced by the careful verification and validation of the model. In this modelling, the extensive monitoring data available on the sea area allowed the suitability of the model to be assessed. Based on the comparison, the modelled values correspond to the sea area's measured temperatures fairly well. The temperature modelled in the hypolimnion matches the observations made in June and July, but increases more towards the end of August. What is key in terms of the assessment of temperature effects is that the modelled temperatures close to the surface correspond with the observations. The equivalence was deemed adequate to assess the effects of the cooling water.

The effects on waterways were assessed from a long-term perspective, given that in extended operation, the thermal effect would continue, at most, until around the 2050s. In terms of the seawater temperatures formed, the uncertainty is related to the materialisation of climate change scenarios and the uncertainty included in the different RCP scenarios. The aim was to account for climate change's temperature-increasing impact by using 2011, which was an unusually warm year, as the modelling year. The impact assessment also had to consider the potential change in the point source diffusion of nutrients over the long term. However, the long-term projections of the nutrient pollution involve uncertainties attributable to the uncertainty related to the materialisation of climate change scenarios, and the extent to which and how fast the measures reducing agricultural pollution will be implemented in the catchment areas of the rivers emptying into the coast of Loviisa.

The assessment also involves uncertainty attributable to the complexity of the water environment's biological and physico-chemical interactions and lengthy response times. For example, it is difficult to forecast the extent to which and how rapidly the sea area will recover from the environmental pressure caused by the thermal effect. The long-term development in the status of the Gulf of Finland will also be reflected in the status of the coastal areas. The Gulf of Finland's nutrient dynamics and the development of the status are also indirectly impacted by the major Baltic inflows, the occurrence of which cannot be projected in the context of this impact assessment. The upwelling and downwelling phenomenon which occurs on the coast, and which also has an impact on the status of Loviisa's nearby sea area, can also be considered an uncertainty from the perspective of the assessment.

9.17 FISH AND FISHING

9.17.1 Principal results of the assessment

In the case of extended operation, the impact that the power plant's cooling waters would have on the Klobbfjärden sea area, and thereby on the fish and fishing, would remain similar to its current level but continue for another 20 years or so. The continuation of the cooling water's thermal effect maintains a situation which favours fish species adapted to warm water, such as pike-perch and cyprinids. Waters warmer than the sea surrounding the area may also allow the non-native species round goby to become more abundant there. Yet this is not expected to have an adverse impact on the area's abundant pike-perch population. The winter fishing opportunities will remain at the same level while ice conditions vary in the sea area surrounding the power plant, but the extent of the ice cover may decrease slightly, and the ice may also remain thinner in the future due to climate change. The significance of the impact that the power plant's extended operation would

Table 9-59. Significance of impacts: surface waters.

Significance of impacts: surface waters			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate (Hästholmsfjärden, in the Klobbfjärden body of water)**	**Moderate/ minor negative**	**The significance of the impacts is at most moderate and negative,** because in the long run, the increase of warm summers, combined with the thermal load, may slightly increase the thermal effect in the sea area. The power plant's thermal load is known to have contributed to the change in the waterbody's temperature and stratification conditions, the lengthening of the growing season and the intensification of eutrophication at a local scale. The significance of the impacts was deemed to vary according to the affected aspect from minor and negative (water quality, phytoplankton and aquatic vegetation) to moderate and negative (temperature and stratification conditions, benthic fauna). Above all, the status of the sea area is impacted by a diffuse source input, which may also reduce in the long run, provided that the agricultural measures are adopted on a wide scale. The continuation of the thermal effect until at least around 2050 would slow down the waterbody's attainment of a good status.
	Moderate (other nearby sea areas)	**Minor negative/ no change**	**The significance of the impacts is at most minor and negative,** given that the thermal load's impact on the temperature and stratification conditions of the other nearby sea areas will continue until around 2050 at the latest. The other affected aspects (including water quality, benthic fauna) are not expected to be subject to an impact. In the other nearby sea areas too, the quality of water and the status of the water environment are largely influenced by the long-term development of the nutrient inputs and the general development in the Gulf of Finland's status.
	Moderate (Lappomträsket lake)	**No change**	**No impact,** given that the regulation has not been found to impair the lake's water quality.
Decommissioning	**Moderate (Hästholmsfjärden, in the Klobbfjärden body of water)**	**Moderate positive**	**The significance of the impacts is moderate and positive,** since after the thermal load comes to an end, Hästholmsfjärden's temperature and stratification conditions and the length of the growing season will return to the natural state and the oxygenation conditions of the hypolimnion are expected to improve gradually; this will contribute to a reduction of the internal input. The positive impacts may become apparent only after a delay as a decline in the nutrient level, changes in the aquatic flora (a decrease in the number of one-year filamentous algae) and an improvement in the status of the benthic fauna. 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.
	Moderate (other nearby sea areas)	**Minor positive/ no change**	**The significance of the impacts is at most minor and positive,** given that the thermal load's impact on the temperature and stratification conditions will remain minor in the rest of the nearby sea area. The excavation of the L/ILW repository is not expected to impact Hudöfjärden's present state.
	Moderate (Lappomträsket lake)	**Minor negative**	**The significance of the impacts is at most minor and negative,** because the changes in the intake of water will be very small initially, and the change is not expected to have an impact on the lake's present state. The potential end of the regulation, which would take place far into the future, could nevertheless result in negative impacts on the quality of water if oxidising is abandoned.
Radioactive waste generated elsewhere in Finland	**Moderate (sea areas, Lappomträsket lake)**	**No change**	**No impact,** given that the operations would have no impact on the surface waters.

have in relation to the present state was deemed, from the perspective of fish, moderate and negative, and from the perspective of fishing, *minor and negative.*

As a result of decommissioning, the impact that the cooling water's thermal load has on the marine ecosystem will end, and the area will gradually return to the state prevailing in the inner bay areas of the surrounding coastal area. At the same time, the likelihood of the increased abundance of non-native species in the area will decrease. The fishing opportunities during the winter will also return to a better level as the ice conditions normalise, but in this option, the occurrence of ice winters is also likely to reduce as a result of climate change. The significance of the impact is expected to be moderate and positive from the perspective of fish and minor and positive from the perspective of fishing.

In terms of the fish in Lappomträsket lake, the lake's potential deregulation and the replacement of the dam structure by a submerged weir would open a migration connection for the fish to Lappomviken after the deregulation, but the discontinuance of the lake's oxidising could expose the lake's fish to a deterioration in the quality of water.

The radioactive waste generated elsewhere in Finland and its storage or final disposal in Hästholmen would have no impact on the fish or fishing.

9.17.2 Baseline data and assessment methods

The assessment of the impact on fish and fishing relied on monitoring studies carried out in the project area, data on the fish and fishing industry in the Gulf of Finland as well as research data on the impact that cooling waters have on fish and on non-native species, including in areas other than the project area. The assessment of the impact on the fish and fishing also relied on the results of the assessment of the impact on the quality of water, including the cooling water modelling (see Chapter 9.16). The indirect impacts that the project activities with an impact on the quality of water would have on the fish and fishing were assessed in the form of an expert assessment.

The fish and fishing in Loviisa power plant's nearby sea area have been monitored since 1971. The data on the ichthyofauna of the area is based on the observations obtained from fishing surveys and fish bookkeeping as well as reviews of the biomass carried to the power plant within the cooling water.

Further information on the area's icthyofauna was obtained by carrying out a fish survey in Loviisa power plant's nearby sea area in the spring and late summer of 2020 (Roikonen & Kangas 2021). The methods employed in the research consisted of Gulf Olympia fry netting and exploratory net fishing. The Gulf Olympia is a net attached to the sides of a boat's bow with vertical rods. The net tows water, collecting the fry in a water column. The aim of the fry netting was to study the locations of the fishes' breeding areas in the intake and discharge sides of the cooling water, and by observing the occurrence of small fry in pelagic zones in the control area. The control areas in the fry netting were the offshore area west of the island Hudö, located in the eastern open sea of Keipsalo, and the head of Loviisanlahti bay. The aim of the exploratory fishing was to examine the structure of the icthyofauna in Loviisa power plant's nearby sea area and the eastern open sea in Keipsalo, selected as the control area. The study was carried out according to widely used research methods and complied with the guidelines for fish studies published by the game and fisheries research institute (Riista- ja kalatalouden tutkimuslaitos) (Borg 2012).

The fish data concerning Lappomträsket lake is derived from the catch data of the exploratory fishing carried out by the Uusimaa ELY Centre in 2011, which is referred to in the preliminary report on the survey and removal of turf rafts in Lappomträsket lake (Niiranen & Hagman 2012).

The emissions of radioactive substances and their impacts are discussed in Chapter 9.8.

9.17.3 Present state

The ichthyofauna in the sea area surrounding Hästholmen consists of both marine fish and freshwater fish species adapted to the brackish water. Marine species important for fishing can be found in the area, such as Baltic herring and Baltic sprat, salmon, sea trout, as well as Coregonus lavaretus and Baltic whitefish, eel and flounder. Among these, migratory species include salmon, sea trout, Baltic whitefish, Baltic herring and eel. Key freshwater species important in terms of fishing include pike-perch, pike, common perch and burbot. Other abundant fish species include cyprinids: roach, silver bream, bream and ide.

Based on the observations made in the exploratory fishing, the structure of the icthyofauna in the research area (Figure 9-64) does not differ significantly from observations made elsewhere in the Gulf of Finland (Roikonen & Kangas 2021). The common perch and roach are generally the most abundant fish species in the coastal area, often accounting, together with silver bream and ruffe, for more than 80% of the total catch. However, compared to observations made elsewhere, the share of common perch in the areas investigated was markedly high, which is explained, particularly with regard to the eastern open sea of Keipsalo (control area 1), by the large number of small individuals. Based on its large pike-perch catch, Hästholmsfjärden differed from the other areas covered by this study. This can be at least partly explained by the effect of the power plant's cooling water, which increases the temperature of the seawater, given that pike-perch favours habitats with warm water. The exploratory fishing caught a few individuals of round goby (Neogobius melanostomus), categorised as a non-native species, from both the intake side of power plant's cooling water and the control area, the eastern open sea of Keipsalo. None were caught in the cooling water's discharge location in Hästholmsfjärden, however.

The breeding areas of the ichthyofauna in the Gulf of Finland have been studied in connection with the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). Based on data from field studies, maps have been prepared in the online service of the environmental administration (VELMU Map Service, 2019) on the breeding areas of various fish species, based on incidence probability modelling. According to the model, favourable breeding areas exist in the vicinity of Hästholmen for common perch and pike, among other species. Based on the incidence probability modelling, pike-perch breeds primarily in the far end of the Loviisanlahti bay and on the northern and south-eastern shores of Klobbfjärden. The most favourable breeding areas for Baltic herring include the shallow vegetation areas of the middle and outer archipelagos as a whole. Loviisanlahti has been identified as an important breeding area for icthyofauna and a potential migratory route for the migration of the sea trout, which may swim upstream in the river Loviisanjoki in the future. Partly based on these grounds, Loviisanlahti has indeed been named as one of Finland's most ecologically significant marine underwater areas, or what are referred to as EMMAs (Lappalainen et al. 2020). Modelling results for the breeding area of whitefish that spawns in the sea are not presented for the sea area off Loviisa in the VELMU map service.

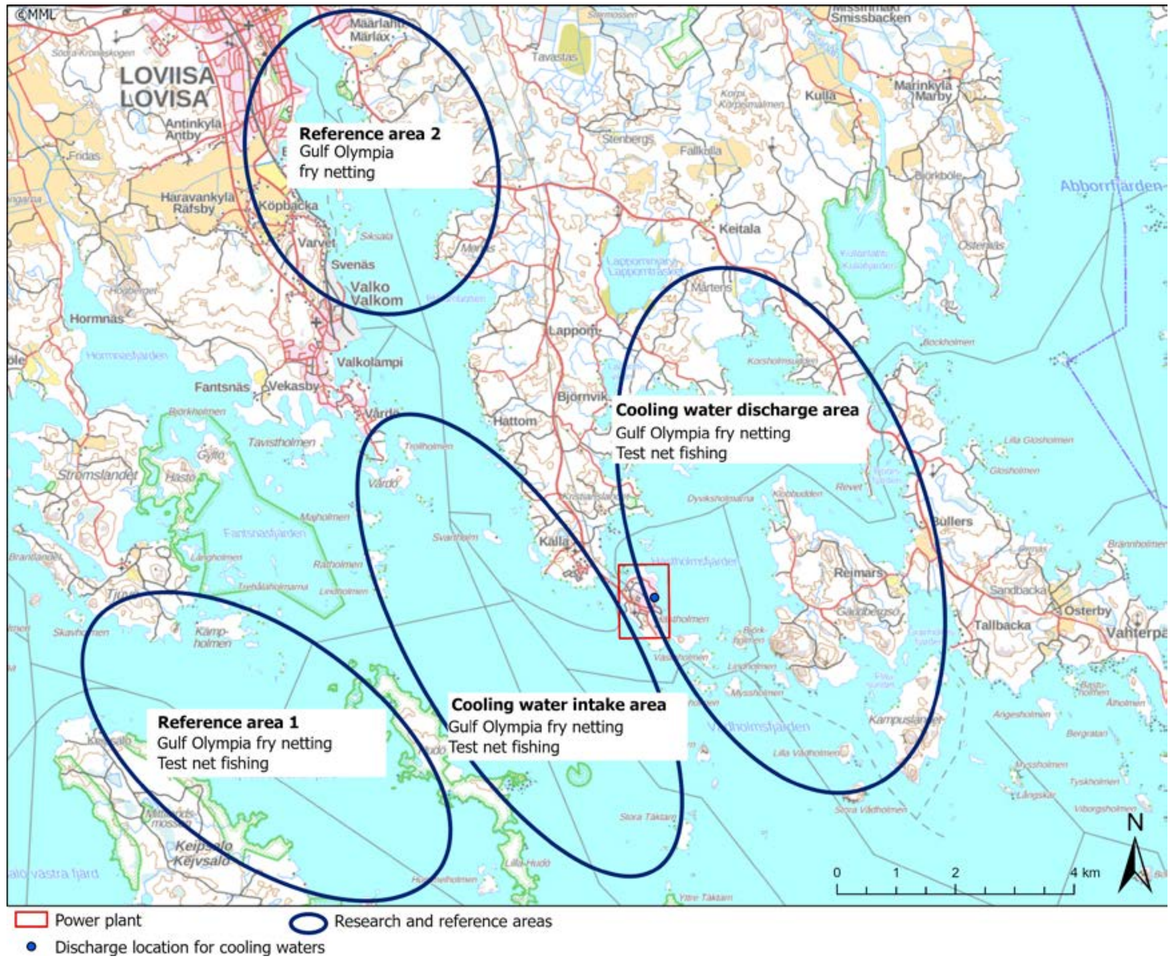


Figure 9-64. The observation areas and research methodologies employed in the 2020 fish study in the sea area off Loviisa.

The fry production areas in Gäddbergson and Kampuslandet were mapped in 2009 (Pöyry 2009) as part of the surveys concerning the current status of the nuclear power plant project being planned by Fennovoima Oy in Ruotsinpyhtää. The survey area is located on the south-eastern side of the island of Hästholmen, at a distance of up to approximately one kilometre from Loviisa power plant. Based on the surveys, there are significant breeding areas for Baltic herring and Gobiidae in the southeastern sea area near Hästholmen. The surveyed area also included shores with sand and gravel floor that whitefish spawning in the sea use as spawning areas.

According to the results of the fish study carried out in Loviisa power plant's nearby sea area (Roikonen & Kangas 2021), Baltic herring and Gobiidae and, to a lesser extent, common perch use Hästholmsfjärden, the discharge area of Loviisa power plant's cooling water, as their spawning ground. While the far end of Loviisanlahti was identified as the breeding area for pike-perch, the discharge area of the power plant's cooling water (Hästholmsfjärden and Klobbfjärden) was also found to be an area favoured by young pike-perch.

Most of the biomass carried to the power plant with the cooling water intake has consisted of fish, primarily Baltic herring or smelt (Leino 2011). The amount of fish carried to the power plant has been 10–25 tonnes a year. The fish are removed from the water with coarse and fine screens and travelling basket filters. The screenings, which consist

Table 9-60. Sensitivity of the affected aspect: fish and fishing.

Sensitivity of the affected aspect: fish and fishing	
The sensitivity of fish and fishing as an affected aspect was assessed on the basis of the fish occurring in the area, the location of the breeding areas in relation to the project area and the fishing carried out in the area.	
Moderate	The fish found in the project area are the fish normally occurring in the Gulf of Finland, which do not differ from the fish occurring elsewhere to any significant degree. Fry production areas of the Baltic herring and Gobiidae, fish species common across Finland's entire sea area, are found in the project area. The area supports some commercial fishing and recreational fishing. 5

of aquatic plants and algae in addition to fish, are taken to an external waste management company for appropriate processing and utilisation as material in the same manner as other organic waste generated in the power plant. This being the case, the collection of the screenings may be seen to have a cleaning impact on the sea, given that roughly 40–100 kg of phosphorus is removed from the sea alongside the screenings every year.

According to monitoring carried out by the Radiation and Nuclear Safety Authority, no nuclides originating from Loviisa power plant have been found in fish (see Chapter 9.8.3.4). The activity concentrations of caesium in Baltic Sea fish are low (STUK 2021g). The most significant source of radiation in fish in the Gulf of Finland is the caesium-137 derived from the Chernobyl nuclear power plant accident.

Fishing in the area is monitored as part of the required monitoring by requesting commercial fishermen to report their catches, and fishing is monitored with annual bookkeeping. Three commercial fishermen who practise fishing in the area submitted their bookkeeping on fishing for 2018. Their primary fishing method was net fishing, focusing on the spring and autumn. In bottom-set gillnet fishing, pike-perch accounted for the majority of the catch (57%), although pike (30%) was also caught. The results were in line with previous years' monitoring results (ÅF-Consult Oy 2019).

According to a survey conducted among recreational and subsistence fishermen, the calculated total catch of recreational fishermen was an estimated 14.9 tonnes and approximately 20.7 kg per household in 2017. The catch consisted primarily of pike, Baltic herring, perch, bream and pike-perch. The recreational fishing in the area focuses strongly on the summer months (ÅF-Consult Oy 2018).

The fish in Lappomträsket lake consist mainly of common perch and roach, which accounted for a majority of the fish caught in the exploratory fishing carried out in 2011 (Niiranen & Hagman 2012). Predatory fish accounted for 23% of the biomass and 7% of the number of fish. The average weight of the common perch was around 35 g and that of the roach 45 g, meaning that the majority of the prey fish were small. Fortum uses Lappomträsket lake as its source of raw water and regulates the lake's surface level (see Chapter 9.16.3.10). The water permit also involves an obligation to transplant 10,000 newly hatched pike fry every year.

Loviisa power plant's nearby sea area is also used for fish farming. Loviisa power plant is on the island of Hästholmen. The Oy Loviisan Smoltti Ab fish farm operates in the northern section of the island. The farming of the fry exploits the power plant's warm cooling water. The Oy Semilax Ab fish farm operates in the archipelago south of the island of Hästholmen. The area is mentioned in the national aquaculture site selection plan (Ministry of Agriculture and Forestry 2014) as a future aquaculture concentration area.

Table 9-60 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

9.17.4 Environmental impact of extended operation

Impact formation

A high water temperature accelerates the metabolism of fish and increases their need for nutrition. Generally speaking, a high temperature is expected to increase the growth of fish, provided that there are no factors restricting growth. A high water temperature also contributes to a waterway's primary production, provided that there are enough nutrients for it. Furthermore, through more abundant primary production, a high water temperature increases the risk of hypoxic conditions in the hypolimnion, which has a negative impact on the habitat of fish.

The power plant's extended operation would result in impacts on the area's fish and fishing, and mainly on Hästholmsfjärden, through the local impact on the marine ecosystem caused by the warming cooling water. The cooling water, coupled with the impact of climate change which warms the sea area, favours the occurrence of fish species adapted to warm water in the impact area. Non-native species favouring warm water may also benefit from the situation and impact the stocks of local fish species by becoming more abundant. The impact resulting from the power plant's operation on the operating conditions of fishing would remain unchanged, but climate change may have adverse effects on winter fishing possibilities in the future. Projections expect the occurrence of ice-free winters to increase in the future.

In the case of extended operation, Loviisa power plant would conduct warm cooling water east of the island of Hästholmen to Hästholmsfjärden, which would have an impact on the local marine ecosystem and thereby also the fish on the discharge side. Based on the cooling water modelling (see Chapter 9.16), the temperature and stratification conditions are expected to remain largely unchanged from their current levels. The thermal effect is local, and during the ice-free season, its impact is mainly observable in Hästholmsfjärden, close to the surface in the vicinity of the discharge location, but also occasionally in the surface layer of the northern part of Vådholmsfjärden.

The likelihood of warmer-than-average summers will increase as a result of climate change, and this will also have an impact on the environment in Hästholmsfjärden. According to the impact assessment concerning surface waters (see Chapter 9.16.4), the long-term development of Hästholmsfjärden's water quality is above all influenced by the development of point source diffusion. Compared to the present state, the change in the quality of water may manifest in the long run as a slight increase in nutrient concentration and the level of primary production. The assessment expects the hypolimnion's oxygenation conditions to remain weak. On the other hand, the possible long-term reduction of point source diffusion would improve the quality of water and the status of the water environment. But poor oxygenation conditions in the seabed are also common on the discharge side of the cooling water, as in the entire eastern Gulf of Finland, which is reflected in the benthic fauna and fish stocks in general.

A number of studies have found warm water to increase the fish biomass locally by improving the reproductive success of species benefiting from warm waters and by accelerating growth (Balkuvienė & Pernaravičiūtė 1994, Hakala et al. 2003, Marttila et al. 2005, Keskinen et al. 2011). An increase in the water temperature benefits fish species spawning in the spring and summer, such as common perch, pike-perch and cyprinids. The Baltic herring has also been found to benefit from the higher water temperature and a slight increase in the nutrient concentration. In particular, the juvenile phases of fish have been found to benefit from an increase in water temperature. In several species, this may increase the number of plentiful year classes and further the amount of food available to predatory fish. However, the increase in temperature impacts different species in different ways. The study conducted in the sea area of Forsmark nuclear power plant (Sandström 1990) found the growth of common perch to be positively correlated for the first few years, but to become negative in the following years as the fish reaches sexual maturity. The temperature's positive impact on the growth rate was also found to make a return in common perch at the age of six. The increase in temperature is the most disadvantageous for coldwater species such as European whitefish, sea trout, salmon, burbot and grayling.

Climate change is expected to increase the temperature of seawater (BACC II Author Team 2015), which will increasingly favour fish species adapted to warm water and their thriving in the discharge location of the cooling water. Several studies have found pike-perch, in particular, to benefit from the increase in temperature (among others, Pekcan-Hekim et al. 2011, Lappalainen et al. 2005, Fontell et al. 2004). Pike-perch has been found to produce more numerous year classes with more rapidly growing individuals in warm water. Fast growth and a larger size improve the chances of fry surviving their first winter. This may further favour the status of pike-perch and cyprinid stocks in the Hästholmsfjärden–Klobbfjärden area. Small pike-perch were found to be more numerous in Hästholmsfjärden than in the reference area in the exploratory fishing (Roikonen & Kangas 2021), which indicates the area's suitability for pike-perch. The inner bay area may therefore also produce more fish for the surrounding sea area through spreading, when the fry of some species begin to favour cooler water as they grow and swim away from the inner bay.

The rise in temperature may also increase fish's stress levels due to the adverse effects resulting from parasites and diseases becoming more widespread. The prevalence of fish diseases and parasites was studied in the impact area of Forsmark nuclear power plant in Sweden, but no increase in the number of diseases or parasites in local fish was detected there (Sandström 1990). The increased production of fry was deemed to compensate for the adverse effect this had on the fish stocks. While this has not been studied in the Loviisa area, the situation there can be considered similar to that in the Forsmark area, given that both areas are located in the Baltic Sea and at nearly the same latitude.

A temperature higher than that of the surrounding environment is also likely to favour the spread of round goby, a non-native species in the area. The species originates in the Black Sea and Caspian Sea areas, from where it has been carried to the Baltic Sea in ships' ballast waters (Vieraslajit.fi). Observations of the round goby in Finland's sea area have been made in the sea area between Oulu and Hamina, especially in the areas surrounding ports (Natural Resources Institute Finland 2021). Round gobies were caught in the 2020 exploratory fishing in the areas west of Hästholmen, but not from Hästholmsfjärden, the discharge side of Loviisa power plant. Round goby is likely to spread to Hästholmsfjärden as well, where the seawater temperature is higher than in the surrounding sea area. While the species is likely to spread to Hästholmsfjärden in the future even without the power plant's warming effect, its high optimum temperature may provide it with a competitive edge over other fish species in Hästholmsfjärden. Given that the species has been found to tolerate high temperatures, with its optimum occurrence temperature being 26 °C (Lee & Johnson 2005), it can be assumed that it will thrive in the conditions of Hästholmsfjärden. Generally speaking, round goby tolerates a temperature range of -1–30 °C (Moskal'kova 1996), while its critical maximum temperature is approximately 33 °C (Cross & Rawding 2009). The round goby is an aggressive competitor which has been suspected of impacting, in its new range in the Baltic Sea, the incidence of common perch, roach and flounder in the same areas (Kornis et al. 2012).

Nevertheless, the impact of round goby on the fish stocks of Hästholmsfjärden-Klobbfjärden is difficult to project due to the complex ecological interactions. Round goby may have an adverse effect on the reproduction of other species by taking over habitats with its aggressive behaviour, but at the same time, it may represent an important food source for predatory fish such as pike-perch and common perch, in addition to cormorants, for example. The biodiversity of the marine nature may be adversely affected if endemic species of goby, such as the black goby, disappear as they make way for non-native species.

Observations of predatory fish and cormorants focusing on the predation of round goby have been made in the southern Baltic Sea (Kornis et al. 2012). Based on exploratory fishing, the surroundings of Hästholmen support a strong stock of common perch, and since common perch has been found to prey on the round goby (Kornis et al. 2012), the common perch could play a significant role in limiting its further abundance. According to a study carried out in the Åland Islands (Herlevi et al. 2018), on the other hand, the round goby competes with large common perch for the same benthic fauna nutrition. Further, according to exploratory fishing, the stock of pike-perch is also strong in the Hästholmsfjärden-Klobbfjärden area. This being the case, pike-perch may also be assumed to focus its predation on the round goby stock, which is becoming more abundant in the area. In a study conducted in the Kiel Canal in Germany (Hempel et al. 2016), pike-perch has been found to have made a clear shift to exploiting the round goby as an important food source. Male pike-perch guard their spawning nests against other predatory fish (Hempel et al. 2016), and it may be presumed that the round goby is unable to disrupt pike-perch's reproduction in the area. The stock of pike-perch, which is important to fishing, is therefore not expected to be adversely affected by the potential increasing abundance of the round goby. Instead, it is possible that the pike-perch stock's nutritional situation will improve. In this case, pike-perch's share of the catch in the fishing practised in the area could even improve.

Entirely ice-free winters are expected to become more common as a result of climate change. Combined with the local thermal effect of the power plant's cooling water, weak ice winters may become more common in Hästholmsfjärden. This may further impair the conditions needed for winter fishing in the power plant's nearby sea area. Among other things, the impaired ice situation makes it more difficult for fishermen to reach their fishing gear and select fishing grounds, which would weaken the opportunities for using static gear.

In the optioncase of extended operation, the impact that the power plant's cooling waters would have on the nearby sea area, and thereby on the fish and fishing, would remain similar to its current level but continue for another 20 years or so. Climate change may slightly intensify the impacts of the thermal load on the impact area. Round goby's possible spread to the Hästholmsfjärden-Klobbfjärden area and a strong increase in its abundance could change the structure of fishing in the area. Taking into account these factors, the magnitude of the change concerning the fish in the impact area is deemed *moderate and negative*. However, from the perspective of fishing, the continuance of the thermal load alongside the impact of climate change, warming the seawater, is not expected to have a greater than *minor negative* impact. The power plant's extended operation is not expected to have an adverse effect on pike-perch, which is an important target species of fishing in the area.

9.17.5 Environmental impact of decommissioning

Impact formation

With decommissioning, the impact of the power plant's cooling water will reduce and eventually end. The structure of the icthyofauna and the fishing opportunities will gradually return to the level prevailing in the surrounding sea area, as the warming effect of the cooling water disappears. In terms of Lappomträsket lake, the end of the water intake may also mean the abandoning of regulation and the replacement of the dam structure of the lake's outlet by a submerged weir, enabling the migration of fish. Discontinuing the lake's oxidising may nevertheless expose the fish to the adverse effects of deteriorating oxygenation conditions.

Once the decommissioning begins, and the volume of discharge water drops to a fraction, the ecosystem in Hästholmsfjärden will slowly start to be restored to a status corresponding to that of the surrounding inner bays of the Gulf of Finland's coastal area. The strong stock of pike-perch in the impact area of the cooling water is likely to decline slightly compared to the present state. Climate change may nevertheless, in the long run, increase the populations of fish species which favour warm water, which will simultaneously favour the incidence of pike-perch.

The round goby is not expected to benefit from a competitive advantage stronger than anywhere else in the Gulf of Finland compared to the other species, because the temperature of seawater in Hästholmsfjärden will no longer differ from the temperatures in the rest of the coastal area. However, climate change in general also promotes the spread of round goby as the seawater warms, and it is probable that in this situation, the species will also spread to Hästholmsfjärden at some point. Nevertheless, it would be positive for the biodiversity of the area's icthyofauna if the round goby does not increase its abundance in the project's impact area to any degree stronger than elsewhere in the coastal area, and thereby change the natural structure of the icthyofauna. The impact on the icthyofauna will be confined to the Hästholmsfärden-Klobbfjärden area.

The ice situation will return to that typical for the area, and the conditions needed for winter fishing will no longer be subject to a similar local impact as when the power plant's thermal load weakened the ice. With regard to winter fishing, the improvement of the ice situation locally covers the area across the northern parts of Hästholmsfjärden and Vådholmsfjärden.

The magnitude of the change concerning the fish as a result of decommissioning is expected to be moderate and positive. The fish in the impact area may recover to the natural status prevailing in the surrounding coastal area. In terms of fishing, the decommissioning is expected to have a minor and positive impact on winter fishing through the improvement in the required conditions.

Ending regulation at Lappomträsket lake would allow the dam structure built in the lake's outlet to be replaced by a submerged weir that would enable the migration of fish. The change would open a route for the fish between the lake and Lappomviken. The route would allow the sea area's pike, among others, to swim all the way up to Lappomträsket lake for spawning. On the other hand, there is no certainty on how the lake's oxygenation conditions will develop when the regulation and oxidising activities come to an end, due to which the magnitude of the impact's positiveness in terms of the icthyofauna is difficult to assess. The restoration of the migration connection would have a positive impact, but if the lake's oxygenation conditions deteriorate at the same time, it would have adverse effects on the living conditions of the fish in the lake.

9.17.6 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage or final disposal of radioactive waste generated elsewhere in Finland would not have an impact on the icthyofauna of the sea area surrounding the power plant or the fishing practised in the area.

9.17.7 Significance of impacts

Table 9-61 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-61. Significance of the impacts: fish and fishing.

Significance of the impacts: fish and fishing			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate**	**Moderate negative (fish)**	**The significance of the impacts is moderate and negative,** because combined with the effect of climate change, which would warm the seawater, the fish species most successful in the impact area would be those favouring warm water, such as pike-perch and many cyprinids, and the impact that the power plant's cooling water would have on the sea area, and thereby on the icthyofauna, would continue for some 20 years. Furthermore, the local thermal effect could give a competitive advantage to the round goby, an invasive alien species, which could become more abundant in the Klobbfjärden body of water.
		Minor negative (fishing)	**The significance of the impacts is minor and negative,** because the fishing opportunities in the winter season would remain at the same level or could, as a result of the combined impact of the cooling water's thermal effect and climate change, deteriorate slightly in the power plant's nearby sea areas. Pike-perch, which is an important target species for fishing, is not expected to be impacted.
Decommissioning	**Moderate**	**Moderate positive (fish)**	**The significance of the impacts is moderate and positive,** given that as a result of decommissioning, the impact that the cooling water's thermal load has on the area's fish will end, and the impact area will gradually return to the state prevailing in the surrounding coastal area. The waters warmer than the surrounding sea area will no longer provide a competitive advantage for possible non-native species.
		Minor positive (fishing)	**The significance of the impacts is minor and positive,** because the opportunities for winter fishing will return to a better level as the ice conditions normalise, although climate change itself will impair fishing opportunities in the future.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No change (fish and fishing)**	**No impact,** because the operations would not impact the sea area.

9.17.8 Mitigation of adverse impacts

The mitigation of impacts on surface waters is discussed in Chapter 9.16.8.

Fortum compensates for the impacts that the cooling water has on the area's fishing industry by paying an annual fisheries charge. The funds accumulated from the fisheries charges paid by Fortum are used for fish transplanting carried out in the Uusimaa sea area. The transplanting aims to strengthen fish stocks and increase the sea area's recreational value by improving the fishing opportunities there. Fortum also transplants pike fry in the Lappomträsket lake every year, in accordance with the order of the water abstraction permit.

9.17.9 Uncertainties

The assessment involves uncertainty due to the uncertainty related to the impacts of climate change. The temperature of seawater in the area is expected to rise due to climate change, but there can be no certainty by how much. The data on fishing in the area, on which the impact assessment was based, were gathered as a time series covering decades, and are not considered to involve uncertainty. The study of the reproductive area of the fish is based on materials obtained in 2020 and therefore involves uncertainty, given that the variation from one year to the next remains invisible in the data of one year. The picture concerning the structure of the area's icthyofauna also involves uncertainty, because the data, based on the exploratory fishing data collected during one year alone, does not reveal annual variation. The ecosystem impacts attributable to the spread of round goby likewise involve uncertainty, given that the complex interactive processes between species are extremely hard to project with a time frame covering several decades.

9.18 FLORA, FAUNA AND CONSERVATION AREAS

9.18.1 Principal results of the assessment

In extended operation, the power plant's cooling waters would maintain Hästholmsfjärden's significance as regionally important wintering ground for waterfowl. If the thermal effect continued for some 20 years longer, it would slow down, for its part, the waterbody's attainment of a good status, which could have an adverse effect on the number of pairs of some archipelago birds in the area through changes in the food web. Overall, extended operation is expected to have a minor and favourable impact in terms of the avifauna and otters. Extended operation would not have significant impacts on conservation areas. In the case of extended operation, the power plant's impact on the flora and fauna of land areas would remain similar to their current levels.

Concerning flora, fauna and biodiversity as a whole, the decommissioning is expected to have a minor and negative impact, which would be manifested as the removal of the regionally important wintering grounds for waterfowl. However, this is not expected to have a significant impact on the populations of the birds in question. The decommissioning will not have an impact on conservation areas. Should the decommissioning be carried out according to the brownfield principle, buildings and other infrastructure will remain in the area, due to which vegetation in the area would not increase to any significant degree. If the decommissioning is carried out according to the greenfield principle, the power plant area's landscaping will increase the area covered by plants, which would increase local biodiversity.

Radioactive waste generated elsewhere in Finland would not have impacts on the flora, fauna or conservation areas.

9.18.2 Baseline data and assessment methods

The assessment concerning the impacts on the flora, fauna and conservation areas relied on the results of the impact assessment concerning noise, dust, traffic and surface waters, including the results of the cooling water modelling (Lahti 2021).

The impact assessment is also based on a survey of the area's avifauna (Metsänen 2021), which covered the nesting bird survey conducted in the vicinity of Loviisa nuclear power plant, the results of the counts of agglomerations during migration, and winter observations of the area's birds. The fieldwork in the area was carried out during a period which lasted a year (December 2019 – December 2020). In addition to the actual survey area (power plant area–Hästholmsfjärden), comparative counts were carried out in terms of the sea area west of the power plant (Hudöfjärden) and Loviisanlahti, in front of the town, during the same counting periods. Besides this monitoring, the avifauna survey also made use of other existing material.

The impact assessment also relied on data available from public sources, the most important of which included the databases of the environmental administration and the Finnish Environment Institute as well as data from the BirdLife Finland association on important bird areas (FINIBA and IBA), and other reports on bird areas deemed regionally important.

The assessment was carried out in the form of an expert assessment, which involved the assessment of the probable impact that each identified impact type had on the flora, fauna and conservation areas found within the impact area. The impact assessment concerning the natural environment also relied on data accumulated in other assessments and scientific studies on the probable impacts that each impact type (such as noise or dust) had on the occurrences and species assessed.

With regard to the impacts on aspects included in the Natura 2000 network, the assessment aimed to determine if the options being assessed were likely to cause significant impacts on the protected nature values in the Natura areas. With regard to aspects in other nature conservation areas and nature conservation programmes, the assessment determines whether significant impacts in terms of the conservation objectives.

Aquatic vegetation, benthic fauna and phytoplankton, as well as the impacts on them, are discussed in Chapter 9.18. The impacts on the avifauna are discussed in Chapter 9-17.

The emissions of radioactive substances and their impacts are discussed in Chapter 9.8.

9.18.3 Present state

9.18.3.1 Overview of the biotopes and vegetation

From the botanic geography perspective, the Loviisa region is located in the anemone belt, and its Lounaismaa part in the southboreal zone. This part of the southboreal zone has the most favourable climate and a rich vegetation. The rich grass-herb vegetation and groves differentiate the area from the rest of southern Finland. The demanding woodland plants of the area include the hepatica, yellow anemone and wood anemone, lung-wort, pilewort, white satin flower, fumitories, wall lettuce, alternate-leaved golden saxifrage and tor-grass. Ash, European hazel and European white elm have also spread to the Loviisa area.

The island of Hästholmen is approximately 75 hectares in area, about half of which is the built-up environment intended for the power plant's operations. Hästholmen is connected to the smaller island of Tallholmen by a narrow isthmus. In addition, the small islands of Hässjeholmen and Tallören are almost connected to the island of Hästholmen by isthmuses, very shallow water areas and cobble deposits. The dominant tree on the islands of Hästholmen and Tallholmen is pine. The islands also feature some patches of bare rock with few or no trees, and plenty of rocky soil. The narrow isthmus between Hästholmen and Tallholmen features typical alder grove stands. The shores of the islands are primarily rocky, and larger reed stands or other flood meadows are rare. Only the shallow between Hässjeholmen and Hästholmen and the isthmus of Tallholmen feature small reed stands. Aquatic plants are reviewed in more detail in Chapter 9.16.3.7.

9.18.3.2 Fauna in land areas

In the area of the town of Loviisa, the fauna consists primarily of typical species that have adapted to living in managed forests, such as fox, brown hare and cervids. The only large predator more generally seen in the Loviisa region is the lynx (Natural Resources Institute Finland 2019a).

A blue hare, a fox and some deer were observed on the island of Hästholmen in 2020, during the avifauna survey (Metsänen 2021). The elk population is fairly strong near the power plant area and in the surroundings of the road leading to the area south of the centre of Loviisa.

Two otter individuals were observed at the intake location of the power plant's cooling water during the avifauna survey (Metsänen 2021) prepared in connection with the impact assessment. There is no prior research on the incidence of the species in the area, but the fact that the sea area remains unfrozen throughout the winter may induce the species to spend its winters and breed in the area. The otter is mentioned in Annex IV(a) to the Habitats Directive, and its breeding and resting areas are therefore protected pursuant to the Nature Conservation Act.

No information is available on the incidence of the other species listed in Annex IV(a) to the Habitats Directive (including the Siberian flying squirrel and bats) in the power plant area. The incidence of Siberian flying squirrels and bats was studied when land use planning was carried out in the component master plan area of the northern part of Loviisa and Tesjoki in 2005. The only breeding area for the whiskered bat and brown long-eared bat observed in the land use plan area is approximately 10 km from Hästholmen. There are no habitats preferred by the Siberian flying squirrel on the island of Hästholmen or the cape next to it, and there are no known breeding or resting areas for the Siberian flying squirrel in the vicinity of the power plant (Fortum Power and Heat Oy 2008). During the spring and autumn migrations, migrating/migratory bats can be found practically everywhere in the coastal region, so it is probable that bat species will also be found in the vicinity of Hästholmen during these migrations.

9.18.3.3 Marine mammals

According to surveys conducted among fishermen, seals have been observed in Loviisanlahti bay. Both grey seals and Baltic ringed seals can be found in the Gulf of Finland area. The grey seal is considerably more common than the ringed seal in the eastern Gulf of Finland. Based on the counts carried out in 2019 by the Natural Resources Institute Finland, the grey seal population of the Gulf of Finland was 685 seals (Natural Resources Institute Finland 2019b). The population (in Finland and Russia combined) of the Baltic ringed seal in the Gulf of Finland is estimated at fewer than 200 seals (Ministry of Agriculture and Forestry 2018). This means that the seals observed in the Loviisa region are probably grey seals. Grey seals were observed in Hästholmsfjärden in connection with the avifauna survey conducted in 2020 (Metsänen 2021).

9.18.3.4 Valuable marine areas

Finland's ecologically significant marine underwater areas (EMMAs) were determined as part of the Finnish Inventory Programme for the Underwater Marine Environment (VELMU). No sites categorised as valuable are located in the vicinity of the power plant or the impact area of the waterways impact (SYKE 2020). The closest EMMA sites are the head of Loviisanlahti (some 8 km northwest of the power plant), due to its valuable fish stock, and the Vahterpää flads (some 8 km east-southeast).

9.18.3.5 Avifauna

In terms of the landbird species, the Loviisa region is representative of the typical forest areas in the southern coastal region. In Loviisa, the landbird species are abundant, but

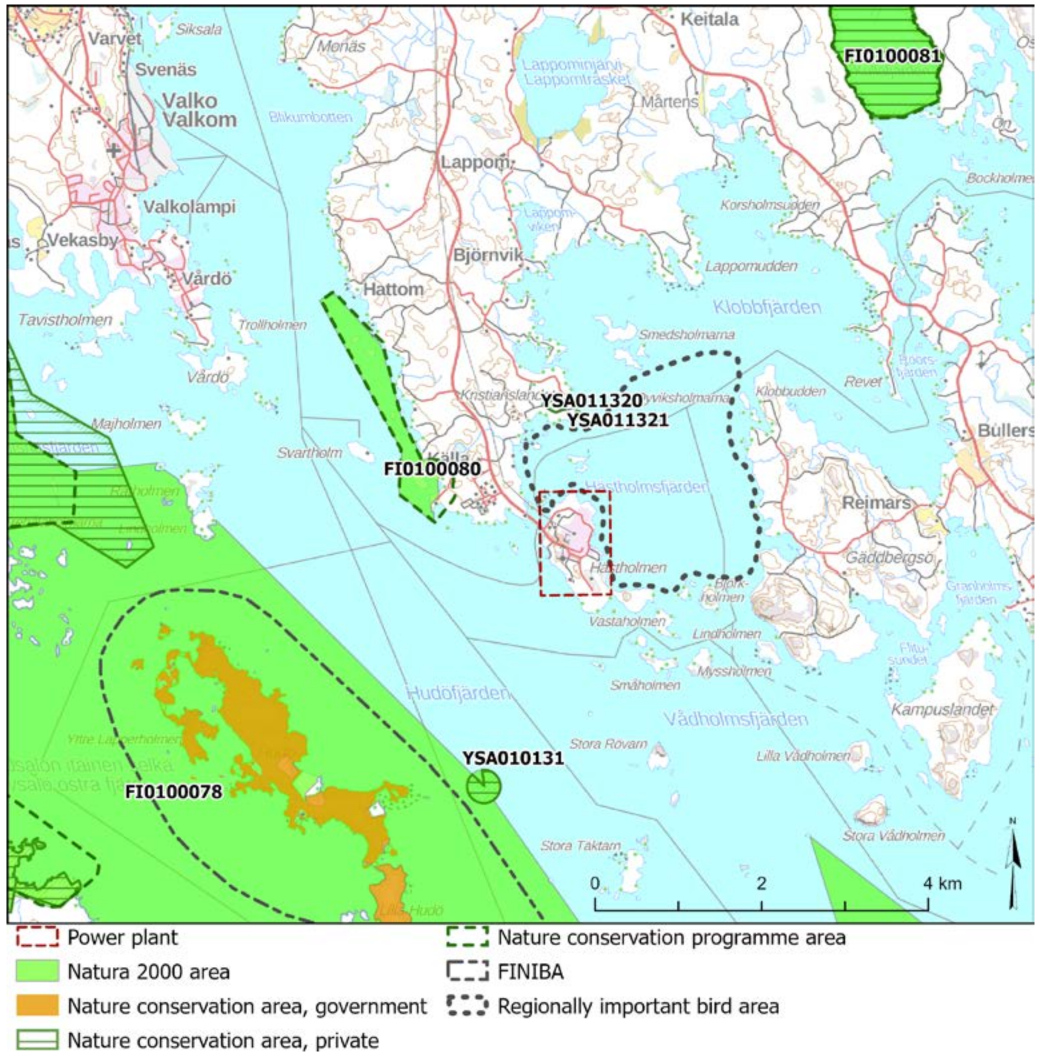


Figure 9-65. Nature conservation areas, sites covered by conservation programmes, Natura 2000 sites and a nationally important bird area (FINIBA) in the vicinity of the power plant.

rare species are few. Waterfowl species and individuals are abundant in Hästholmsfjärden, particularly in the winter and during the spring and autumn migratory seasons. The abundance of winter avifauna in Hästholmsfjärden, in particular, is explained by the thermal effect of the power plant's cooling water; Hästholmsfjärden has indeed been categorised as a regionally important bird area, at least partly due to the influence of the power plant.

There are no internationally important (IBA) or nationally important (FINIBA) bird areas in the power plant area or its immediate vicinity. The sea area east of the power plant, Hästholmsfjärden, has been categorised as a regionally important bird area (MAALI) due to the diverse population of waterflow wintering in the area. The impact area of the cooling water remains unfrozen throughout the winter, enabling waterfowl to overwinter in the area. Mallard, goldeneye, tufted duck and goosander are some of the species wintering in the area in large numbers (Leivo & Lehtiniemi 2019). The nesting grounds of the species wintering in the area are located primarily outside Hästholmsfjärden. Some of the birds may even nest beyond Finland's borders, given that the waterfowl wintering in the Baltic Sea are part of a larger population, the wintering grounds of which vary greatly, depending on the ice situation. The nearest bird area categorised as nationally important is the sub-area included in the FINIBA area of the archipelago in the eastern Gulf of Finland, more than two kilometres to the southwest (Figure 9-65).

The avifauna survey related to the EIA procedure was carried out over a one-year period, beginning in December 2019. The power plant's warm cooling water in the impact area can be considered a positive impact attracting birds in the winter, and partly also during the spring and autumn (Metsänen 2021).

Large numbers of goldeneye, tufted duck and goosander were observed during the 2019–2020 winter season. The number of white-tailed eagles in the winter can also be seen as notable, at least regionally. In the spring of 2020, a large number of black-throated divers and cormorants gathered

Table 9-62. Sensitivity of affected aspect: flora, fauna and conservation areas.

Sensitivity of affected aspect: flora, fauna and conservation areas	
In respect of the flora, fauna and conservation areas, the aspect's sensitivity is influenced by incidences of notable species, the presence of bird areas categorised as valuable or other categorised natural sites in the area, and the presence of nature conservation areas, conservation programmes and sites belonging to the Natura 2000 network in the area.	
Moderate	No conservation areas or sites of the Natura 2000 network are located in the power plant area or its vicinity. While no notable habitat types are located within the power plant area, endangered or protected species have been found there. Hästholmsfjärden, located within the area of the power plant's waterways impact, is categorised as a regionally important bird area.

in Hästholmsfjärden. The agglomeration of roughly 50 black-throated divers counted in late April can be considered regionally notable. The abundant occurrence of black-throated divers is probably explained by the fact that the bay offers them a sheltered, nutrient-rich resting area along their migratory route. The greatest numbers of cormorants approached 500 individuals, greatly exceeding the numbers present in the reference areas (Hudöfjärden and Loviisanlahti) at the same time. Cormorants gathered particularly in the vicinity of the discharge locations of water and on the small islet of Flitun in Hästholmsfjärden (Metsänen 2021).

The maximum number of gadwalls counted in the autumn of 2020 was 75, which can be considered a regionally significant agglomeration. A large number of great crested grebes, at most 179 individuals, gathered in Hudöfjärden, in the sea area west of the power plant, in the autumn of 2020 (Metsänen 2021).

The birds nesting in Hästholmsfjärden consist of species typical of the coastal archipelago, and the lack of actual bird rocks is visible as the scarcity of both communal species (such as the common tern and black-headed gull) and the species comfortable nesting under their protection (including goosander and shoveller). Notable species nesting in Hästholmsfjärden in the 2020 survey included the endangered goosander; one nest was found on the islet of Flitun. A great black-backed gull and a herring gull, both listed as a vulnerable species (VU) in the most recent conservation status, were also found nesting on the same islet. Notable species found in the power plant area and its vicinity during the inventories made in the summer of 2020 included the black redstart (near threatened, NT). Barn swallows (vulnerable) and common house martins (endangered, EN) were also apparently nesting in the power plant's structures. Early in the spring, a woodlark displayed south of the power plant. While the species does not nest in Finland in great numbers, it is still listed as a species of least concern.

9.18.3.6 Nature conservation

The Natura 2000 network site closest to the power plant area is the Källaudden–Virstholmen area (ID FI0100080), located at least approximately 1.3 km to the southwest (Figure 9-64). The area is protected as a site referred to in the Habitats Directive (a SAC area). The next closest Natura 2000 network site is the marine reserve (FI0100078) in Pernajanlahti bay and the Pernaja archipelago located at least approximately 2.3 km to the southwest. It is markedly vast and protected as a site compliant with both the Wild Bird and Habitats Directives (a SAC and SPA area). The Natura area in the marine reserve of Pernajanlahti bay and the Pernaja archipelago also includes the small islet of Kuggen, which is protected as an avifauna conservation area (YSA010131). The Kullafjärden waterfowl habitat (FI0100081) is approximately 7 km to the northeast of the power plant.

The established nature conservation areas closest to the power plant, at a distance of 0.8–1 km to the north, are the privately owned nature conservation areas of Karhulahti shore (YSA011320) and Bastuängen common forest (YSA011321) (Figure 9-64). The nature conservation area of Karhulahti shore is approximately 0.2 hectares, and the area of the Bastuängen common forest is approximately 4 hectares.

Table 9-62 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

9.18.4 Environmental impact of extended operation

Impact formation

Loviisa power plant's most significant environmental impact on flora and fauna is the warming effect of the cooling water in the sea area on the discharge side. In extended operation, the power plant's impact on the flora and fauna would remain similar to its current level.

In extended operation, the impact of the thermal load would continue for a longer period of time, in line with the extended operating time, which would maintain Hästholmsfjärden's significance as important wintering grounds for waterfowl. The continuation of the cooling water's thermal effect would maintain ecosystem changes that favour the abundant occurrence of cyprinids in Hästholmsfjärden. This is likely to benefit the fish-eating waterfowl currently abundant in the area (including the great crested grebe, tufted duck and cormorant). The power plant's cooling water also maintains meltwater in the area during cold winters, which allows otters to fish by the areas free of ice.

SYKE monitors the status of the Baltic Sea with the aid of several different indicators, one of which is the development in the number of pairs in the avifauna of the Baltic Sea. Of the 29 species being monitored, a declining trend is observable in the stock of 14 species, and a rising trend in as many species (SYKE 2018). Examples of sea birds which, based on indicators, have been declining in recent decades (since the beginning of the 1980s) and which nest in the Loviisa nest area, include the tufted duck, velvet scoder, eider and black guillemot. The reasons for the decline of many of the aforementioned species include changes in their food chains and other indirect changes caused by the chemical status of the Baltic Sea. Thus, the status of the bird stocks is also a wider indication of the status of the Baltic Sea's biodiversity.

A minor deterioration in the quality of water on the discharge side contributed to by the power plant's thermal load cannot be entirely ruled out (see Chapter 9.16.4.2). In extended operation, a potential, minor change in the quality of water is not expected to have a detectable impact on the biodiversity of the water environment (phytoplankton, aquatic vegetation, benthic fauna) compared to the present state. In respect of the impact on avifauna, the potential spread of the round goby to the discharge side is expected to have a negative effect on biodiversity if endemic species of gobies, such as the black goby, disappear to make way for non-native species (see Chapter 9.17.4). With some archipelago birds, the potential minor deterioration in water quality may have an adverse effect on their pairs in the area of Hästholmsfjärden.

The continuation of the thermal effect may have both positive and negative effects on some species. The number of tufted ducks wintering in the power plant's vicinity, for example, is higher than usual due to the meltwater in the area during winter. On the other hand, the increasingly abundant stock of cyprinids may reduce the benthic fauna on which the tufted duck feeds (Finnish Wildlife Agency 2019).

Without the impact of the cooling water, the area would lack the meltwater enabling the otter's wintering, at least during cold winters. The most important factor in terms of otters and seals (mainly the grey seal occurring in the area) in extended operation would be the impact on the area's fish stocks. Based on the assessment of the impact on the icthyofauna, the warm water on the cooling water's discharge side favours fish species adapted to warm water, such as pike-perch. The Baltic herring has also been found to benefit from the higher water temperature and a slight increase in the nutrient concentration. In the present state, this is expected to benefit the otter and seal populations in Hästholmsfjärden.

Climate change is expected to increase the temperature of seawater (BACC II Author Team 2015), which will increasingly favour fish species adapted to warm water and their thriving in the discharge location of the cooling water. Several studies have found pike-perch, in particular, to benefit from the increase in temperature.

Overall, extended operation is expected to have a minor and favourable impact in terms of the avifauna and otters.

Extended operation would not have an impact on the land area's flora or fauna. The fauna in the power plant's impact area can be expected to be accustomed to human-derived disturbance (noise, the movement of people and machinery). Nor would extended operation require the clearing of new built-up areas.

The most significant environmental impact of extended operation would be the thermal load on Hästholmsfjärden and the resulting indirect impact on this body of water's ecological status. The closest site of the Natura 2000 network, which is protected on the basis of habitat types dependent on the water ecology, is the Källauden–Virstholmen area, 1.3 km to the northwest, on the side of Hudöfjärden (ID FI0100080) (Table 9-63). Based on the cooling water modelling (Lahti 2021) and the assessment on the waterways impact (see Chapter 9.16), the thermal effect on the intake side of the cooling water in the Källaudden–Virstholmen Natura area will be very small, practically negligible, during the ice-free season. The Natura area in question is therefore not subject to adverse effects. During ice cover, the thermal effect does not extend to the Källauden–Virstholmen Natura area. Based on this, the Natura area in question is not expected to be subject to adverse effects.

Nor is any other more distant site within the Natura 2000 network expected to be subject to adverse effects. Based on the cooling water modelling and the assessment concerning the impact on waterways, the thermal effect on the area will be negligible (Figure 9-66). As is evident from the figure concerning the modelling (Lahti 2021), the thermal effect on the Natura area, even in the case of the maximum temperature differences, is small, principally in the region of 0–1°C. At its greatest, the effect may be 1.5–2.0 °C at the Natura area's sharp headland extending to Vådholmsfjärden. Any situations involving maximum temperature differences are nevertheless short-lived, and in average conditions, the thermal effect of the power plant's operation does not, in essence, extend to the Natura area at all during the ice-free season.

Table 9-63. The habitat types mentioned as grounds for protection with regard to the Källaudden–Virstholmen Natura area (FI0100080), their connection to the waterways impact and the probability/significance of the impact.

Code and name of natural habitat type	Potential impact on waterways
1150 Flads, gloe lakes and coastal lagoons	The impact on the area attributable to the thermal load is negligible in the present state and the indirect **impacts are deemed negligible.**
1210 Annual vegetation of drift lines	The impact on the vegetation of drift lines would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat type is not impacted.**
1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation	**The impact on the area attributable to the thermal load is negligible in the present state and the indirect** impacts are deemed negligible.
1640 Boreal Baltic sandy beaches with perennial vegetation	The impact on the vegetation of sandy beaches would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat type is not impacted.**
9080 Fennoscandian deciduous swamp woods	The status of the sea area has no impact on the habitat type. **The habitat type is not impacted.**

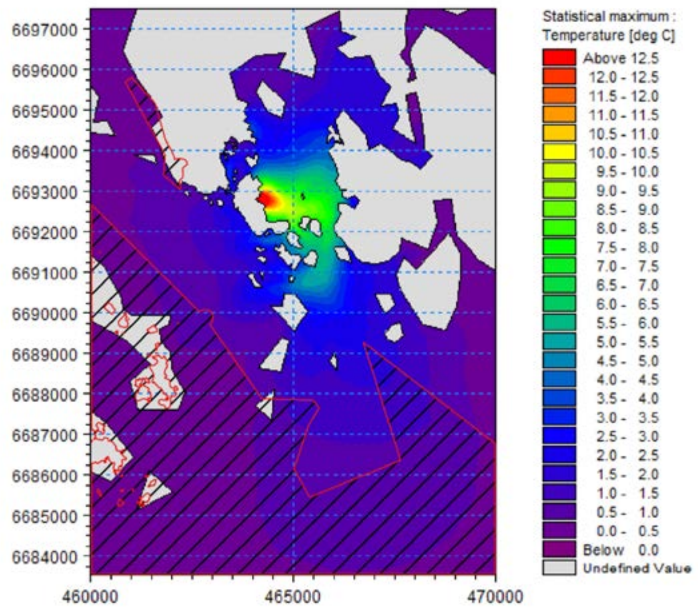


Figure 9-66. The maximum difference in surface temperature (power plant in operation – power plant not in operation) according to the modelling during the ice-free season. The hatched area delimited in red is the Natura area (Lahti 2021).

The grounds for protection mentioned with regard to the sea conservation area of the Pernaja bays and archipelago include a large number of different types of water habitat and waterfowl (Table 9-64), but not the species which gather in the power plant's meltwater area in the greatest numbers for wintering. This being the case, the minor positivefavourable impact on the avifauna will have no indirect impacts on the grounds for protection related to the sea conservation area of the Pernaja bays and archipelago.

The power plant's other operations (noise, dust) or traffic have no impact on the conservation areas.

9.18.5 Environmental impact of decommissioning

Impact formation

With decommissioning, the impact of the power plant's cooling water will end. The local impacts on the flora and fauna related to decommissioning will be caused primarily by dismantling measures and transport as well as the possible interim storage of quarry material. For the most part, the measures concern the built areas.

Table 9-64. The habitat types mentioned as grounds for protection with regard to the sea conservation area of the Pernaja bays and archipelago Natura area (FI0100078), their connection to the waterways impact and the probability/significance of the impact. The bird species mentioned as grounds for protection and the fauna listed in Annex II to the Habitats Directive are given at the bottom of the table.

Code and name of natural habitat type	Potential impact on waterways
1110 Sandbanks which are slightly covered by sea water all the time 1150 Flads, gloe lakes and coastal lagoons 1160 Large shallow inlets and bays 1170 Reefs 1610 Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation 1620 Boreal Baltic islets and small islands 1650 Boreal Baltic narrow inlets	In the present state, the impact on the Natura area attributable to the thermal load concerns a very small area, and even in this area, the impact is very small. The indirect **impact is deemed negligible.**
1130 Estuaries	The Estuaries habitat type principally depends on the impact of the freshwater carried by a river. Incidences of the habitat type are located far from the project area. **The habitat type is not impacted.**
1210 Annual vegetation of drift lines 1220 Perennial vegetation of stony banks 1640 Boreal Baltic sandy beaches with perennial vegetation	The impact on the littoral vegetation would require extremely strong eutrophication and the resultant increased abundance of helophytes. **The habitat types are not impacted.**
1230 Vegetated sea cliffs of the Atlantic and Baltic coasts 1630 Boreal Baltic coastal meadows 6270 Fennoscandian lowland species-rich dry to mesic grasslands 7140 Transition mires and quaking bogs 7160 Fennoscandian mineral-rich springs and springfens 8220 Siliceous rocky slopes with chasmophytic vegetation 9010 Western Taiga 9020 Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in epiphytes 9050 Fennoscandian herb-rich forests with Picea abies 9080 Fennoscandian deciduous swamp woods 91D0 Bog woodland	The sea area's temperature has no impact on the habitat type. **The habitat types are not impacted.**
large white-faced darter	A species of eutrophic reed fields. **The species is not impacted.**
grey seal, ringed seal	The seals are dependent on the development of the Natura area's fish stocks and the sea area's ecological status. The project will not have an impact on the Natura area's icthyofauna or the ecological status of its sea area. As an indirect impact, Hästholmsfjärden's abundant cyprinid and other fish species may have a **minor positive impact** on the grey seal.
great reed warbler, razorbill, pintail, shoveller, garganey, gadwall, taiga bean goose, ruddy turnstone, greater scaup, Eurasian bittern, black guillemot, western marsh harrier, corn crake, tundra swan, whooper swan, Eurasian hobby, common kestrel, great snipe, common crane, red-backed shrike, lesser black-backed gull, little gull, velvet scoder, smew, osprey, European honey buzzard, ruff, spotted crake, common eider, Caspian tern, common tern, Arctic tern, barred warbler, wood sandpiper, common redshank, common murre	The species mentioned as grounds for protection do not feed or winter in the area of Hästholmsfjärden to any significant degree. **The project will not have an impact on the species.**

With decommissioning, the impact of the warm cooling water will end, and the occurrence of winter birds in Hästholmsfjärden will decline. As a result of this change, it is likely that Hästholmsfjärden can no longer be categorised as a regionally important bird area. As the thermal load reduces, the status of the Klobbfjärden body of water, located on the cooling water's discharge side, is expected to improve. In general, the change is expected to have a favourable local impact on the living conditions of archipelago birds and the marine environment's biodiversity once the thermal load impairing the natural state in the area comes to an end. When examining solely impacts on the avifauna, and particularly the significance of the impact in terms of bird areas categorised as valuable, the decommissioning will have a negative impact.

The otter's possibilities for wintering in the area will be adversely affected when the meltwater area in the winter disappears, but the improvement in the sea area's status is considered a positive change of an equal magnitude. Therefore, the impact in terms of the otter is considered neutral.

The decommissioning will not have direct impacts on conservation areas, given that the disturbance caused by the dismantling activities will not extend to the conservation areas or the sites which are part of the Natura 2000 network.

The local impacts on the flora and fauna related to decommissioning are primarily caused by dismantling measures and transport. For the most part, the measures concern the built areas. The impact will concern conventional vegetation, and there is no knowledge of any particularly notable species or endangered habitat types occurring in the impact area. If the quarry material generated in the excavation of the L/ILW repository is placed in interim storage within the power plant area, the clearing of the potential storage area may require the removal of trees or the levelling of topsoil. Should the decommissioning be carried out according to the brownfield principle, buildings and other infrastructure will remain in the area, due to which vegetation in the area would not increase to any significant degree. If the decommissioning is carried out according to the greenfield principle, the power plant area will be restored to a state as close to its natural state as possible, and the area of plant cover there will increase compared to the present state. The impact that the landscaping will have on the fauna depends on the vegetation used, but in principle, the change can be expected to increase the flora and fauna, and thereby biodiversity, in the area. The impact is local and small in area.

As a whole, decommissioning is expected to have a minor and negative impact, which will be manifested as the disappearance of the regionally important wintering grounds for waterfowl. This is nevertheless not expected to have a significant impact on the populations of the birds in question, because their primary wintering grounds are naturally further west and south within the area of the Baltic Sea.

9.18.6 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 have an impact on the flora, fauna or conservation areas. The increase in disturbance caused to traffic by the transports along the transport route is deemed a negligible factor compared to other traffic on the transport route.

9.18.7 Significance of impacts

Table 9-65 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-65. Significance of impacts: flora, fauna and conservation areas.

Significance of impacts: flora, fauna and conservation areas			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate**	**Minor positive**	**The significance of the impacts is minor and positive,** given that the continuance of the cooling water's thermal load would maintain Hästholmsfjärden's significance as regionally important wintering grounds for waterfowl. The thermal load may nevertheless contribute to a deterioration of the quality of water on the discharge side, which may, in terms of some archipelago birds, have an adverse effect on their pairs in the area and, more generally, on the sea area's biodiversity. Extended operation would have no impact on conservation areas.
Decommissioning	**Moderate**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the end of the cooling water's thermal load will weaken the regionally important wintering grounds for waterfowl in Hästholmsfjärden. However, this is not expected to have a significant impact on the populations of the birds in question. The decommissioning will not have an impact on conservation areas.
Radioactive waste generated elsewhere in Finland	**Moderate**	**No change**	**No impact** on the flora, fauna or conservation areas.

9.18.8 Mitigation of adverse impacts

The impacts of the dismantling activities can be mitigated by planning the interim storage of the machinery and materials on site so that the impact on the flora and habitats occurring in the area is as minor as possible.

9.18.9 Uncertainties

Due to climate change, the number of winters with ice cover, or the number of days with ice cover during the winter, is likely to decrease in the Loviisa area, which will increase the number of wintering grounds suitable for waterfowl in the Loviisa area and beyond. This will complicate the assessment of Hästholmsfjärden's significance in terms of avifauna in the coming decades.

9.19 PEOPLE'S LIVING CONDITIONS AND COMFORT

9.19.1 Principal results of the assessment

The significance of the impacts of extended operation was deemed, as a whole, minor and negative, given that the impacts on people's living conditions and comfort under extended operation would continue for approximately 20 years. The discharge of warm cooling water, combined with the changes brought about by climate change, may impact the recreational value of the area's waterways, mainly in Hästholmsfjärden. In other respects, the impacts and adverse effects experienced by people will remain largely similar to their current levels. The potential additional construction could cause some additional adverse effects. In extended operation, the possible concern over safety risks would continue and could grow as the waste volumes increase and the plant ages. Extended operation could also have a positive impact on the area's demographics.

The power plant's decommissioning will result in a clear and observable change in the operations taking place in the power plant area. All in all, the various phases of the decommissioning will take several decades. A change of such duration may give rise to uncertainty among residents about the future, with the associated related concerns and expectations. The significance of the impacts was deemed moderate and negative. The occasional noise caused by the operations carried out during the decommissioning may impact particularly the comfort of holidaymakers staying in holiday homes in the vicinity of the power plant and the recreational experiences of people using the waterways and shores. The increased traffic during the most active dismantling phase may impair the nearby area's road safety and affect the smooth flow of traffic. The interim storage and transports of spent nuclear fuel may involve concerns about safety risks. Transports may especially raise concerns, even on a wider scale. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and concerns about the effect that the change will have on the vitality of the Loviisa region.

Once the L/ILW repository has been closed, the significance of the impacts will become minor and positive. As operations in the power plant area come to an end, any concerns about the risk of accidents or other incidents related to the operations will end. As a result of the end of operation, the need for cooling water and the thermal load will first reduce to a fraction during the operation of plant parts to be made independent and ultimately terminate completely. The positive impacts that the change will have on the status of Hästholmsfjärden's water environment may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties in the long run If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).

The transports, handling and final disposal of radioactive waste generated elsewhere in Finland would not result in impacts on people's living conditions and comfort. Loviisa power plant's reception of waste generated elsewhere in Finland nevertheless raises concerns among residents. Even if there were no realistic grounds for such concerns, it is still an actual social impact, the magnitude of which has been deemed minor and negative.

9.19.2 Baseline data and assessment methods

The assessment of social impacts reviewed the potential impacts on humans, the community or society as follows:
- the comfort and safety of the residential and living environment;
- traffic and mobility;
- the nearby areas' recreational use;
- community spirit and local identity;
- services and economic life;
- demographics;
- the use of tangible property and real estate in the nearby area.

The results of the assessment concerning impacts on the regional economy are presented in Chapter 9.13. The possible impacts of incidents and accidents are addressed in Chapters 9.21 and 9.22.

Social impacts are tightly linked to other impacts (such as the regional economy, noise, emissions, traffic and landscape), either directly or indirectly. In addition, social impacts – in the form of residents' concerns, fears, wishes, and uncertainty about the future – may emerge as early as during the planning and assessment stage of a project, for example.

The assessment concerning social impacts was carried out in the form of an expert assessment, based on the following baseline data:
- the results of other impact assessments;
- the results of the residential survey;
- the feedback received in the small group event;
- the opinions submitted on the EIA Programme;
- any other feedback received during the assessment procedure (in public events, the meetings of the audit group and evening meetings held with fishermen);
- population, map and other statistics.

Table 9-66. Activeness in responding to the survey among different groups of respondents. Three control forms have been added to the number of forms sent to residents and holidaymakers at a minimum distance of 5 km from the power plant.

	Forms sent	Number of respondents	Response rate
Permanent resident, 0–5 km	37	30	81%
Resident of secondary home, 0–5 km	258	99	38%
Permanent resident, 5–20 km	831	158	19%
Resident of secondary home, 5–20 km	177	75	42%
Total	**1303**	**362**	**28%**

Table 9-67. Population structure of the town of Loviisa in 2019 (Statistics Finland 2021a) and respondents to the survey.

	Residents, total	Women	Men	aged 18–30	aged 31–50	aged 51–65	over 65
Town of Loviisa	14,772	50%	50%	12%	27%	28%	33%
All respondents	362	41%	59%	3%	17%	32%	49%

The impact on people's living conditions and comfort was assessed with the aid of guidelines prepared by the National Research and Development Centre for Welfare and Health ("Ihmisiin kohdistuvien vaikutusten arvioiminen", Kauppinen and Nelimarkka 2007) and a handbook of the Ministry of Social Affairs and Health ("Ympäristövaikutusten arviointi, Ihmisiin kohdistuvat terveydelliset ja sosiaaliset vaikutukset", Ministry of Social Affairs and Health 1999).

9.19.2.1 Resident survey

A survey conducted among the residents living in the vicinity of Loviisa nuclear power plant during the EIA report phase aimed to gauge the use and meaning of the power plant's nearby areas, the respondents' views of the present state of their residential environment and their perceptions of the planned operations.

The resident survey was sent to a total of 1,300 households on 9 December 2020. The survey was sent to all permanent residents and secondary homeowners within a 0–5 km radius of the power plant, including the residents of the lakeside properties of Lappomträsket lake. The total number of households in this area was 295. In addition, the survey was sent by way of random sampling to households located at a distance of 5–20 km from the power plant.

In accordance with the selection criteria, the survey was only sent to households with residents aged 18–80 who have not chosen to opt out of direct marketing. According to the data in the registry of the Digital and Population Data Services Agency, households were sent a total of 1,303 survey forms. This figure includes three control forms posted for the purposes of the survey's official inspection to Posti Group, the main postal service in Finland, and the Digital and Population Data Services Agency.

Respondents were given the choice to respond to the survey either by posting the completed form, or by responding to the questions online, by 11 January 2021. The number of responses received by this date was 362.

The response rate was 28%. Table 9-66 shows a breakdown of response activity according to respondent groups. Permanent residents in the nearby area made up the most active group of respondents. The residents of secondary homes nearby and further away also responded to the survey at a higher rate than in general.

The proportion of male respondents and respondents who were aged 65 or more was greater than their proportion of the population (Table 9-67). Half (49%) the respondents had lived or holidayed in the nearby region for more than 40 years, and 25% for at least 20 years. Respondents who had lived or holidayed in the area for less than 10 years made up only 9% of the total number of respondents.

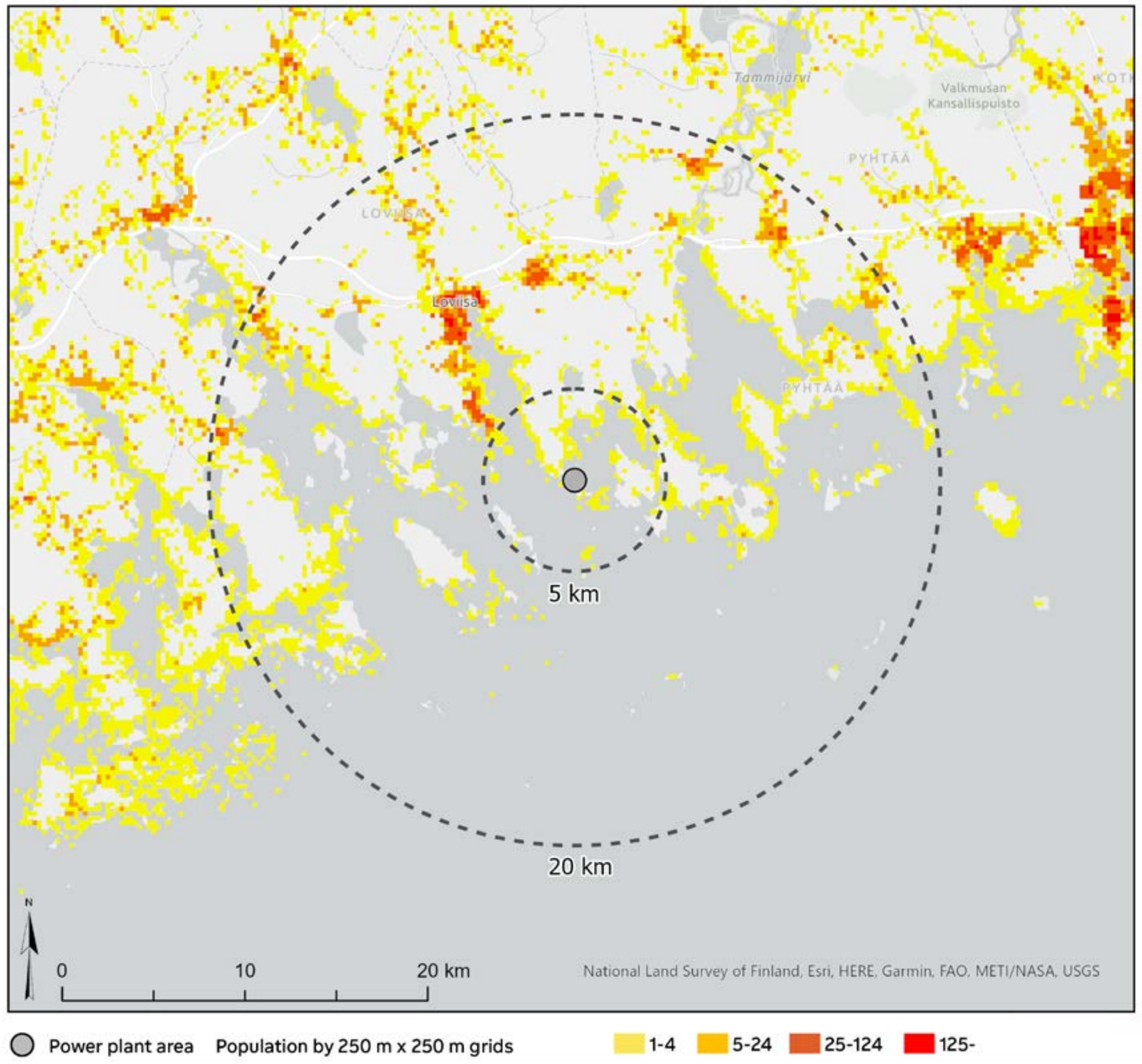


Figure 9-67. Distribution of population at a distance of 5 and 20 kilometres from the power plant.

The results of the resident survey were processed with a statistical application (the Excel-based Tixel application). The statistical significance in relation to the underlying variables (respondent's gender, age group, stage of life, duration of residence and the location of their permanent residence/secondary home) was investigated with a chi-squared test. The review of the results focuses only on the statistically significant results which hold practical relevance in terms of the survey and the assessment of the social impacts. The charts showing the results of the resident survey show only the questions in which there is a statistically significant difference (P=0.005) between neighbouring residents and respondents living further away.

9.19.2.2 Small group events

A small group event for residents was held in February 2021. Information about the small group event was distributed in the cover letter of the resident survey, which contained a link through which two of the participants expressed their interest in participating in the event. In addition to these two residents, an invitation to the event was sent to two individuals who gave their contact details on the resident survey's response form.

Due to the prevailing Covid-19 situation, the small group event was held remotely, using the Microsoft Teams application. The participants were composed of one resident, two representatives of the project owner and two representatives of the EIA consultant. The topics discussed at the event included the progress of the EIA Procedure, the preliminary results of the resident survey and the results of the assessment concerning the impacts on the regional economy.

9.19.2.3 Other feedback received during the assessment procedure

During the assessment procedure, feedback was also received through other channels, including the public event held during the EIA Programme phase and the meetings of the audit group set up for the EIA Procedure (see Chapter 8.5.3) as well as the evening meetings organised for the area's fishermen. The opinions on the EIA Programme submitted to the coordinating authority and their consideration are discussed in Appendix 3.

A total of 11 opinions was submitted on the EIA Programme. The issues raised in the opinions included the nuclear safety risks which would increase as the plant ages, uncertainties related to the final disposal of nuclear waste, the impacts that the intake of raw water would have on the eutrophication and water level of Lappomträsket lake, the scope of the waterbody's monitoring programme, and the impacts of cooling water. One opinion was in favour of extending the operating licences so that Finland would be able to attain its climate objectives.

The topics discussed in the EIA Programme's public event included potential investment needs, the reception of radioactive waste generated elsewhere in Finland and the future of the plant building after decommissioning. A member of the public also raised a question concerning the impacts on the value of real estate in the power plant's vicinity.

9.19.3 Present state

9.19.3.1 Population and residents

The town of Loviisa lies on the coast of the Gulf of Finland, approximately 90 km east of Helsinki. Its neighbouring municipalities are Lapinjärvi, Pyhtää, Myrskylä, Kouvola and Porvoo. Loviisa forms the Loviisa sub-regional area with Lapinjärvi. In 2019, Loviisa's population was 14,772. Of the neighbouring municipalities, Lapinjärvi had a population of 2,606, while the population of Pyhtää was 5,140, Myrskylä 1,882, Kouvola 82,113 and Porvoo approximately 50,380.

The share of Swedish-speaking population in Loviisa (40.5%) and in Lapinjärvi (30.4%) is considerably higher than in Pyhtää (7.2%). In the Loviisa sub-regional area, the share of people aged 65 years or older is higher, and the share of people under 15 is lower than in Uusimaa and the average for Finland as a whole. The share of people of studying and working age in the population is slightly lower than in Uusimaa and the average for Finland as a whole. The demographic trend in the Loviisa region has been declining for a long time. In 2019, net emigration amounted to 15 people in Loviisa, 29 in Lapinjärvi and 11 in Pyhtää (Statistics Finland 2021b). According to the population forecast, the population in the Loviisa area will remain fairly unchanged until 2040 (Helsinki-Uusimaa Regional Council 2019).

There are about 40 year-round residents up to a distance of five kilometres from the power plant (Figure 9-67). The closest residential buildings in private use are located in Bodängen, at a distance of roughly 900 metres from the power plant area (Figure 9-3). For the most part, the permanent residents are concentrated in the areas of Björnvik and Lappom, both north of the power plant. There are about 12,400 year-round residents up to a distance of 20 kilometres from the power plant (Figure 9-67). The largest population concentration in the vicinity is the centre of the town of Loviisa, roughly 12 km from the power plant. Tesjoki and the municipal centres of Ruotsinpyhtää and Pyhtää are built-up areas of less than 1,000 inhabitants each. Smaller population centres include Kuggom, the Pernaja municipal centre, the village of Isnäs in Pernaja and the village of Purola in Pyhtää.

There are many secondary/holiday homes in the vicinity of Hästholmen (Figure 9-3). The secondary homes closest to the power plant area 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. There are a little less than 500 secondary homes within five kilometres of the power plant and approximately 3,000 secondary homes within 20 kilometres of it.

9.19.3.2 Sensitive sites as well as tourist destinations and recreational sites

The nuclear power plant is surrounded by a precautionary action zone extending to a distance of five kilometres, in which 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).

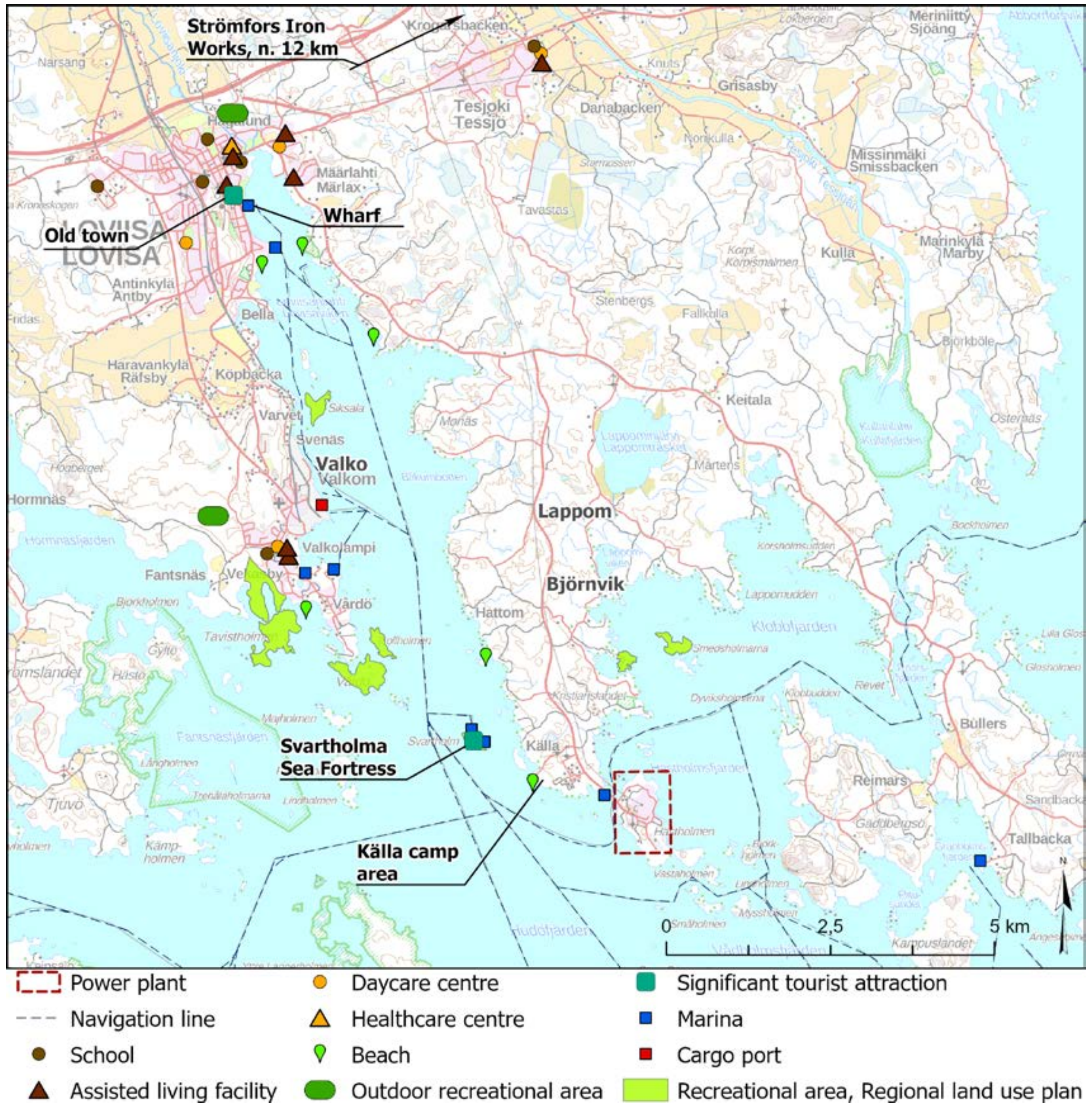


Figure 9-68. The sensitive sites as well as tourist destinations and recreational sites closest to the power plant area.

The sensitive sites as well as tourist destinations and recreational sites closest to the power plant area are shown in the figure (Figure 9-68). The nearest school and day care centre are in the village of Valko, approximately seven kilometres from the power plant.

The closest tourist destination is the Svartholma Sea Fortress, roughly two kilometres from the power plant. Other tourist destinations located further away include the old town of Loviisa, the Laivasilta marina and the Strömfors Iron Works. Svartholma is a popular destination which can be reached by private boats in addition to a regular service vessel. Loviisa's other marinas and docks include Bockhamn, Lillfjärden, Kabböle, Rönnäs and Backstensstrand. The Loviisa area is home to a number of enterprises offering fishing, accommodation, nature and activity services. While tourism to the area has been increasing in recent years, it is not among the key travel destinations in Finland (Visit Loviisa 2021).

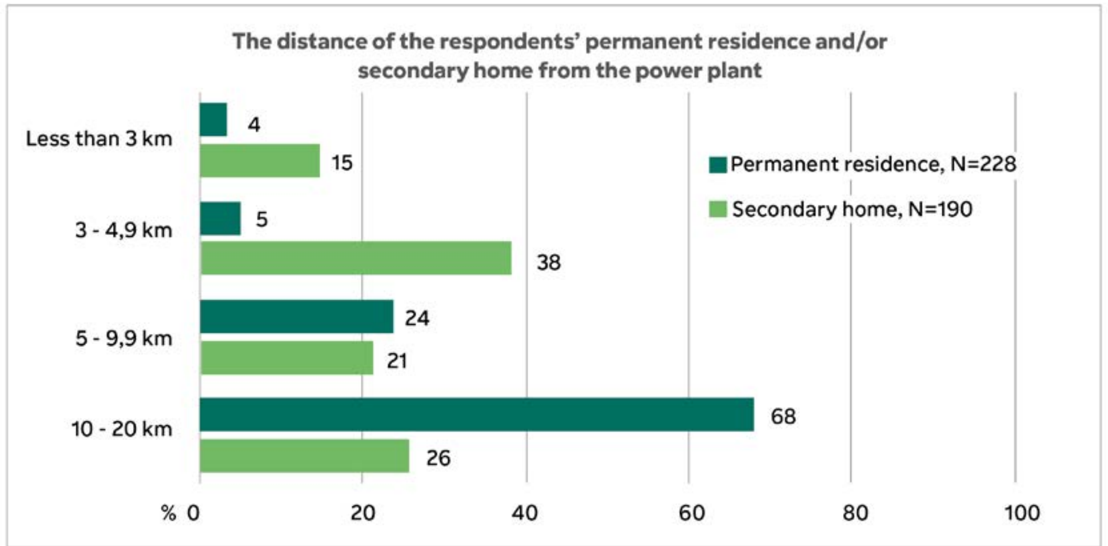


Figure 9-69. The distance of the respondents' permanent residence or secondary home from the power plant area. The percentages of residences located at different distances and the number of respondents (N) are shown in the figure.

The town of Loviisa's Källa camp area is located approximately a kilometre west of the power plant. The camp area is intended for the camping, outing and recreational activities of the town's various branches of government as well as local associations and communities, with priority given to youth activities. Loviisa offers several recreational destinations in its water areas, as well as hiking trails, nature trails and outdoor recreation areas.

9.19.3.3 Residents' use of the areas

Of the people who responded to the resident survey, 228 have a permanent residence in the distribution area, while 190 people have a secondary home there. The distance of the respondents' homes or secondary homes from the power plant is shown in Figure 9-69. The respondents in the survey who reported living or holidaying at a distance of less than five kilometres (0–4.9 km) from the power plant were categorised as neighbouring residents. The residents of the lakeside properties at Lappomträsket lake were also counted as neighbouring residents. Of all the respondents, 36% (129 respondents) were neighbouring residents, and a fourth of them permanent residents. The permanent residence or secondary home of some of the neighbouring residents who responded to the survey was located in the area of Hästholmsfjärden or Klobbfjärden. The areas delimited

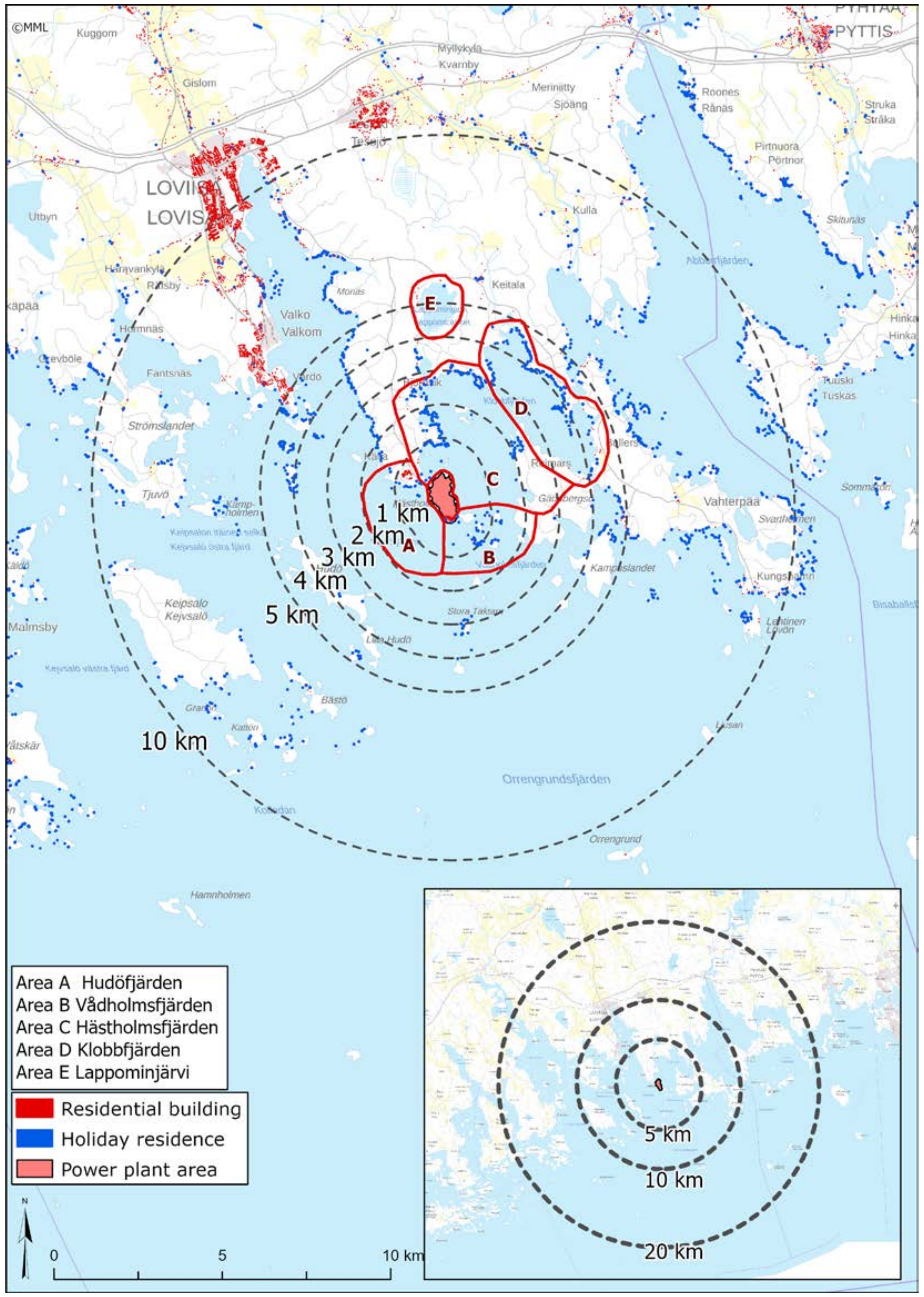


Figure 9-70. The map in the resident survey's cover letter on the water areas and the location of residential areas in the vicinity of the power plant. The distance sectors are counted from the shoreline of the island of Hästholmen.

on the map in the survey's cover letter (Figure 9-70) were Hudofjärden, Vådholmsfjärden, Hästholmsfjärden, Klobbfjärden and Lappomträsket lake.

According to the resident survey, the residents use the water areas and shores surrounding the nuclear power plant in the summer to spend time at their secondary home and for outdoor activities, boating and nature observation (Figure 9-71 and Figure 9-72). There is a statistically significant difference in all of the responses between the neighbouring residents and respondents living further away, in that the neighbouring residents are more active in using the areas. Although most of the residences located at a distance of less than 5 km from the power plant are secondary homes, some of these holiday properties are in year-round use. More than a third of the neighbouring residents reported spending time at their secondary home or in outdoor

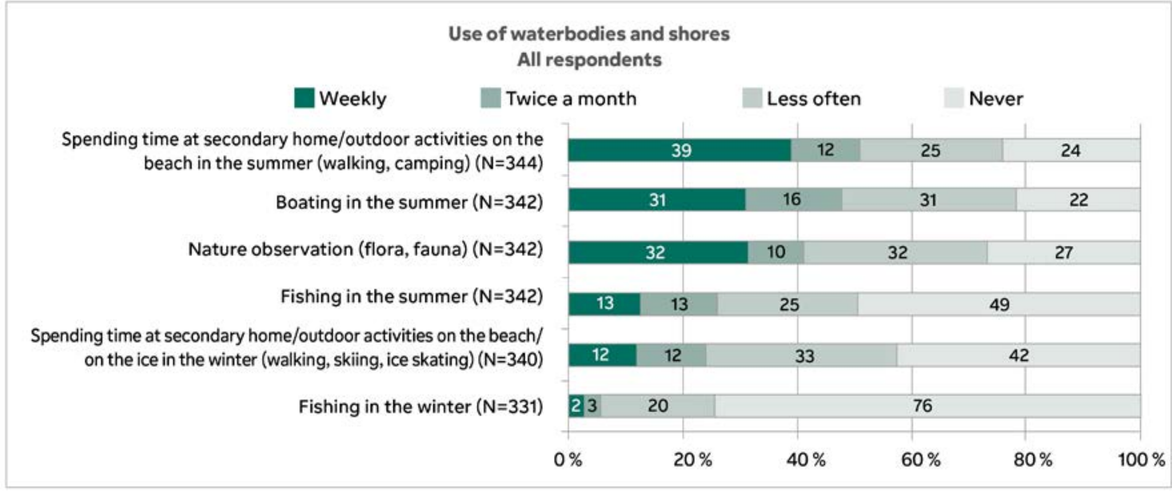


Figure 9-71. The views of the resident survey's respondents on the use of the waterbodies and shores in the vicinity of the power plant area (all respondents). The figure shows the percentages of the respondent groups and the number of respondents (N).

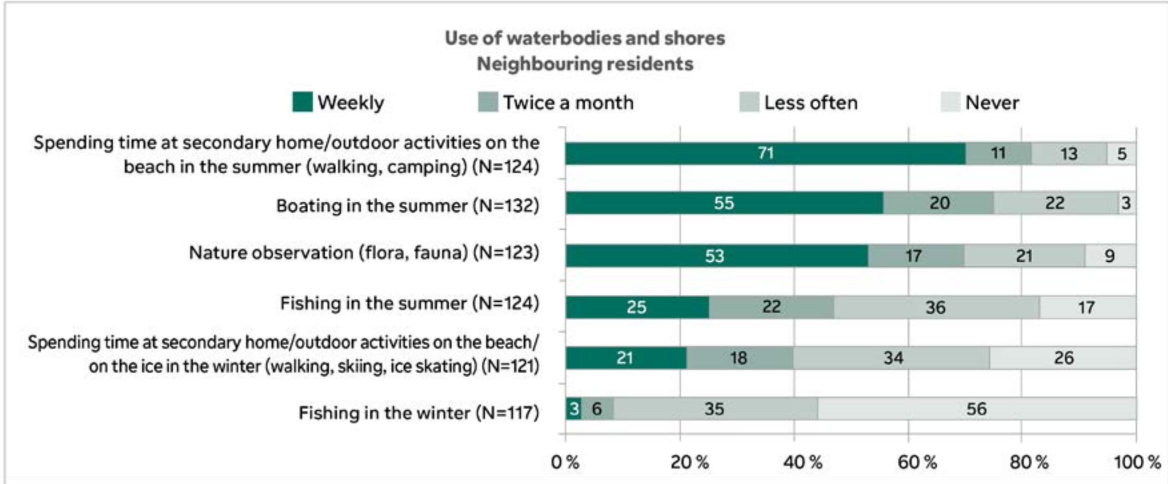


Figure 9-72. The views of the resident survey's respondents on the use of the waterbodies and shores in the vicinity of the power plant area (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

Table 9-68. Sensitivity of affected aspect: people's living conditions and comfort.

Sensitivity of affected aspect: people's living conditions and comfort	
The sensitivity of the affected aspect is influenced by the number of people in the area who are potentially subject to adverse effects and by the location of particularly sensitive aspects such as schools, daycare centres or assisted living facilities. The sensitivity increases if the area has hobby or recreational value or landscape values, and no alternative areas are available. In addition to the affected aspects, the sensitivity is influenced by the status of the area's current environmental nuisances (such as traffic and noise) and the environment's process of change.	
Moderate	The area of the nuclear power plant is surrounded by a precautionary action zone extending to a distance of five kilometres. This precautionary action zone may not contain facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities or shops. There are many secondary homes at a distance of less than five kilometres from the power plant. Loviisa offers several recreational destinations in its water areas, as well as hiking trails, nature trails and outdoor recreation areas. The camp area Källa and the Svartholma Sea Fortress are located in the vicinity of the power plant. The power plant area has been in the area for a long time, and its construction has previously altered the island of Hästholmen and its environment, due to which the adaptability for changes is moderate. The area has remained unchanged for a fairly long time and is today subject to very little environmental nuisance, such as operations emitting noise.

activities in the area at least monthly during the winter. A statistically significant difference between the responses of neighbouring residents and respondents living further away was observable when the respondents were asked how well they knew the bodies of water. The best known of them were Hästholmsfjärden and Klobbfjärden, east and north-east of the power plant. A little less than half the neighbouring residents viewed these areas as personally important and familiar, whereas some 10% of those living further away thought this.

Table 9-68 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

9.19.4 Residents' views

9.19.4.1 Residents' views on the impact of current operations

The respondents' views on the impact that the power plant's current operations have on the nearby areas varied (Figure 9-73 and Figure 9-74). The results included statistically significant differences in relation to a residence's distance and the stage of life. The neighbouring residents viewed the impacts of the current operations more negatively than those living further away.

The analysis of the resident survey's results focused on the responses of the neighbouring residents in questions

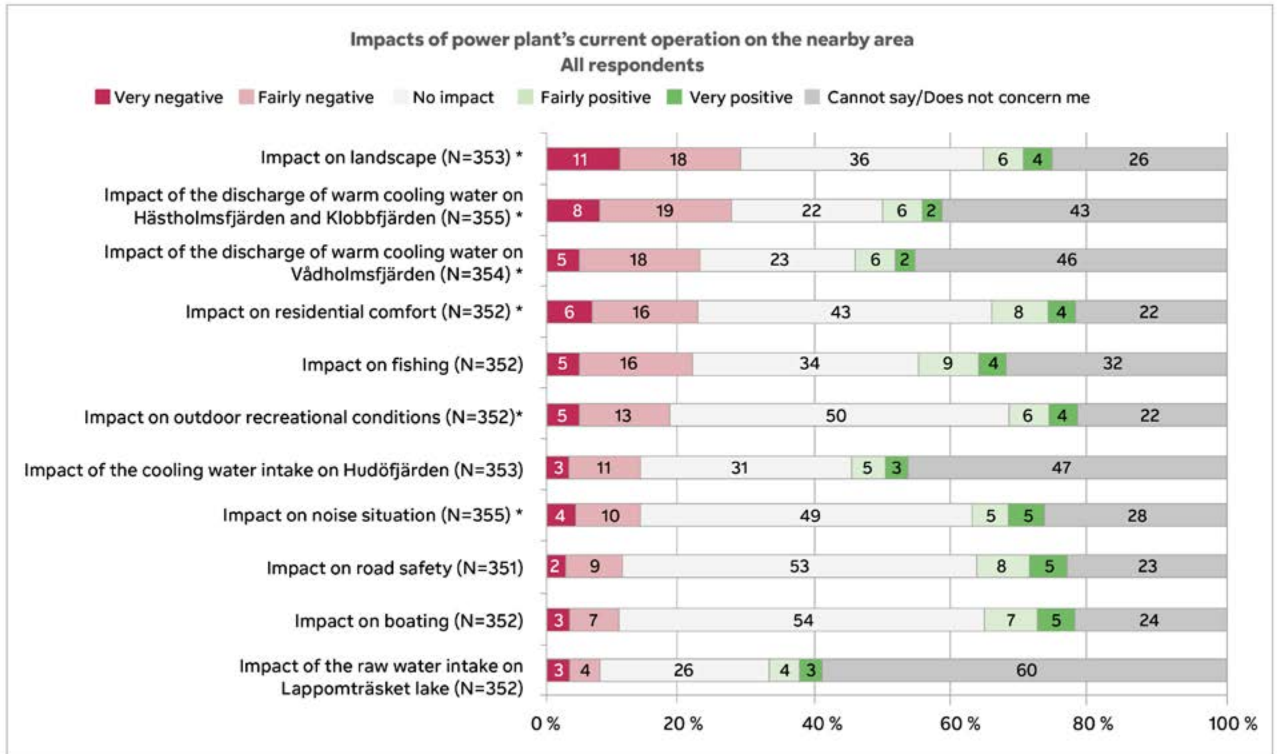


Figure 9-73. The views of the resident survey's respondents on the impact that the power plant's current operations have on its vicinity (all respondents). The figure shows the percentages of the respondent groups, the number of the respondents (N); the issues marked with an asterisk (*) indicate a statistically significant difference per respondent group in relation to a residence's distance.

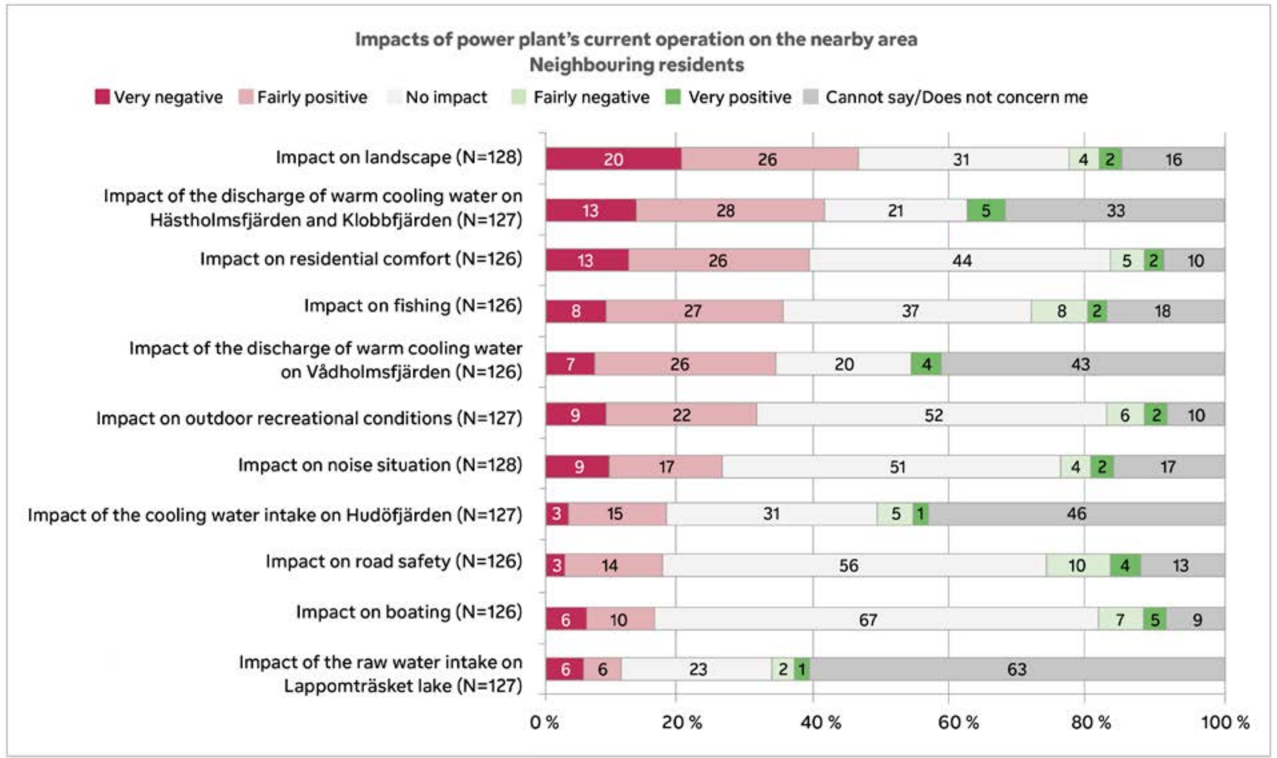


Figure 9-74. The views of the resident survey's respondents on the impact that the power plant's current operations have on its vicinity (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

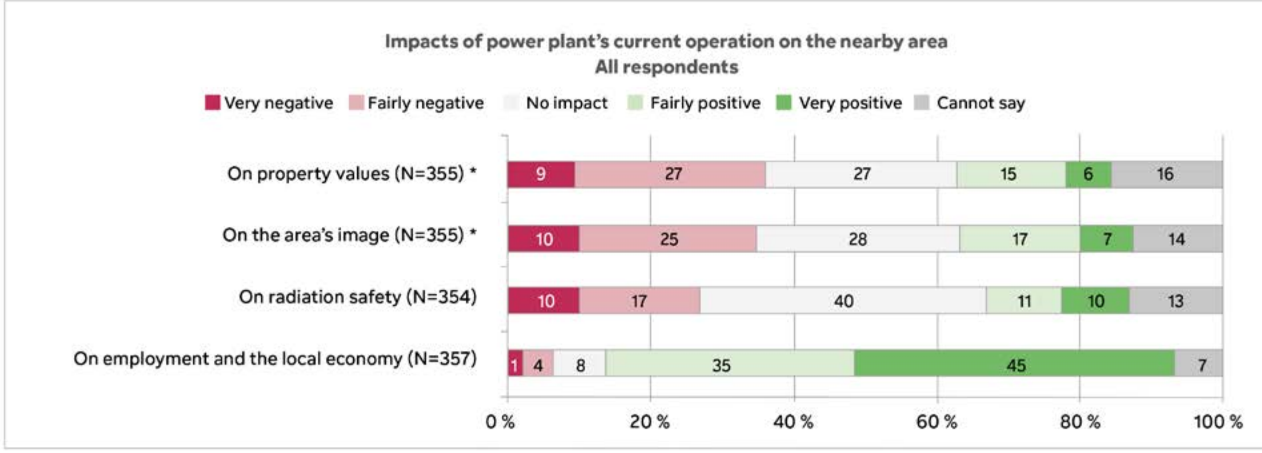


Figure 9-75. The views of the resident survey's respondents on the impact that the power plant's current operations have in the region (all residents). The figure shows the percentages of the respondent groups, the number of the respondents (N); the issues marked with an asterisk (*) indicate a statistically significant difference per respondent group in relation to a residence's distance.

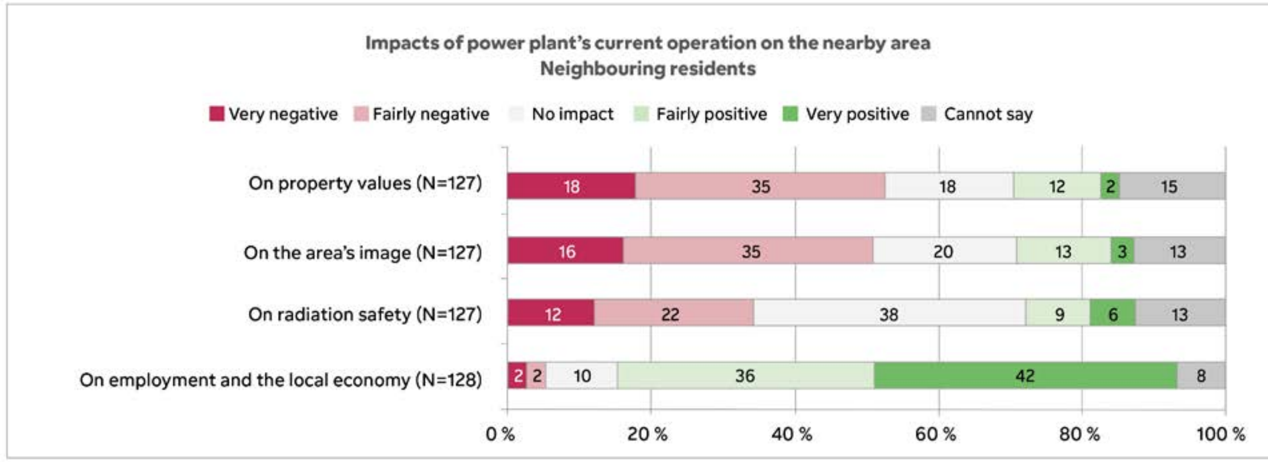


Figure 9-76. The views of the resident survey's respondents on the impact that the power plant's current operations have in the region (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

concerning the impacts of the operations in the vicinity of the power plant. The proportion of respondents who viewed the impacts negatively was the greatest in questions concerning the impacts on the landscape; the impacts that the discharge of the warm cooling water would have on Hästholmsfjärden, Klobbfjärden and Vådholmsfjärden; and the impacts on residential comfort and fishing. The respondents' views were more neutral in terms of the impacts on boating, road safety, recreational conditions and the noise situation (Figure 9-73).

The respondents were given the opportunity to specify their responses in the comment section of the open-ended questions. Negative observations included the eutrophication of the shores, the impacts on movement on ice and winter fishing, the adverse effect of the power plant's floodlights as well as the occasional noise and hum from the power plant. Some of the comments perceived the high driving speeds on Atomitie, and the traffic volumes there during annual outages, as well as the lack of a pedestrian and cycle lane, as a factor impairing road safety. On the other hand, some of the respondents appreciated the good maintenance of the roads leading to the power plant, which also benefits holidaymakers. Concern over the eutrophication of the Lappomträsket lake and Lappomviken was also mentioned in a few of the open-ended responses and in one opinion submitted on the EIA Programme.

The high number of "cannot say/does not concern me" responses to questions pertaining to the power plant's nearby bodies of water suggests that some of the respondents have been unable to assess the operations' impact on waterways.

When asked about the impact of current operations in the region, most of the respondents were of the opinion that the operations had a positive impact on employment and the local economy (Figure 9-74 and Figure 9-75). When asked about the impact on property values, the area's image and radiation safety, the responses included more variation between positive, neutral and negative views. Neighbouring residents saw the impacts on property values and the area's image as more negative than those living further away.

In the resident survey, the respondents were asked about their attitude to nuclear power at a general level. Three quarters of the respondents reported having a positive attitude to nuclear power (Figure 9-77).

9.19.4.2 Residents' views on the planned operations

The views of the resident survey's respondents on the planned operations varied, but they had the most positive attitude to extending the power plant's operation until 2050 (Figure 9-78, Figure 9-79 and Figure 9-80). There was a statistically significant difference in all the responses between the neighbouring residents and respondents living further away. The neighbouring residents had a more negative attitude than those living further away to any operations other than the end of operation in 2027/2030. Nearly three quarters of the neighbouring residents had a negative attitude on radioactive waste generated elsewhere in Finland being handled, placed in interim storage and deposited for final disposal at Loviisa power plant. More than half the neighbouring residents likewise had a negative attitude to the expansion of the L/ILW repository.

Among all respondents to the resident survey, extended operation received more support than the termination of operation (Figure 9-81). The results showed statistically significant differences between the neighbouring residents and respondents living further away. While a clear majority of those living further away was in favour of extended operation, the responses of the neighbouring residents were distributed more evenly between extended operation and the termination of operation.

When the respondents' views on the best project option were analysed to take their attitude to nuclear power into account, statistically significant differences between the respondents were observed. Of those with a positive attitude to nuclear power, 78% were in favour of extended operation, while the corresponding percentage among those with a neutral attitude was 34%. Of those with a negative attitude to nuclear power, 86% were in favour of decommissioning, while the corresponding percentage among those with a neutral attitude was 57%. The reception of radioactive waste generated elsewhere in Finland garnered some support among all groups.

As can be seen from the responses to the survey, there is a great deal of variation in the respondents' views. In addition to uncertainties and concern, the operation of the nuclear power plant involves positive views.

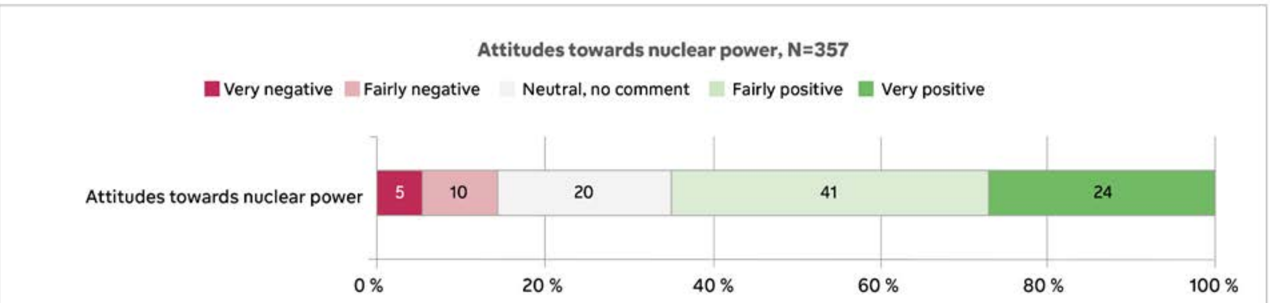


Figure 9-77. Respondents' attitudes to nuclear power. The percentages of the respondent groups are shown in the figure.

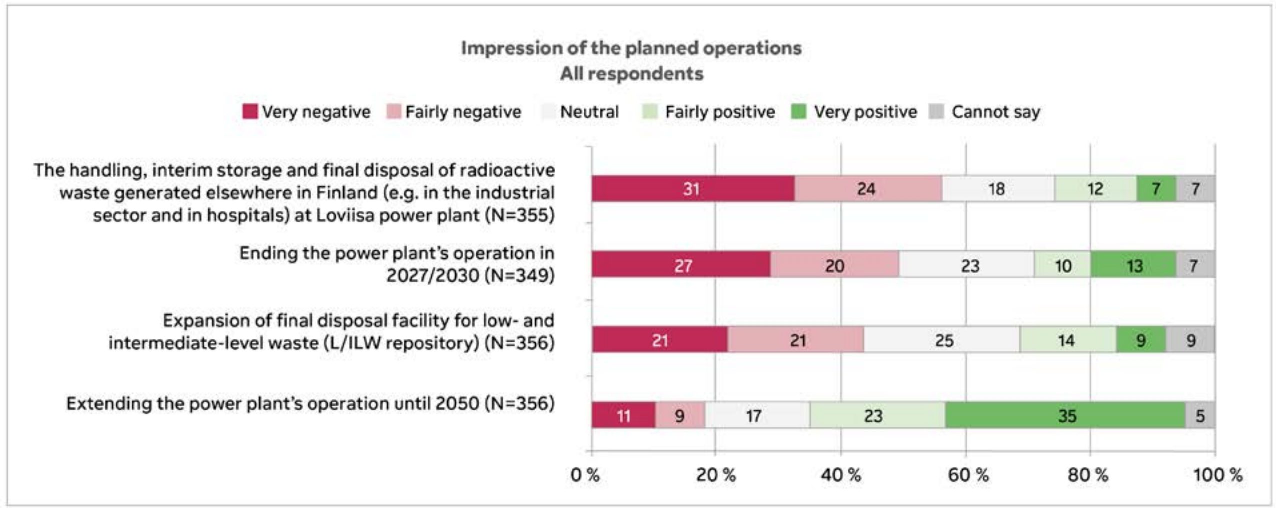


Figure 9-78. Respondents' views on the planned operations (all respondents). The figure shows the percentages of the respondent groups and the number of respondents (N).

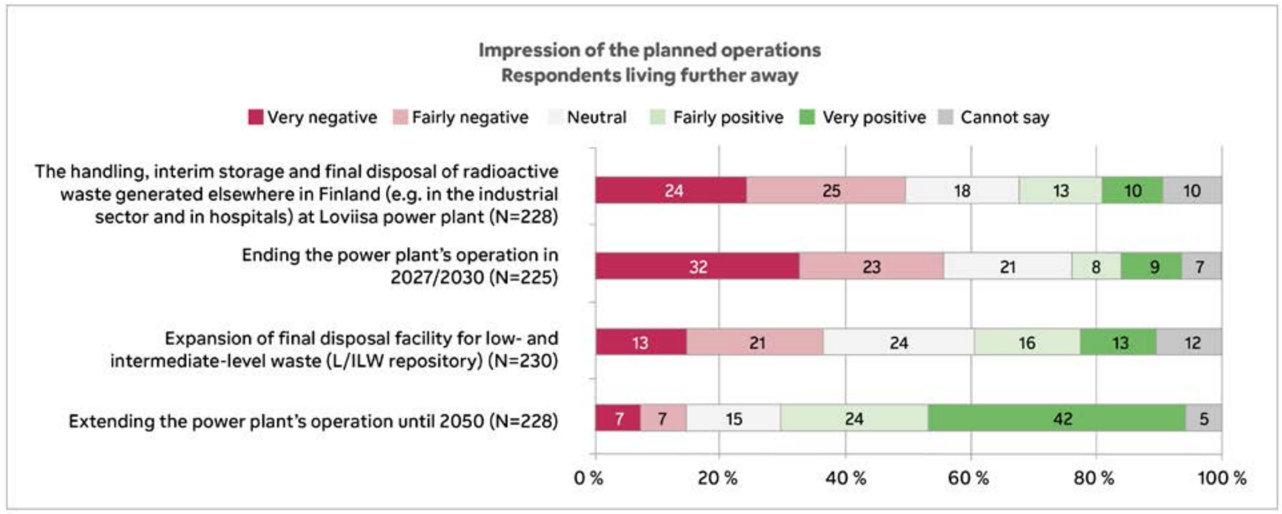


Figure 9-79. Respondents' views on the planned operations (respondents living further away). The figure shows the percentages of the respondent groups and the number of respondents (N).

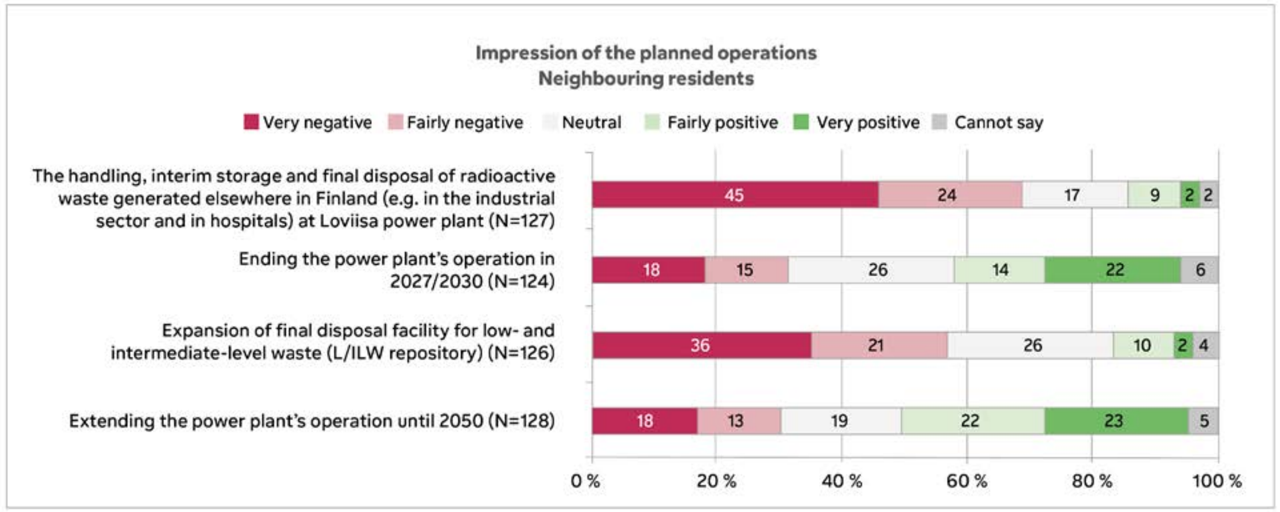


Figure 9-80. Respondents' views on the planned operations (neighbouring residents). The figure shows the percentages of the respondent groups and the number of respondents (N).

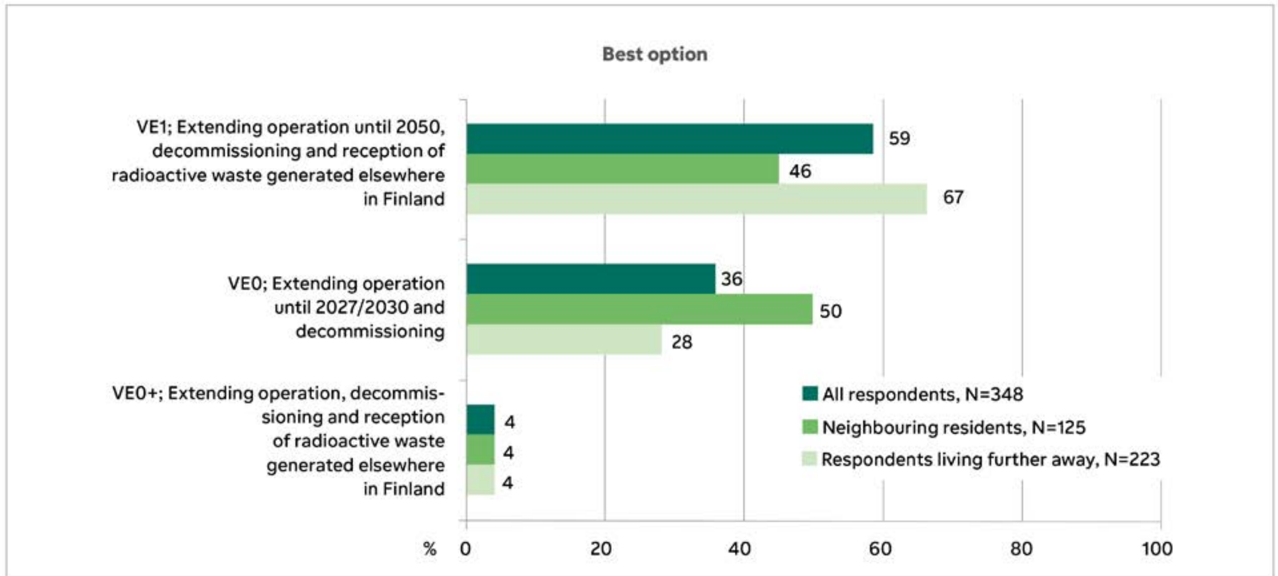


Figure 9-81. The resident survey's respondents' view of the best option. The figure shows the percentages of the respondent groups and the number of respondents (N).

Several of the open-ended responses indicated satisfaction with the power plant's current operations and support for extended operation. The power plant's positive significance for the economy and employment of the town of Loviisa was brought up in several comments. Some of the respondents in favour of extended operation considered it important that the existing power plant and the expertise on nuclear power accumulated over the years be taken advantage of in future operations. An extension to the operation of the power plant was also considered a form of energy production to be favoured until the facilities for replacing energy produced with nuclear power with renewable methods were in place.

"I hope the power plant extends its operation. It will provide the area with much needed jobs. The placement of nuclear waste here is not an attractive thought."

"Electricity must be produced somewhere anyway (with climate impacts as small as possible), and given that the plant in Loviisa is already there and has operated well, I see extended operations as a good alternative – provided that the maintenance and repair investments related to extended operation are carried out appropriately."

"The entire lifecycle of a good plant should be put to use as well as possible, accounting for the safety aspects."

"The nuclear power plant is important for the town of Loviisa in terms of employment, among other things. It would be important in terms of the future to investigate how the heat of the cooling waters could be used to heat properties in Loviisa or some of the other nearby towns and cities, for example."

"Back in the old days, I was unsure and concerned about safety. Now I have confidence in safety being maximised. The alternatives are limited, and few of them are clean. We need various [forms of energy production], and nuclear power is one of them."

"Loviisa power plant possesses all the facilities needed for continuing the production of safe nuclear power until at least 2050. The competence in the storage of radioactive waste should also be put to use."

"I'm not in favour of building new nuclear power. Even so, the operation of old plants should be extended for as long as they are safe, and the climate issues/adequacy of renewable energy have/has been solved."

The responses to the survey also show that the expansion of the L/ILW repository and the handling and final disposal of radioactive waste generated elsewhere in Finland, in particular, raise concern; this could also be seen in the open-ended responses. Several comments favoured extending operation until 2050 without radioactive waste brought from elsewhere. A few of the respondents who provided an open comment were under the impression that radioactive waste transported from other nuclear power plants would be placed in the area of Loviisa. The uncertainties and risks associated with the operation of an ageing nuclear power plant and the final disposal of spent nuclear fuel were also brought up in the opinions given on the EIA Programme. A lack of knowledge and uncertainty about the content and impacts of the radioactive waste to be handled and deposited in final disposal in the future may have caused conflicting emotions in the respondents.

"Extending operation until 2050 is OK, but we have enough to take care of in the waste we've generated ourselves."

"Conflicting emotions; the need for energy will not reduce and if/when Loviisa's units are decommissioned, the energy must still be produced somewhere else in another way."

"Even in Finland, seismic stability and the integrity of the bedrock are not perfect, so why would the waste be placed at the shore of a sea from where pollution can spread via the sea over time?"

"We are not in favour of extending the operation of Loviisa nuclear power plant post 2030. This opinion is a result of the location of the Baltic Sea and the obsolescence of nuclear power. Nuclear power feels unnecessarily difficult and burdensome, especially from the perspective of final disposal."

Loviisa power plant has been in operation for a long time now, and the residents have an idea of the impacts generated during the power plant's operation, which mainly concern the nearby areas. The power plant's impacts on the region's economy and employment are considered positive, and they also have an impact on many residents who are in favour of extending operation until 2050. However, some respondents in favour of extended operation have a negative attitude to the expansion of the L/ILW repository. The project raises hopes of positive impacts on the economy and employment, while raising concern and uncertainty about the safety of the handling and final disposal of nuclear waste and the operations' impacts in nearby areas.

People's concerns or expectations can be construed as effects or indicators of impacts that people generally consider important, because they would change the people's surroundings. The concerns and expectations are usually at their greatest during the project's planning phase, when there is more room for speculation, the planning is still incomplete, and not all decisions have been made. Once the possible construction, dismantling or other activity gets underway and the potential impacts begin to materialise, the expectations and concerns usually begin to dissipate, provided that no adverse effects emerge, and that uncertainty is replaced by more precise and concrete information. The experience and intensity of the concern may be impacted by the light in which Loviisa nuclear power plant's operations or issues related to nuclear power in general are discussed in public and within a community. People can sometimes change their perceptions even during the project, based on interaction, additional information, the results of impact assessments and news. Concerns or expectations are considered social impacts as they are, regardless of the results of expert assessments and recipients' related knowledge, because they have a certain kind of impact on the recipient.

9.19.5 Environmental impact of extended operation

Impact formation

The impacts of extended operation would form largely in the same manner as in the power plant's current operation. Operations with an impact on people's living conditions and comfort consist especially of the impact that the discharge of warm cooling waters have on the recreational use of Hästholmsfjärden's waterway, the power plant structures' visibility in the landscape, the restrictions to the use of nearby areas resulting from the operations, the traffic on the roads leading to the power plant area as well as the impacts on employment and the regional economy, which are also reflected in the population structure. Social impacts also include any concerns and expectations that extended operation would raise among residents, and impacts on the local identity. Any modification and additional construction work that may be carried out in the area during extended operation may cause vibration, noise, landscape, air quality and traffic impacts in the power plant's vicinity.

While the social impacts of extended operation would form largely in the same manner as in the power plant's current operation, they would continue for some 20 years beyond the end of the current licence period, i.e. until roughly 2050.

The impacts on the landscape and on the waterways attributable to the discharge of warm cooling water, as well as the impacts on residential comfort and fishing, were considered the most negative impacts of the power plant's current operation in the resident survey.

The power plant's construction has altered the island of Hästholmen and its environment since the 1970s, and the power plant has been an element visible in the landscape for several decades. Over the years, some people living and holidaying in the area have grown accustomed to the power plant's visibility in the landscape, but in the resident survey, nearly 50% of the neighbouring residents still viewed the power plant's impact on the landscape as negative. The power plant area's bright lighting has also been considered disturbing. Alongside the yard of a secondary home, the power plant can also be visible in the landscape when residents and other recreational users use the bodies of water surrounding the power plant for boating or recreational fishing, for instance. In extended operation, the landscape impacts would continue to be largely similar to their current levels. The changes to the landscape resulting from the construction of any additional buildings in the area would be only minor, and they would br primarily concentrated in the vicinity of the power plant (see Chapter 9.3).

The impacts that the power plant's extended operation would have on the residential comfort of nearby areas and the use of nearby recreational sites such as the Svartholma Sea Fortress and the Källa camp area would remain largely unchanged. The possible adverse effects experienced by residents would remain unchanged.

The discharge of cooling water into Hästholmsfjärden has had an impact on the lives of people living or holidaying in the power plant's nearby areas for several decades. According to the impact assessment concerning waterways (see Chapter 9.3), the thermal load caused by the cooling water has impacted the extent of the ice cover and may itself have intensified Hästholmsfjärden's eutrophication. On the other hand, eutrophication in general has increased across the entire Gulf of Finland. According to the impact assessment concerning waterways, the thermal load caused by the cooling water may slightly intensify eutrophy in the long run locally, and primarily in the area of Hästholmsfjärden. In addition to the thermal load, the extent of the ice cover and the sea area's use during winter may be affected by the increasing number of mild winters. Based on the impact assessment concerning the icthyofauna (see Chapter 9.17), the temperature increase will benefit, through the longer growing season, species such as the common perch, pike-perch and cyprinids. At the same time, the temperature increase may bring non-native species to the area that may displace local fish species.

Should the discharge of warm cooling water continue, the recreational value of the area's waterways and the residential comfort of the shores would remain largely unchanged from the present state, but when accounting for the possible impact of climate change as well, the future recreational value of Hästholmsfjärden, for example, may deteriorate slightly, particularly in terms of the ice situation. A deteriorating ice situation may weaken the opportunities for movement on the ice and winter fishing.

According to plans, the power plant's service water would continue to be taken from Lappomträsket lake, either entirely, as today, or partly, in which case some of the water intaken from Lappomträsket lake would be replaced by the procurement of other service water. Based on the impact assessment concerning the waterways, extended operation would not have an impact on the present state of Lappomträsket lake.

The traffic impacts of current operations are at their greatest in the summer, during annual outages, when some of the residents have perceived road safety to have weakened as the traffic on the roads leading to the power plant has increased. The annual outages last for 2–8 weeks, and they are implemented between July and October. According to the impact assessment concerning traffic (see Chapter 9.4), the impacts in the event of extended operation would be similar to their current levels. While the impacts would also largely remain similar to their current levels, according to the impact assessment concerning noise and vibration (Chapters 9.5 and 9.6), temporary noise or vibration may be generated during the construction of any additional buildings. Some of the neighbouring residents have found the hum emitted from the power plant and the sounds generated during annual outages disturbing. The possible adverse effects experienced by residents would remain unchanged. The potential additional construction could cause some additional adverse effects.

According to the impact assessment concerning the regional economy (see Chapter 9.13), the Loviisa area has a narrow economic structure and high unemployment. Extended operation would have a positive employment impact in both the Loviisa sub-regional area and beyond it. Extended operation could also have a positive impact on the area's demographics if the power plant's operations employ working age population and encourage them to stay in the area.

The power plant is surrounded by a five-kilometre precautionary action zone that may not contain sensitive sites such as schools or healthcare centres. In addition, the sea area in the vicinity of the power plant is monitored, and disembarkation in the power plant area is prohibited. In extended operation, the restrictions would remain in force. A little fewer than 500 secondary homes, some of which are in year-round use, are located at a distance less than five kilometres from the power plant. There are many long-term residents in the power plant's nearby areas, given that roughly half the respondents to the survey reported having lived or holidayed there for more than 40 years. Some of the neighbouring residents expect the power plant's current operation to have a negative impact on property values. The proximity of the power plant and uncertainty about the future may be reflected in the attractiveness of property in the power plant's vicinity.

Risks related to the nuclear power plant's operation may give rise to concern about the safety of nuclear energy both in the nearby area and more generally among Finland's population, as well as beyond the country's borders. Nuclear safety is described in more detail in Chapters 7.5–7.8, while the impacts of a severe reactor accident and other incidents and accidents are described in Chapters 9.21 and 9-22, respectively. If the operations continue, concern about the risk of accidents would continue and could increase as the plant ages. Furthermore, should the operations continue, the volume of the spent nuclear fuel in interim storage within the area and the volume of the low and intermediate-level radioactive waste to be deposited for final disposal in the L/ILW repository would increase, which could increase any concern over the safety risks related to the handling of the waste.

The magnitude of the change in the social impacts of extended operation was deemed minor and negative as a whole when accounting for the power plant's additional years of operation.

9.19.6 Environmental impact of decommissioning

Impact formation

During the decommissioning phase, impacts on living conditions and comfort will result primarily from the excavating related to the L/ILW repository's expansion, the crushing and transports of the quarry material, the dismantling of buildings and the potential crushing of concrete as well as from heavy vehicle traffic, both on the roads leading to and within the power plant area. The volume and thermal load of the warm cooling water conducted into Hästholmsfjärden will reduce and eventually end, which will have an impact on the waterway's recreational use. The termination of the power plant's operation may result in changes to the local identity. Social impacts also include the potential concerns and expectations to which the decommissioning will give rise in residents.

The power plant's current operations have continued for a long time. Although some residents, especially those living and holidaying in the nearby areas, have experienced adverse effects attributable to the current operation, the impacts of the current operation have remained largely similar. The power plant's decommissioning will result in a clear and discernible change in the operations taking place in the power plant's area and their impacts at different phases of the decommissioning. All in all, the various phases of the decommissioning will take several decades. A change of such duration may give rise to uncertainty among residents about the future, with the associated related concerns and expectations.

Loviisa power plant is Finland's first nuclear power plant. It has been in the area since the 1970s and has become part of the identity of the Loviisa area. The power plant's decommissioning and the end of its electricity production may result in changes to the local identity. The changes can be both positive and negative, and they will also be influenced by the long duration of the decommissioning. The plans related to the decommissioning, and the changes it will introduce to the operations, may give rise to concerns in the residents about the impact that the changes will have on the vitality of the Loviisa region, when both the adverse effects and benefits of the operations come to an end during the final phase of the decommissioning.

Expansion of the L/ILW repository

The L/ILW repository's expansion is expected to take about three years, and it will be carried out while the power plant is still in operation. The blasting related to the expansion of the L/ILW repository and the possible crushing of the excavated rock and its transport either to the power plant area or elsewhere for interim storage will generate noise, traffic, vibration and dust impacts.

In line with the impact assessment concerning vibration, the blasting work will be carried out so that the radioactive waste already in the L/ILW repository will not be adversely affected. The increased heavy vehicle transports may increase the vibration caused by traffic to a slight degree in the immediate vicinity of roads. The vibration impact of the decommissioning is expected to be minor and negative. The noise and dust resulting from the blasting done within the rock is not expected to spread beyond the power plant area other than to a minor degree.

Although the vibration and noise of the blasting work is not expected to have adverse effects on housing or recreation, residents may nevertheless become concerned about the impacts of the work. In addition to the mere magnitude of the vibration, the degree to which people find it disturbing is influenced by the circumstances in which it is detected. How people experience vibration is individual. It can be found disturbing particularly in situations in which the noise emitted by the source of the vibration is also found disturbing.

According to the noise impact assessment, the most significant source of noise in the L/ILW repository's expansion is the transport of quarry material. Furthermore, if the quarry material is crushed above ground rather than under it, in the L/ILW repository, the noise may be momentarily audible on the nearby islands and the mainland. The crushing of the quarry material will not be continuous. Instead, it will be carried out occasionally, when necessary. 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, it will increase the noise, vibration and air quality impacts of traffic along the transport routes.

For example, the occasional banging sound generated in connection with the loading of vehicles is short in duration, but may be found very disturbing. The same applies to the reversing alarms of machinery. How people experience noise is subjective, which is why individuals experience sound differently. The experiences of noise are also influenced by expectations and hopes on the environment's soundscape. In addition to the acoustic properties of noise, the degree to which a noise is found disturbing is affected by factors related to the situation and circumstances, such as the exposed individual's living conditions, their ability to influence the source of the noise and psychological factors related to noise, such as preconceived notions about and attitudes towards the source of the noise as well as fears and concerns related to it (Jauhiainen et al. 2007). The shores of the waterbodies surrounding the power plant are home to a lot of holiday housing. Given that the bodies of water are used for recreation, it is likely that at least some of the holidaymakers may find the sounds of heavy vehicle traffic and machinery generated in the power plant area disturbing.

According to the noise impact assessment, the planning of the operations makes use of the experiences gathered in the power plant area in connection with the previous excavation of the L/ILW repository. The noise impacts and how to mitigate them are known. Based on them, the activities will be planned so that the noise impacts can be mitigated. The interim storage of the quarry material in the power plant area or outside it will last for some 30–40 years. If the quarry material is placed in interim storage within the power plant area, it will have minor and negative impacts, according to the assessment concerning the landscape impacts. The impact that the L/ILW repository's expansion will have on the living conditions and comfort was deemed minor and negative in terms of its magnitude.

First dismantling phase

The first dismantling phase involves the dismantling of most of the activated and contaminated parts. This dismantling phase is expected to take around seven years. The radiation impacts of the dismantling work are assessed in Chapter 9.10.5.

Of the impacts generated during the dismantling phase, the noise and traffic impacts, in particular, will be detectable outside the power plant area. For example, the sounds of machinery may carry beyond the area. According to the assessment concerning the traffic impacts, traffic volumes during the first dismantling phase will increase from the present volume and will, at their greatest, be temporarily comparable to the traffic volumes during the annual outages in current operation. The increased traffic may impair especially the road safety of permanent residents and holidaymakers using the roads leading to the power plant and impact the smooth flow of traffic. In the present state, the impacts of the increased traffic have occurred during the annual outages, but during the dismantling phase, the traffic impacts will coincide with different seasons.

According to the impact assessment concerning waterways, when the operation of the power plant units ends, the need for cooling water and the thermal load will reduce to a fraction of their levels during the power plant's operation. In the long run, the change's positive impacts, especially on the status of Hästholmsfjärden's water environment, may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties. The magnitude of the impacts will be minor and positive.

According to the impact assessment concerning waterways, the changes in the intake of water from Lappomträsket lake during the decommissioning option will initially be very small, and the intake will continue in the current manner. In the future, the potential end of regulation related to the termination of the water intake may have minor negative impacts on the quality of water. The impacts that any deregulation would have on the recreational use of Lappomträsket lake and residential comfort in the lakeside properties cannot be assessed with the currently available information.

The impact that the first dismantling phase will have on living conditions and comfort was deemed moderate and negative in terms of its magnitude.

Operation of the plant parts to be made independent, second dismantling phase and the closure of the L/ILW repository

According to the expert assessment, the noise, dust or vibration nuisance possibly generated in the power plant area during the operation of the plant parts to be made independent – which will continue for several decades – is so minor that it is not expected to have an impact on the residential comfort of the closest secondary homes or permanent residences, or the waterbodies' recreational use.

The spent nuclear fuel which has remained in interim storage in the power plant area during the operation of the plant parts to be made independent will be transported in phases from Loviisa to Olkiluoto, Eurajoki, either as road transports or as road-maritime-road combinations. As the storage of spent nuclear fuel in the Loviisa power plant area comes to an end, any concern about risks related to the storage will also end. Yet concern about the safety of the transport of spent nuclear fuel and the final disposal to take place in Olkiluoto, Eurajoki, may have social impacts in an area wider than the power plant's nearby areas. The impacts of the spent nuclear fuel's handling, transport and final disposal are described in Chapter 9.10.5.1. 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 long-term safety of the final disposal of the spent nuclear fuel in Olkiluoto, Eurajoki, is described in Chapter 9.10.5.1.

The dismantling of the plant parts to be made independent (the second dismantling phase) and the operations during the L/ILW repository's closing phase will generate noise and vibration impacts. If the rock excavated during the L/ILW repository's expansion is placed in interim storage in the power plant area, it will not need to be transported from outside the power plant area during the L/ILW repository's closing phase. If the quarry material is placed in interim storage elsewhere, it will increase heavy vehicle traffic to some degree during the closing phase and the resulting adverse effects along the transport routes.

A decommissioning carried out according to the brownfield principle would not have a significant impact on the landscape of the nearby area, because the power plant area's buildings would remain in place.

According to the impact assessment concerning the regional economy (see Chapter 9.13), the positive impacts on the economy and employment of the Loviisa region would disappear as a result of the power plant's decommissioning. At the same time, businesses operating in the Loviisa sub-regional area would face new demand. 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 positive impacts will conclude at the end of the decommissioning phase, when operation has ended.

The magnitude of the impacts that the operation of the plant parts to be made independent and their dismantling phase will have on living conditions and comfort was deemed moderate and negative before the impacts become minor and positive with the L/ILW repository's closure.

Finalisation of dismantling measures and landscaping

All buildings and structures containing radioactivity will be dismantled from the area during the first and second dismantling phase of decommissioning (the brownfield principle). If all the remaining buildings in the plant area are also dismantled according to the greenfield principle, noise and traffic impacts would especially be generated during this conventional dismantling work. The measure generating the loudest noise will be the occasional crushing of concrete, the noise of which may be audible on the nearby islands and the mainland, thereby diminishing residential comfort and the recreational use of the bodies of water, nearby islands and shores. Even so, the noise impact of such activities can be mitigated with the selection of the crushing location and dimensioned noise shields. The sounds of machinery may also be found disturbing. According to the impact assessment concerning air quality (see Chapter 9.7), the dismantling work and crushing of concrete will result in some dust and tailpipe emissions, but they are expected to have an impact primarily on the island of Hästholmen and along the transport routes of the heavy vehicle traffic. The vibration possibly caused by the dismantling measures is small in scale and not expected to have adverse effects on housing or recreational use.

The dismantling of the buildings will have an impact on the landscape when viewed from both a short or long distance. The power plant structures are an element visible in the landscape, and their dismantling will have positive impacts on the landscape. 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.

If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).

The magnitude of the impacts of the conventional dismantling measures were deemed, in terms of the dismantling, moderate and negative, before the impacts become moderate and positive with landscaping.

9.19.7 Radioactive waste generated elsewhere in Finland and its impact

Based on the resident survey, the residents have a negative attitude to the reception of radioactive waste generated elsewhere in Finland at Loviisa power plant and its final disposal in the L/ILW repository. The respondents are concerned about the impacts of this despite the fact that the radioactive waste generated elsewhere in Finland would account for a maximum of 2% of the total volume of waste generated by the power plant.

The emergence of concerns and negative views may partly be influenced by the fact that the nature of radioactive waste, the volume of the waste generated, and the risks related to its handling may be challenging to understand. The operating models involved in the handling and final disposal of radioactive waste are not clear to everyone. Radioactive waste generated elsewhere in Finland and brought to Loviisa power plant can also be perceived as an additional and unnecessary adverse effect, given that it does not provide electricity production benefits like the power plant.

The transports, handling and final disposal of radioactive waste generated elsewhere in Finland would not, according to other impact assessments, result in impacts that would affect people's living conditions and comfort. Even if there were no realistic grounds for such concerns, it is still an actual social impact, the magnitude of which has been deemed minor and negative.

9.19.8 Significance of impacts

Table 9-69 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-69. Significance of impacts: people's living conditions and comfort.

Significance of impacts: people's living conditions and comfort			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Moderate**	**Minor negative**	**The significance of the impacts is minor and negative,** given that the impacts on people's living conditions and comfort under extended operation would continue for approximately 20 years. The discharge of warm cooling water, combined with the changes brought about by climate change, may impact the recreational value of the area's waterways, mainly in Hästholmsfjärden. In other respects, the impacts and adverse effects experienced by people will remain largely similar to their current levels. The potential additional construction could cause some additional adverse effects. In extended operation, the possible concern over safety risks would continue and could grow as the waste volumes increase and the plant ages. Extended operation could also have a positive impact on the area's demographics.
Decommissioning: *Expansion of the L/ILW repository* *First dismantling phase* *Operation of the plant parts to be made independent* *Second dismantling phase*	**Moderate**	**Moderate negative**	**The significance of the impacts is moderate and negative,** given that the power plant's decommissioning will result in a clear and observable change in the operations taking place in the power plant area. Overall, the various phases of the decommissioning will take several decades, which may give rise to uncertainty about the future and related concerns and expectations in residents. The occasional noise caused by the operations carried out during the decommissioning may impact particularly the comfort of holidaymakers staying in holiday homes in the vicinity of the power plant and the recreational experiences of people using the waterways and shores. The increased traffic during the most active dismantling phase may impair the nearby area's road safety and affect the smooth flow of traffic. The interim storage and transports of spent nuclear fuel may involve concerns about safety risks. Transports may especially raise concerns, even on a wider scale. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and concerns about the effect that the change will have on the vitality of the Loviisa region.
Decommissioning: *After the closure of the L/ILW repository*	**Moderate**	**Minor positive**	**The significance of the impacts is minor and positive,** given that operations related to the nuclear power plant in the area will end. As operations in the power plant area come to an end, any concerns about a risk of accidents or other incidents related to the operations will end. As a result of the end of operation, the need for cooling water and the thermal load will first reduce to a fraction during the operation of plant parts to be made independent and ultimately terminate completely. The positive impacts that the change will have on the status of Hästholmsfjärden's water environment may have a positive impact on the year-round recreational use of the waterbody and on residential comfort in the lakeside properties in the long run If all power plant structures and buildings are dismantled at the end of the decommissioning, and the area is landscaped according to the greenfield principle, the impact on the nearby area's residential comfort and recreational use will be more positive than the impact of a partial dismantling of the structures (the brownfield principle).
Radioactive waste generated elsewhere in Finland	**Moderate**	**Minor negative**	**The significance of the impacts is minor and negative,** because the reception of radioactive waste generated elsewhere in Finland at Loviisa power plant concerns residents, even though there will be no actual direct impacts on people's living conditions and comfort.

9.19.9 Mitigation of adverse impacts

Many concerns related to the production of nuclear energy are linked to radiation safety. Potential changes to current operations, such as the expansion of the L/ILW repository or the dismantling of the reactor buildings, may increase such concerns. Communications and interaction contribute to reducing unfounded concerns, fears and uncertainty.

The reception, handling and final disposal of radioactive waste generated elsewhere in Finland at Loviisa power plant has also raised concerns in the residents. To mitigate the concerns, it is important to provide people with clear communication. The matter may be clarified by using illustrative examples of the quality and quantity of the waste to be received as well as of the significance of safe handling, interim storage and final disposal. Increased knowledge will help people understand the kind of waste that may be received. The same principles are also effective when communicating about the handling, interim storage and final disposal of the radioactive waste generated at the power plant.

The provision of researched information, monitoring data and open communications also reduces the spread of false or distorted information, and the emergence of rumours which give rise to concerns. Examined from another perspective, any adverse effects during operation can be monitored and responded to better with the help of adequate information, if an already effective communication channel to the surrounding community exists.

Adverse effects during the planned operations can be partly reduced with planning. The means by which adverse effects are mitigated will be discussed in more detail in the impact assessment chapters on noise, dust, vibration, traffic, emissions of radioactive substances and radiation.

9.19.10 Uncertainties

The impacts on living conditions and comfort are subjective and bound to the person who experiences them, as well as the time and place. During the impact assessment, the views and thoughts of individual residents – i.e. the subjects of the impacts – must be brought to a more general level, at which point some of the individual information will be lost. On the other hand, it would be impossible to perform the impact assessment individually, due to which some degree of generalisation in terms of the information will be necessary.

The spread of the planned operations over a long period of time will increase the assessment's uncertainty, particularly in terms of assessing impacts that may not materialise or be felt for several decades. Uncertainty increases due to future global phenomena and technological advancements, for example.

The documentation of the assessment process aims to minimise uncertainties related to subjectivity, so that the person reading the assessment can deduce the grounds for the impact assessor's view. Possible uncertainties of other impact assessments may be repeated in the assessment of social impacts insofar as they impact the comfort of the residential and living environment.

9.20 PEOPLE'S HEALTH

9.20.1 Principal results of the assessment

Noise, vibration, tailpipe emissions and dust, among other things, will be generated during extended operation and decommissioning in the same manner as during the power plant's current operation. The operations occurring in the power plant area are not expected to have direct health detriments to residents in the nearby area. The tailpipe emissions and dust caused by road traffic are confined to the vicinity of the road network, due to which exposure to conventional health detriments is minor.

The impact that radioactive emissions resulting from normal operation would have on the radiation load of the surrounding nature is expected to remain very low, as it currently is, and no direct health detriments will result. The dismantling methods to be used in decommissioning are selected so that the emission limits for radioactive substances confirmed by the authorities will not be exceeded, which means that health detriments will not be formed.

The handling and transport of radioactive waste generated elsewhere in Finland is not expected to cause conventional health effects. Radiation exposure is confined solely to the personnel handling waste, and the radiation doses remain clearly below the set dose limits.

9.20.2 Baseline data and assessment methods

The assessment of the health effects aimed to investigate the probable direct and indirect health detriments which the project's different optionsextended operation or decommissioning could cause. The Health Protection Act (763/1994) defines a significanthealth detriment as a disease diagnosed in a human, another health disorder, or a factor that can reduce the healthiness of the population's or an individual's living environment.

The common grounds for identifying significant health effects include:

- severity (death, injury, the risk of an epidemic, disease, disease symptoms, sleep disorders);
- variation according to time (hourly, daily and seasonal variation);
- duration (permanent, years, months);
- a focus on certain groups (children, the elderly, the infirm, individuals sensitised to various predisposing factors);
- pattern of exposure (transdermal, inhaled, ingested, through the sensory organs);
- the number of individuals exposed (one person – the population of the entire impact area).

Some projects may also cause mild and/or temporary impacts on people and their living environment. These include the adverse effects on comfort caused by noise and odours, which are nevertheless not considered health effects. The impacts of incidents and accidents are addressed separately in Chapters 9.21 and 9.22.

Health effects can be direct or indirect. The path of impact in exposure to a direct health detriment can be the skin, digestion, respiratory tract, sensory organs, circulatory organs, skeletal and muscular structure as well as the internal organs and the nervous system. The path of impact in exposure to an indirect health detriment can be the respiratory air, domestic water, food, housing conditions, working conditions, exercise, rest and recreation as well as leisure activities. Examined from this perspective, "health" is a very broad concept.

Conventional health effects were assessed mainly on the basis of the results of the impact assessments concerning noise, vibration and air quality. The magnitude of the effects was compared to known limit and guideline values as well as other indicators. The limit and guideline values based on studies define the exposure and concentration limits for preventing health detriments. Any exceeding of limit or guideline values is likely to cause health effects in some of the exposed, whereas such effects are unlikely when the values are not exceeded. The review accounted for the effects extending primarily to the closest residences and secondary homes, nearby trails and outdoor routes as well as recreational areas. The impacts related to health were assessed in the form of an expert assessment.

The assessment of the noise impacts' health effects is based on the project's planning data and the results of the noise measurements conducted in the power plant's surroundings previously, in 2013, 2017 and 2020 (see Chapter 9.5), as well as on previous experience of the noise emissions of construction and dismantling work as well as excavations. The results were compared to the limit values specified in the power plant's environmental permit.

In terms of vibration, the assessment accounted for the vibration impacts attributable to the excavating of the L/ILW repository as well as the dismantling activities and transports. The vibration assessment accounts for any nuisance experienced by people. The significance of vibration was assessed in the form of an expert assessment based on similar previous excavation projects and on the knowledge and experience gathered during the L/ILW repository's quarrying.

The impact that air quality may have on any health detriments was assessed on the basis of an expert assessment. In addition, the assessment covered various emission sources, and the probable physical and chemical properties of their emissions from the perspective of health effects. The emissions of the power plant's emergency diesel generators and diesel-powered emergency power plant were assessed on the basis of their operating times and estimated fuel consumption. The tailpipe emissions of traffic and the emissions of the quarrying and dismantling activities attributable to decommissioning were also taken into account.

In addition to conventional health detriments, radiation doses were assessed by calculation. The emissions of radioactive substances and radiation are discussed in more detail in Chapter 9.8, and the health effects of radiation are described at a general level in Chapter 7.2. This chapter provides a summary of the theoretical radiation exposure and its health effects, based on the aforementioned chapters. The impact assessment reviews the radiation doses caused by normal operation by comparing them to the limit value for an annual dose of a member of the public (0.1 mSv). Possible incidents and accidents and their adverse effects are assessed separately in Chapters 9.21 and 9.22.

9.20.3 Background information on health effects

9.20.3.1 Noise

Exposure to noise may affect people's health or comfort. The degree to which noise is found disturbing is influenced by the recipient's characteristics: age, gender, morbidity or other sensitivity. Noise that is found disturbing may have negative health effects. Alongside air pollutants, ambient noise is one of Europe's biggest environmental problems, because it is a stressor, and its modes of action are still partly unknown. Exposure to noise is nevertheless known to cause physiological stress which has been linked to the risk factors of cardiovascular diseases and sleep disorders, among other things. While the stress reaction is often unconscious, it can be intensified by a conscious awareness of the nuisance caused by the noise.

According to Government Decision 993/1992, the equivalent continuous sound level pressure (LAeq) of noise in a residential area may not exceed 55 dB during the daytime (7 a.m.–10 p.m.) and 50 dB during the night-time (10 p.m.–7 a.m.). The corresponding LAeqs for secondary homes are 45 dB during the daytime and 40 dB during the night-time. The guideline values for residential areas are considered health-based, given that exposure in such areas is continuous. The lower guideline values applicable to areas of secondary homes are based on the adverse effects on recreational values and the expectations of soundscapes in such areas. According to the permit regulations of Loviisa power plant's environmental permit, the noise caused by the power plant's operation, excluding noise attributable to statutory tests, at sites used for holiday housing may not exceed a daytime level of 45 dB or of 40 dB during the night-time.

9.20.3.2 Vibration

In addition to the mere magnitude of the vibration, the degree to which an individual finds vibration disturbing is influenced by the circumstances in which it is detected. Vibration tends to disturb people more during the night, for example. In addition to the time of day, this is influenced by the fact that vibration is easier to detect in rest and when lying down. Noise experienced simultaneously with vibration may result in a combined impact in which the vibration is perceived to be greater than it would be without the noise. Furthermore, if the vibration has an impact on the surrounding building – by shaking things or rattling windows, etc. – the residents' experience of disturbance increases to a marked extent.

How people experience vibration is individual. While some people find vibration that barely passes the threshold of detection strongly unpleasant, other people are not disturbed by even significant vibration as a result of having grown accustomed to it. Vibration is found disturbing particularly easily when the noise emitted by the source of the vibration is also found disturbing.

9.20.3.3 Air quality

In terms of their properties, air-borne particulates are a mixture of different kinds of particulates of various sizes, the origins of which cover numerous different emission sources. Particulates spreading as air pollutants and/or gaseous compounds end up in the atmosphere due to human activities, including industrial processes, traffic and residential wood combustion. In Finland, more than half of the particulates in the air are derived from long-range transboundary air pollution. The very smallest – ultrafine and nano-sized – particulates, on the other hand, are primarily confined close to their source, such as an incineration process. The limit values for respirable particulates in terms of air quality are provided in Government Decree 79/2017.

Changes in air quality impact primarily the respiratory tract and circulatory system, but they can also contribute to the development or worsening of several diseases. In terms of particulates, the emergence of health detriments is influenced by their concentration, physical and chemical properties, as well as their size. The concentration of particulates in the air, as well as their harmfulness, varies according to season. The principal mechanism by which particulates impact the body is inflammation. Long-term exposure to fine particulate matter is known to increase the risk of heart and respiratory tract diseases as well as lung cancer. Fine particulate matter has also been shown to be linked to the development of several other diseases, such as asthma and neuropathic diseases. In addition, it has been suggested that the combined effect of exposure to particulates and noise may increase the risk of the development of new diseases. The population groups most sensitive to air pollutants are children, senior citizens and individuals with an underlying disease of the respiratory tract or circulatory system.

9.20.3.4 Radiation

Ionising radiation may harm cells. What is significant in terms of cell damage is the magnitude of the radiation dose, and whether the individual receives the radiation dose over a short or long period. The health effects of radiation and the reference data on radiation sources and radiation doses in Finland are discussed in more detail in Chapter 7.2.

Direct effects are unambiguous detrimental effects related to sudden very large single doses of radiation. The direct detrimental effects of radiation include radiation sickness, radiation burns, cataracts and foetal damage.

In principle, random long-term effects can arise from even minor exposure to radiation. Random effects are statistical detrimental effects, and what is typical of them is that the risk of a detrimental effect grows in step with the increase of the radiation dose. The random detrimental effects of radiation include various types of cancer and genetic mutation.

In practice, the cancer risk caused by small doses of radiation cannot be detected in the population, given how common a disease cancer is. The small increase possibly attributable to radiation is lost within statistically natural variation. For example, the fallout from Chernobyl – the total dose of which in a person residing in Finland over an 80-year period is two millisieverts, on average – is expected to cause some cancer deaths in Finland during that time. During the same period, a million people will die of cancer attributable to other causes, however (STUK Guide 2021h).

9.20.4 Present state

The morbidity index of the Sotkanet Indicator Bank, maintained by the National Institute for Health and Welfare (THL), was drawn up to function as an indicator of regional variation in morbidity and changes in the morbidity of individual regions. The index accounts for seven groups of diseases, which include the cerebrovascular and coronary diseases common to Finns, as well as musculoskeletal disorders, accidental injuries and dementia. The greater the value of the index, the more common the morbidity in a particular area is. Based on the last few years, the age-standardised morbidity index for the Loviisa area has been slightly higher than the national average. In 2016, the value of the index in Loviisa was 102.5, whereas in the entire country, it was 100. The index has declined in recent years; as recently as 2012, for example, it was 111.8. The age-standardised cancer index for the Loviisa area in 2016 was 110.7. Morbidity in Loviisa is therefore slightly higher than on average in Finland. While the higher-than-average morbidity may be attributable to the population's age structure, there are several possible reasons for the cancer index, including Loviisa's location in an area where the levels of radon in indoor air are higher than average.

Residents in the surroundings of the nuclear power plant are given an opportunity, within the framework of STUK's environmental radiation monitoring programme, to participate in annual measurements which investigate the amount of radioactive substances accumulated in the human body. The invitation is mailed primarily to individuals whose residential address during the year of each measurement lies within a five-kilometre radius of the nuclear power plant. In addition, the group of invitees is supplemented by a random sampling of individuals whose residential address is located within a 5–7-kilometre radius of the nuclear power plant. The gamma emitting radionuclides in the bodies of residents in the area surrounding the nuclear power plant are determined with a direct gamma ray spectrometer measurement outside the body. In 2019, the measurements did not detect radioactive substances originating from the power plant in the residents of Loviisa power plant's surroundings. Nor did the whole-body measurements of previous years detect radioactive substances originating from the power plant.

The environmental radiation monitoring of Loviisa power plant is discussed in Chapter 9.8.3.4. The amounts of radioactive substances originating from the power plant's operation detected in the environment of Loviisa power plant are small enough to be negligible in terms of the environment's or people's radiation exposure. The radiation dose calculated, on the basis of emissions, for the most exposed individual in the environment of Loviisa power plant in 2019 was less than 1% of the constraint set in the Nuclear Energy Decree (161/1988), which is 0.1 millisieverts (STUK Guide 2020c).

Table 9-70 shows the sensitivity of the affected aspect and some factors determining sensitivity (see Chapter 9.1.4).

Table 9-70. Sensitivity of affected aspect: people's health.

Sensitivity of affected aspect: people's health	
The impact area's level of sensitivity is determined on the basis of the residential and living environment's properties, including the area's housing, services, demographics, and the environment's resilience or adaptability. The sensitivity level is influenced by the location of sensitive facilities, the number of residents and any current adverse impacts on humans, for example.	
Minor	The nuclear power plant area is surrounded by a precautionary action zone extending to a distance of five kilometres. This zone may not contain facilities inhabited or visited by a considerable number of people, such as schools, hospitals, care facilities or shops. Nor are there any other sensitive facilities in the zone, including schools or daycare centres. There are no permanent residents up to a distance of one kilometre from the power plant. There are about 40 year-round residents up to a distance of five kilometres from the power plant. 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 the area. The air quality of the Loviisa area is good. The calculated dose of the individual most exposed in the environment due to the power plant's operation in Loviisa has remained significantly below 1% of the 0.1 mSv constraint set in the Nuclear Energy Decree (161/1988) (STUK 2021e). In 2019, the measurements did not detect radioactive substances originating from the power plant in the residents of Loviisa power plant's surroundings.

9.20.5 Environmental impact of extended operation

Impact formation

The impact of extended operation on air quality would consist of the emissions (carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions, dust) of the emergency diesel generators and the diesel-powered emergency power plant, as well as traffic. Noise is generated by the power plant's operation, traffic and machinery. The sole source of vibration is traffic. The nuclear power plant generates radioactive substances during its operation. These substances are treated by way of filtering and are delayed so that their radiation impact on the environment is very small. The impacts would remain primarily unchanged, but they would continue for another 20 years.

The conventional health effects resulting from extended operation would be primarily related to the noise and air emissions as well as the vibration generated by the activity. Given that the operations would continue in their current form, exposure to conventional health effects would be minor. The impacts would be confined primarily to the power plant area, but residents of the residential and holiday buildings on nearby islands and the mainland could be exposed to occasional noise.

Given that the operations would continue in their current form, there would be no changes to the noise levels. Modification and construction work could result in limit values being exceeded occasionally. The related noise would nevertheless be temporary and would therefore not lead to health detriments. Given that the operations would continue in their current form, the noise is not expected to generate health detriments. Temporary vibration impacts could occur in connection with the construction of additional buildings and traffic, but they would be confined to the power plant area and the immediate vicinity of roads, and are not expected to cause health detriments.

Extended operation would have a slight impact on air quality. The emissions into the air would consist primarily of the short-term tests of the emergency diesel generators and the diesel-powered emergency power plant. The impact of the local traffic emissions would remain in the vicinity of the roads. The amount of tailpipe emissions will decline in the future as cars are electrified, due to which traffic-based emissions would consist mainly of road, tyre and brake dust. The impact of this dust would be confined primarily to the immediate vicinity of roads. In terms of emissions into air, extended operation is not expected to cause direct health detriment in areas beyond the power plant and the roads.

The radioactive substances detectable in the environment of Loviisa power plant originate primarily from nature or have migrated from elsewhere; only a minor amount originates from the power plant. In extended operation, the impact that radioactive emissions resulting from the normal operation of Loviisa nuclear power plant would have on the radiation load of the surrounding nature is expected to remain very low, as in the current situation (see Chapter 9.8.3). In Finland, the radiation dose caused to residents in the areas surrounding nuclear power plants has been significantly below one per cent of the dose constraint set by the government, which is 0.1 mSv a year (STUK 2021a).

The power plant's extended operation is not expected to result in changes to the plant's current health effects, but the impacts would continue for another 20 years.

9.20.6 Environmental impact of decommissioning

Impact formation

The excavation of the L/ILW repository and the power plant's dismantling activities will generate occasional noise and vibration. In addition, traffic will generate tailpipe emissions and dust. 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.

Dust emissions related to the L/ILW repository's expansion will be generated by the underground blasting work, for example, and by transports and the stacking of the quarry material. The underground blasting will also involve emissions of nitrogen oxides and sulphur oxides. Furthermore, some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. Dismantling activities during decommissioning will result in controlled radioactive discharges into the air and waterways as well as in the radiation exposure of mainly personnel participating in the dismantling work and waste handling. The emissions and radiation doses will remain below the limit values, and will not result in health effects.

Noise during decommissioning will be generated by the excavation of the L/ILW repository and the dismantling measures in the power plant area. The noise will be occasional in nature and may, in suitable conditions, be audible on the nearby islands and the mainland. Nevertheless, the most significant noise will be confined to the power plant area or its vicinity. The impacts of the noise are expected to remain minor, when accounting for their confinement primarily to the power plant area and for their temporary nature. This is not expected to have detrimental effects on health.

The vibration generated by the excavation of the L/ILW repository and the dismantling activities will be mild in nature and confined to the vicinity of the source of the vibration. The transports related to the decommissioning may cause traffic-based vibration of a longer duration, but it will be confined to the vicinity of the transport routes. The vibration is not expected to cause health detriments at the residential and holiday buildings in nearby areas.

The impacts on air quality are related to the excavation of the L/ILW repository and the resulting dust emissions, as well as to the emissions of nitrogen and sulphur oxides generated by the blasting. Dust can also be generated in connection with the crushing of the quarry material or any concrete, and by traffic. Traffic will also generate tailpipe emissions. Some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. The conventional emissions into the air (consisting of, among others, carbon dioxide, nitrogen oxides and particulate emissions) will be mainly local and occasional, and will be confined to the vicinity of the power plant area and transport routes. 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. However, in suitable weather conditions, traffic emissions could cause temporary increases in concentrations. However, this is not expected to cause health effects, given that the situations in question are probably transient in nature and short in duration. The spread of the impacts on the air is influenced by the size of the particulates generated by the operation. The particulates generated in the decommissioning and the excavation of the L/ILW repository's expansion are mostly larger than fine particulate matter, i.e. more than 2.5 µm in diameter, due to which they fall earlier and closer. The greatest concentrations comparable to the limit and guideline values are found near the source of the emission, such as a crusher or transport route.

When the operation of Loviisa power plant ends, it will no longer generate emissions of radioactive substances in the current manner. Momentary controlled radioactive discharges into the air and waterways may nevertheless take place during the decommissioning phase. The targets and emission limits for radioactive emissions during the decommissioning phase will be defined as the decommissioning plans progress. The methods to be used in the decommissioning will be selected so that the emission limits subsequently confirmed by the authority are not exceeded, meaning that there will be no health effects. 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 reactor, at 0.01 mSv (section 22 b 161/1988).

9.20.7 Radioactive waste generated elsewhere in Finland and its impact

The reception, handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland at the power plant is not expected to cause conventional health effects. Radiation exposure would be confined solely to the personnel handling waste, and the radiation doses would remain significantly below the set dose limits.

9.20.8 Comparison of options and Significance of impacts

Table 9-71 presents an assessment of the significance of the impacts based on the sensitivity of the affected aspect and the magnitude of the change (see Chapter 9.1.4).

Table 9-71. Significance of impacts: people's health

Significance of impacts: people's health			
Operational phase	**Sensitivity**	**Magnitude**	**Significance**
Extended operation	**Minor**	**No change**	**No impact.** Noise, vibration, tailpipe emissions and dust, among other things, would be generated during extended operation in the same manner as during the power plant's current operation. The operations occurring in the power plant area are not expected to be detrimental to the health of residents in the nearby area. The tailpipe emissions and dust caused by road traffic will be confined to the vicinity of the road network, in terms of which exposure to conventional health detriments is minor. The impact that radioactive emissions resulting from normal operation would have on the radiation load of the surrounding nature is expected to remain very low, as it currently is. Extended operation is not expected to effect changes to the plant's current operation and the resulting impacts.
Decommissioning	**Minor**	**No change**	**No impact.** Noise, vibration, tailpipe emissions and dust, among other things, will be generated during the decommissioning. Some emissions will be generated in the tests of the diesel generators during the operational phase of the plant parts to be made independent. The operations occurring in the power plant area are not expected to be detrimental to the health of residents in the nearby area. The tailpipe emissions and dust caused by road traffic will be confined to the vicinity of the road network, in terms of which exposure to conventional health detriments is minor. The dismantling methods to be used in decommissioning are selected so that the emission limits for radioactive substances confirmed by the authorities will not be exceeded, which means that health detriments will not be formed.
Radioactive waste generated elsewhere in Finland	**Minor**	**No change**	**No impact.** The handling and transport of radioactive waste generated elsewhere in Finland is not expected to cause health detriments. Radiation exposure would be confined solely to the personnel handling waste, and the radiation doses would remain significantly below the set dose limits.

9.20.9 Mitigation of adverse impacts

Means by which to mitigate adverse effects are presented in the following chapters:

- traffic (see Chapter 9.4)
- noise (see Chapter 9.5)
- vibration (see Chapter 9.6)
- air quality (see Chapter 9.7)
- emissions of radioactive substances and radiation exposure (see Chapter 9.8).

9.20.10 Uncertainties

The uncertainties in the assessment of health effects are principally related to the uncertainties described in the sections on impact assessments. Differences between individuals also introduce uncertainties to the assessment of health effects.

9.21 SEVERE REACTOR ACCIDENT

In the event of a nuclear power plant accident, radioactive substances detrimental to health could end up in the environment. This chapter discusses a severe reactor accident in which the amount of radioactive substances ending up in the environment is significant. Milder cases are discussed in Chapter 9.22.

A severe reactor accident at the power plant is a highly unlikely extreme event, the materialisation of which would require several failures in the plant's systems and problems in the plant's control. Various incidents and accidents, including a severe reactor accident, have been prepared for in the plant's design and operation so that their consequences can be minimised. Chapter 7.5–7.8 contains a more detailed discussion of nuclear safety.

9.21.1 Methods of assessment

This chapter presents the calculation method for and assumptions concerning an environmental emission caused by a severe reactor accident.

The assessment of a severe reactor accident is based on the assumption that an amount of radioactive substance equivalent to the limit value for a severe accident pursuant to section 22 b of the Nuclear Energy Decree is released into the environment. The emission would contain 100 terabecquerels (TBq) of the caesium-137 (Cs-137) nuclide and other radionuclides in equal proportion to how much of them would be expected to be released in proportion to caesium-137 in the accident. Based on the activity released in the emission, the reviewed fictitious severe reactor accident corresponds with an INES level 6 accident on the International Nuclear and Radiological Event Scale. The impact of the release's dispersion in the accident was studied over a distance of 1,000 km from the power plant.

The modelling results are compared to the civil protection-related action limits pertaining to evacuation and seeking shelter indoors presented in STUK's preparedness guideline VAL 1 (STUK 2020a). In addition, the assessment covers the impacts of the radioactive fallout and radiation doses resulting from a severe reactor accident. The accident's follow-up as well as social and socioeconomic impacts are discussed on a general level.

9.21.1.1 Emission and dose limits

According to section 22 b of the Nuclear Energy Decree (161/1988), the emission of radioactive substances resulting from a severe nuclear power plant accident may not necessitate large-scale protective measures for the population nor any long-term restrictions to the use of extensive areas of land and water. To limit long-term effects, the limit value for a Cs-137 emission into the ambient air is 100 TBq. The possibility of the limit value being exceeded must be extremely small. The possibility of an emission requiring protective action in terms of the population in an early phase of the accident must likewise be extremely small.

Guideline VAL 1 provides orders of magnitude for the civil protection-related action limits and indicative levels (STUK 2020a). The dose criteria for seeking shelter indoors and evacuation, the areas, and the action levels regarding a fallout's strong gamma and beta emitters related to guidelines VAL 1 (STUK 2020a) and YVL C.3 (STUK 2019a) are summarised in Table 9-72. The five-kilometre precautionary action zone and the 20-kilometre emergency planning zone mentioned in Table 9-72 are shown, in terms of Loviisa power plant, in Figure 9-66.

9.21.1.2 Emission and its release into the atmosphere

The radiation doses and fallout resulting from a severe reactor accident were modelled on the basis of analyses performed for Loviisa power plant which allow for estimating the amount of radionuclides which would be released into the environment. The radiation dose assessments were based on a fictitious accident in which the activity of a total of 200 radionuclides or states is released into the environment.

In this fictitious severe reactor accident, 100 TBq of the Cs-137 nuclide and other radionuclides in equal proportion to how much of them would be expected to be released in proportion to caesium-137 in the accident. In a severe reactor accident, iodine is one of the key radioactive substances from which radiation doses arise. Given that the various states of iodine have dose coefficients that differ from each other, the dispersion calculation generally accounts for the different states of iodine to prepare a more precise dose estimate. In the dispersion calculation, iodine's state for all isotopes of iodine contained by the emission is assumed to divide as follows: 95% of the iodine is released as aerosols (particulate), 4.85% in element form and 0.15% as organic iodine (European utility requirements for LWR nuclear power plants 2016).

In the severe reactor accident under review, the power plant is producing electricity for the national grid at full capacity when a pipe of the primary system breaks. As a result of several failures, the reactor's water level drops, due to which the fuel is damaged, and radioactivity is released into the containment building. The accident is also assumed to include a leak from the containment building, as a result of which the activity is provided with a leakage route from the containment building to the atmosphere. The emission is assumed to begin some 2.5 hours after the reactor's shutdown (reactor trip) and it will be released into the atmosphere, unfiltered, at a height of approximately 31 m above ground level. The impacts of the emission were modelled by employing 22 hours as the duration of the emission in the dose calculation.

Table 9-72. Actions to protect the population, dose criteria and area delimitations, as well as action levels related to fallout.

Action	Dose criterion (VAL 1)	Greatest distance from power plant to which the action may extend (YVL C.3)	Indicative action level (VAL 1)
Seeking shelter indoors	> 10 mSv over a period of two days	Power plant's emergency planning zone (20 km)	The fallout of the fallout's beta and gamma emitters exceeds 10,000,000 Bq/m² for longer than two days
Evacuation	> 20 mSv during the first week for an unsheltered individual	Power plant's precautionary action zone (5 km)	The fallout of the fallout's beta and gamma emitters exceeds 10,000 000 Bq/m² for longer than two days

9.21.1.3 Dispersal calculation

The modelling of the radiation doses and the radioactive fallout was performed with the Tuulet programme developed by Fortum Power and Heat Oy. The program has been approved by STUK for use in the calculation of the radiation doses of the residents of nearby areas. The modelling is based on the Tuulet 2.0.0 program version, which has been modified for the purpose of the environmental impact assessment to allow for an assessment of the emission up to a distance of 1,000 km from the power plant. The results provided by the modified version of the program were compared, in terms of external doses, to the HYSPLIT model published by the National Oceanic and Atmospheric Administration (NOAA) of the United States (NOAA 2020). The comparisons show that the external radiation doses modelled with the Tuulet program are of the same magnitude as those of the HYSPLIT model.

The Tuulet program accounts for the effect that the power plant's buildings would have on the wind field and, thereby, the impact that the emission's release height would have on the dispersion. The emission cloud's vertical dispersion accounted for reflection from the ground and the atmosphere's inversion layers, the height of which depends on the atmosphere's stability.

In the Tuulet program, the dispersion of the emission cloud is described with the Gaussian trail model, which accounts for the decay of radioactive substances and their deposition on the ground as dry and wet fallout. To enable the statistical processing of the results, the modelling employed the weather data of three years retrieved from Loviisa power plant's weather observation system. The weather data was selected so that they represented the climate in the power plant's nearby areas in a diverse manner. The calculation of the effective whole-body radiation dose accounted for direct gamma radiation from the emission cloud, the gamma and beta radiation from the fallout and lake water, and the internal dose resulting from radioactive substances that enter the body through breathing and food. The emergence and migration of daughter nuclides was not modelled separately, but their dose impact was taken into account in the parent nuclides' dose coefficients and in the average gamma energies.

The accumulation and migration of radioactive substances in the biosphere has been modelled in the Tuulet program. The nuclides' deposition directly on the surfaces of plants and their migration from the soil to a plant's inner parts via root uptake was taken into account. Activity can also run off the surfaces of plants. Whether the activity ends up in plants depends on whether the emission occurs in the summer, during the growing season, or during another season. Harvest time has an impact on the migration of radioactivity from pasture grass and forage to cows. From cows, the activity ends up in humans through beef and milk. Radioactivity may also end up in game animals through forest meadows, and finally in humans who eat the game. In winter, the emission is initially deposited on top of ice and snow, meaning that the activity ends up in the food web with a delay, once the snows have melted. Activity deposited in lakes is initially mixed into the lake's water volume, finally ending up in the freshwater fish and ultimately, the humans who eat the fish. The radiation dose that accumulates through food over a year can be divided into the period of use of fresh food and stored food.

At distances of more than 100 km, it was conservatively postulated that radiation doses would accumulate at each calculation point through all dose pathways, although in reality, the doses accumulating in sea areas originate solely from the direct radiation emitted by an emission cloud passing overhead and from radioactive substances entering the body through breathing. The fallout and radiation doses estimated with the Tuulet program are therefore conservative.

No protective action was postulated when modelling the radiation doses, meaning that any decreasing effect that seeking shelter indoors and making changes in the food ingested would have on radiation doses was not taken into account. The fallout and radiation doses are presented according to a 5% exceeding probability. This means that there is a 95% probability that the fallout or radiation dose would remain smaller than the result presented here.

9.21.4 Age groups and the integration times of radiation doses

According to the International Commission on Radiological Protection (ICRP), it is advisable to account for different age groups when modelling radiation doses, given that the groups have different types of consumption pattern when it comes to nutrition. In accordance with the ICRP's recommendations (ICRP 2006), this modelling covered the age groups of one-year-olds, 10-year-olds and adults. Of these age groups, an adult is what is referred to as a representative person for the radiation doses in the environment of Loviisa power plant. The radiation dose accumulated throughout a lifetime was assessed by applying a 70-year exposure period (integration time) for one-year-olds, a 60-year exposure period for 10-year-olds and a 50-year exposure period for adults. The amount of nutrition typically ingested by each age group, based on Finnish consumption patterns, was accounted for in each age group. When assessing the radiation doses in terms of children, the individual's growth and the way of life and nutrition that change as a result of the growth were taken into account.

Both seeking shelter indoors and evacuation should be observed when modelling the potential actions for protecting the population attributable to a severe reactor accident. According to the VAL 1 guideline (STUK 2020a), seeking shelter indoors must be examined in terms of the radiation dose received over two days, and in terms of evacuation, the radiation dose received during the first week must be reviewed. The radiation dose caused by a severe reactor accident during the first year and throughout an individual's entire life can also be reviewed.

Table 9-73. The radiation doses caused by a severe reactor accident to a one-year-old, 10-year-old and an adult at a distance of 1–1,000 km from the emission's release point over two days, seven days, one year and the person's lifetime.

	Estimated dose of the one-year-old [mSv]				Estimated dose of the 10-year-old [mSv]				Estimated dose of the adult [mSv]			
Distance (km)	2 d	7 d	1 a	70 a	2 d	7 d	1 a	60 a	2 d	7 d	1 a	50 a
1	24.1	26.1	121.0	267.0	25.2	27.4	105.0	292.0	19.5	21.6	88.8	320.0
5	4.4	4.8	26.1	60.1	4.5	4.9	22.9	65.7	3.8	4.1	20.1	73.1
10	2.0	2.2	15.0	27.7	2.1	2.2	10.6	30.0	1.8	1.9	10.0	34.1
15	1.3	1.4	11.7	21.3	1.4	1.5	7.9	20.1	1.2	1.3	7.0	22.1
20	1.0	1.1	8.0	14.5	1.0	1.1	5.4	13.9	0.9	1.0	4.8	15.2
50	0.35	0.37	2.08	3.91	0.36	0.38	1.49	3.78	0.32	0.35	1.35	4.26
100	0.23	0.23	0.31	0.41	0.23	0.23	0.28	0.40	0.22	0.23	0.27	0.43
300	0.07	0.07	0.11	0.16	0.07	0.07	0.10	0.16	0.07	0.07	0.09	0.17
500	0.04	0.04	0.06	0.09	0.04	0.04	0.05	0.09	0.04	0.04	0.05	0.10
700	0.02	0.02	0.04	0.06	0.02	0.02	0.03	0.06	0.02	0.02	0.05	0.06
1,000	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.04

9.21.2 Radiation doses and fallout

The radiation doses resulting from a severe reactor accident are shown in Table 9-73. The radiation doses have been estimated for children aged one and 10, and for an adult, at a 1–1,000 km distance from Loviisa power plant. For the assessment of civil protection actions, the radiation doses are shown according to two-day and seven-day exposure periods. In addition, the radiation doses were assessed in terms of a year's and an entire lifetime's exposure periods.

According to the modelling (Table 9-73), the radiation dose that an adult living 20 km from the emission's release point would be subject to as a result of a severe reactor accident would be around 4.8 mSv with a one-year exposure period. The radiation dose caused by a severe reactor accident during an exposure period of one year outside Loviisa power plant's emergency planning zone of 20 km would remain smaller than the average annual radiation dose of an individual residing in Finland. The estimated magnitude of the annual radiation dose of an individual residing in Finland is 5.9 mSv (STUK 2020b).

The radiation doses of the children aged one and 10 would typically be greater than the adult's radiation doses in the vicinity of the power plant. This is due to different nutrition, for instance, in which the consumption of milk, among other things, is more pronounced than in adults. Although the lifelong exposure of the one-year-old and 10-year-old would be longer than the adult's, this would not automatically translate into a greater lifelong radiation dose, given that the accumulation of the radiation dose would be at its greatest in the moments following the accident.

Estimates of the fallout resulting from a severe reactor accident are presented in Table 9-74 for those caesium (Cs), iodine (I) and tellurium (Te) nuclides which, according to the radiation dose analysis, cause the greatest dose through the fallout during a one-year exposure period. In terms of the iodine isotopes I-131 and I-132, fallouts are shown for the three states of iodine (aerosol, organic and element), because these have different deposition rates from the air to the ground. The table also accounts for the long-lived strontium-90 (Sr) nuclide.

9.21.2.1 Effects of radiation doses

The health effects of radiation at a general level are described in Chapter 7.2.

Based on the modelling, the greatest radiation dose at a distance of one kilometre, accounting for all age groups, is approximately 25 mSv during the first two days, and approximately 27 mSv during the first week. Radiation doses of this magnitude do not have direct radiation effects on humans or cause developmental impairment in foetuses. A roughly 30-mSv radiation dose is equivalent to three whole-body CAT scans (STUK 2021i). A change in complete blood counts within a few days requires a radiation dose of approximately 500 mSv. Sudden radiation doses of more than 100 mSV when a foetus is at a sensitive developmental stage may lead to developmental disorders (STUK 2019b).

By comparing the results of the modelled radiation dose estimates (Table 9-73) to the dose criteria in Table 9-72, the dose criteria for both seeking shelter indoors and evacuation are exceeded in the zone located at a distance of less than five kilometres from the power plant. In other words, at a distance of more than five kilometres from the power plant, the dose criteria for seeking shelter indoors or evacuation are not exceeded.

When examining the radiation dose at the outer limit of the power plant's precautionary action zone – i.e. at a distance of five kilometres from the power plant – the estimated radiation doses caused by a severe reactor accident throughout an entire lifetime are roughly 60 mSV for a child aged one (70-year exposure period), roughly 66 mSv for a child aged 10 (60-year exposure period) and roughly 73 mSv for an adult (50-year exposure period). At a distance of 20 km from the power plant, the radiation doses are in the range of 1 mSv during the first days, regardless of age group. The radiation doses estimated for entire lifetimes are, at a 20-kilometre distance, in the range of 15 mSV at maximum.

In the case of the adult, the radiation dose was also estimated for a fisherman. The fisherman is assumed to live five kilometres away from the power plant and to use local fish for food around eight times as much during a year than an average person residing in Finland does. Due to the impact of the pronounced consumption of local fish, the lifelong radiation dose was expected to be 164 mSv at most (50-year exposure period).

When the results of the modelling are compared to the annual average radiation dose of a person residing in Finland, which is around 5.9 mSv a year (STUK 2020b), one can conclude that the amount of radiation accumulated by a person residing in Finland from other sources over 50 years is approximately 295 mSv. In addition, a person living in a block of flats in a location in which they are exposed to abundant radon through domestic water or indoor air may be subject to a maximum radiation dose in excess of 1,500 mSV over a period of 50 years (STUK Guide 2020b).

When reviewing the results of the modelling, one should note that in the event of a severe reactor accident, the authorities would initiate action to protect the population, such as seeking shelter indoors, at a very rapid schedule – a factor not accounted for in the dose estimates presented. This being the case, the results presented are also conservative in this sense. Actions protecting the population implemented at an early stage can significantly reduce the greatest radiation doses received during the initial stage of the accident, which are attributable to activity entering the body through respiration as well as direct external radiation caused by an emission cloud travelling in the air stream and to deposition on the ground.

The relative proportions of the seven-day exposure period of an adult person presented in Table 9-73 are illustrated in Figure 9-82 as a function of distance. The nutrition dose

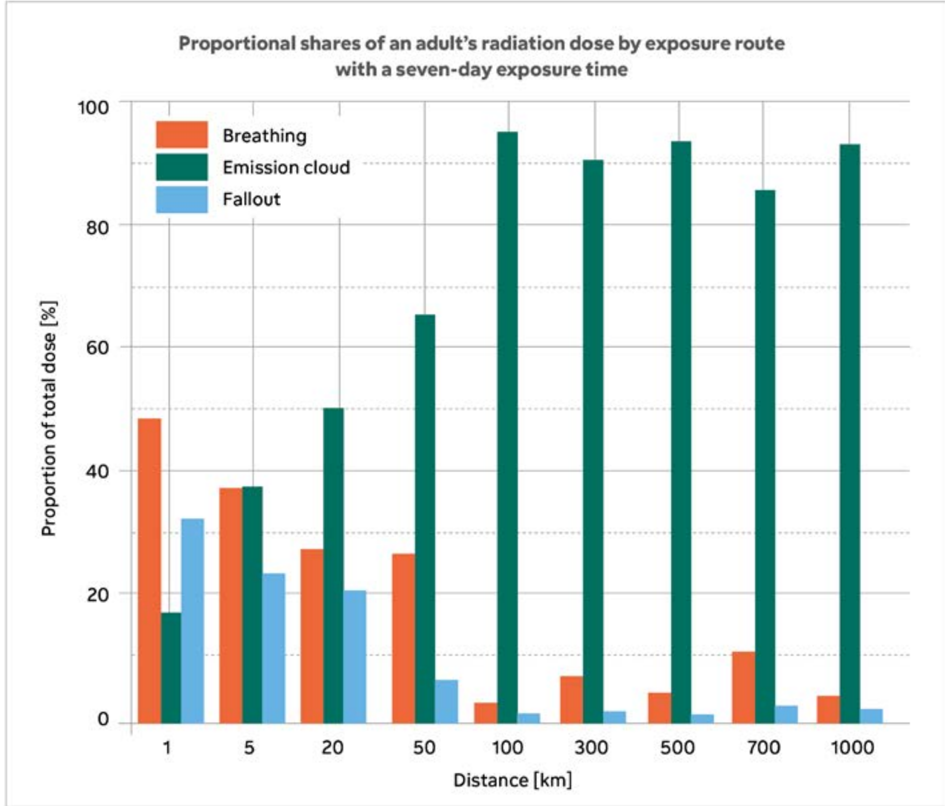


Figure 9-82. The relative proportions of an adult's radiation dose per exposure pathway during a seven-day radiation dose exposure period.

pathway is not shown in the figure, because practically no radiation dose is received through this exposure pathway during a seven-day exposure period (as opposed to a one-year exposure period, for example). The figure shows that during the first week, respiration and deposition cause most of the radiation dose in the power plant's nearby areas. However, when the distance grows the radiation emitted by an emission cloud begins to dominate. A direct radiation dose attributable to an emission cloud can be efficiently limited by seeking shelter indoors (see Chapter 9.21.3), which is also relatively effective in sheltering a person from radiation doses received through respiration and deposition.

In longer periods of exposure, the effects of the deposition and particularly food intake begin to dominate the radiation dose. By avoiding the consumption of food products from the polluted areas, it is also possible to at least partly avoid the radiation dose attributable to food.

9.21.2.2 Effects of radioactive fallout

Fallout refers to the airborne radioactive particles originating from an accident deposited from an emission cloud on the ground or water as a result of both gravity (dry fallout) and rain (wet fallout). The fallout may remain above ground and cause a radiation dose via direct radiation, or it can migrate more deeply into the soil and transfer, in part or in full, through complex mechanisms, to plants, fungi and animals. Radioactivity can also end up in humans through food. It is also possible for the fallout to return from the ground into the air due to wind, for example. In waterways, part of the fallout mixes with the water, while part ends up in the sediment at the bottom, where it can also be remixed into the water as a result of currents.

When reviewing the effects of the fallout, one should especially account for the long-lived Cs-137 nuclide (with a half-life of some 30 years) and for the Cs-134 nuclide, with a slightly shorter half-life (a half-life of approximately two years). The shorter-lived isotopes of iodine in their different states are also often examined in connection with fallout (the half-life of I-131, for instance, is around eight days), as is the Sr-90 nuclide (with a half-life of approximately 29 years). In addition, the review included the nuclides Te-132 (with a half-life of roughly three days) and the short-lived I-132 (with a half-life of approximately 2.3 hours), which is the radioactive decay product of the Te-132 nuclide. Noble gases are not discussed in this context, given that they do not cause fallout.

By comparing the results of the modelled fallout estimates (Table 9-74) with the action levels in Table 9-72, the action levels for both seeking shelter indoors and evacuation are exceeded in the zone located at a distance of less than five kilometres from the power plant. In other words, at a distance of more than five kilometres from the power plant, the dose criteria for seeking shelter indoors or evacuation are not exceeded.

According to the modelling, when reviewed according to criteria in line with STUK's VAL 1 guideline, the area at a distance of less than one kilometre from the power plant is extremely contaminated, meaning that the area contains abundant radioactivity on all surfaces. The area at the outer limit of the power plant's precautionary action zone (at a distance of five kilometres from the plant) is heavily contaminated. The area at a distance of 15 kilometres is contaminated, and starting from a distance of 80 kilometres, the area is mildly contaminated or nearly clean.

Of the nuclides reviewed, the isotopes of iodine have the greatest impact immediately after an accident. In a human, iodine tends to be stored in the thyroid gland, but its effects can be mitigated with the timely intake of iodine tablets, which make the thyroid store stable iodine instead of radioactive iodine. Of the nuclides with a long half-life, Cs-134 and particularly Cs-137 and Sr-90 cause a radiation dose for years in the form of fallout. Caesium typically accumulates in the muscles and strontium in the bones of a human body. The biological half-life is often significantly shorter than the physical half-life, meaning that the Cs-137 ending up in a human body, for example, leaves the body more quickly than with the help of physical decay alone.

Radioactive fallout may demand either short-term (e.g. iodines) or long-term (e.g. caesiums and strontium) restrictions in the use of land or water areas as well as restrictions related to the use of foodstuffs. By comparing the fallout estimates in Table 9-74 and the VAL 1 guideline, the modelled severe reactor accident would result, among other things, in the clean-up of the built environment, restrictions related to the recreational use of natural areas and the organising of measurements and purification of humans living within a radius of less than 15 kilometres 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 also impose restrictions on products used as food, such as berries, mushrooms, fish, game and dairy products, based on their activity concentrations (VAL 1 guideline).

9.21.3 Mitigation of impacts

The impact of an emission resulting from a severe reactor accident can be mitigated by various actions that aim to protect the population, such as the administration of iodine tablets and seeking shelter indoors, by evacuating the population before the emission reaches a particular area or by evacuating the population at a later stage, if the radiation situation requires this.

If the population is evacuated before the emission reaches an area, the radiation dose caused by the accident can even be avoided completely. In some cases, such as when the population, for one reason or another, cannot be evacuated in time before the emission cloud reaches an area, seeking shelter indoors is a good way to reduce the radiation exposure attributable to a radioactive cloud.

Table 9-74. The depositions [kBq/m²] of the nuclides causing the greatest radiation doses through fallout at different distances from the power plant in a severe reactor accident.

	Deposition [kBq/m²]									
Distance (km)	Cs-134	Cs-137	I-131 (aerosol)	I-131 (organic)	I-131 (element)	I-132 (aerosol)	I-132 (organic)	I-132 (element)	Te-132	Sr-90
1	706	441	4353	0,5	1,472	5,424	0,6	1,828	4,983	1.1
5	126	79	779	0.07	181	970	0.09	225	892	0.2
10	56	35	344	0.03	65	429	0.04	81	394	0.09
15	33	21	205	0.02	35	256	0.02	43	235	0.05
20	23	21	141	0.01	22	176	0.02	28	162	0.04
50	6.3	4.0	39	0.005	4.8	49	0.006	6.0	45	0.01
100	0.4	0.3	2,6	0.0004	0.2	3.3	0.0005	0.3	3.0	0.0007
300	0.2	0.1	1,1	0.0003	0.07	1.4	0.0004	0.09	1.2	0.0003
500	0.1	0.07	0,7	0.0003	0.04	0.8	0.0003	0.05	0.8	0.0002
700	0.08	0.05	0,5	0.0002	0.03	0.6	0.0003	0.04	0,.05	0.0001
1,000	0.05	0.03	0,3	0.0002	0.02	0.4	0.0002	0.03	0.03	0.0001

Among other things, the effectiveness of seeking shelter indoors depends on the material used in the building and the location of the space used as a shelter within it. STUK has estimated (STUK 2020a) that even at its minimum, seeking shelter indoors, when carried out in an orthodox manner, can reduce the radiation dose to one-third of what it would be without seeking shelter indoors. Seeking shelter indoors is at its most effective when the building's ventilation has been stopped, and when the space used for the sheltering is the civil defence or air-raid shelter of an apartment building, for example. In such cases, the radiation dose is estimated to remain as low as one five-hundredth of the dose received without the shelter (STUK 2020a).

The impacts of the fallout can be mitigated in several ways, depending on the area in question. Paved urban environments, for instance, can be washed, which means that significant portions of the fallout can be removed with water. Land areas can also be modified so that the soil material on their surface containing the most fallout is removed and transported to a controlled storage location. In a fallout situation, the principal clean-up measures target living environments in which people spend a large part of their time (including housing) or with a high population density (urban areas).

STUK's VAL 1 guideline (STUK 2020a) provides guidelines for the protective actions that aim to protect the population in the early and intermediate stages of an emergency exposure situation. The guideline reviews the content of and grounds for the protective actions, and provides various dose criteria and indicative action levels which, if exceeded, necessitate the initiation of protective action. In an emergency exposure situation, STUK assesses the situation's safety significance in accordance with the Rescue Act (379/2011) and gives recommendations on protective action to the authorities which decide on such action. In an emergency exposure situation, a nuclear power plant's licence holder works in close cooperation with STUK, ensuring the safety of the power plant and its environment in the best possible way. The key responsibilities for the protective action in an emergency exposure situation are compiled in Appendix 4 to

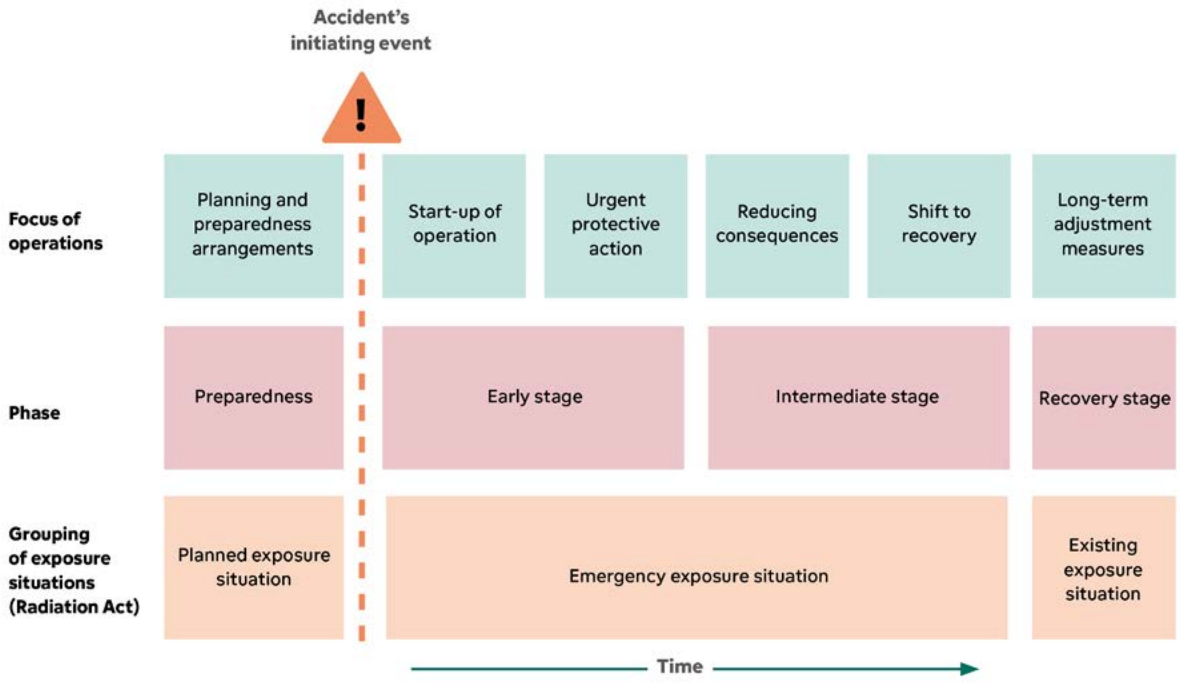


Figure 9-83. Development and stages of an emergency exposure (STUK 2020a).

the VAL 1 guideline. The radiation situation manual published by the Ministry of the Interior (Ministry of the Interior 2016) provides instructions for the authorities' measures in an emergency exposure situation. Figure 9-83 shows the focal points of the protective action during the various stages of an emergency exposure situation.

Preparing in advance for a potential accident is an important principle of protective action. It enables the rapid initiation of the planned action as soon as the accident has occurred.

During the early stage of the accident, the focus of the protective action is on initiating the action and urgent protective action. The protective actions during the early stage focus particularly on people and production, with the aim of both protecting people as well as facilitating and mitigating the action required during the intermediate stage. Urgent protective action concerning the population and the people working in the hazardous area includes seeking shelter indoors or curfews, taking iodine tablets, isolating the area and access restrictions, the population's evacuation and protecting the people working in the hazardous area. Action will also be taken to shield foodstuffs, the primary production of animal feed and domestic water, the raw materials of foodstuffs, finished products and production facilities. If necessary, restrictions on food and the trade of goods will also be imposed (STUK 2020a).

The focus of the protective action during the intermediate stage of an accident is on reducing the consequences and the transition to recovery from the accident. During the intermediate stage, the protective action focuses on the living environment and on restoring society's activities, in addition to people and production. In terms of the population and people working in a contaminated area, the protective actions are similar to those during the accident's early stage. Additional actions include the measurement and purification of humans as well as the removal of radioactive substances and the reduction of their migration. Other possible actions include potential restrictions to land use as well as the use of foodstuffs, food production and water supply (STUK 2020a).

The recovery stage is the final stage of the protective actions, during which the focus is on the long-term adjustment measures (STUK 2020a).

9.21.4 Social and socioeconomic impacts

A severe reactor accident's impacts on society are varied and of a long-term nature. Among other things, the impacts on society and its activities depend on the place of residence (urban environment or rural areas) and the actions imposed by the authorities that aim to protect the population (evacuation and the applicable limit values related to the dose rate and fallout). Managing the aftereffects of the accident, long-term healthcare and mental wellbeing, as well as supporting society in many other ways, should also be paid attention to as a countermeasures.

Areas contaminated as a result of the accident, including food production areas, may have to be removed from use for a long time or even permanently. Settled urban areas can be cleaned up much more easily than croplands or forests, for example. In some areas, this could lead to a significantly steeper drop in the areas' value than elsewhere, even if the level of contamination is identical.

The impacts of a severe reactor accident concern both built infrastructure and nature, but they also have psychological effects on humans. The large-scale contamination of the environment resulting from a severe reactor accident may lead to job losses, and thereby impact people's livelihoods and result in chronic anxiety and various well-founded or unfounded fears related to radiation in the environment. Furthermore, the mere large-scale evacuation of the population may lead to significant problems in mental wellbeing, even if the direct impacts of radiation could be completely avoided with timely evacuation. The people exposed to radiation in the accident may also be subject to discrimination.

The social and socioeconomic impacts of the Chernobyl accident have been studied extensively (see Chernobyl Forum 2005). Some 116,000 residents were evacuated soon after the accident, and overall, the number of residents evacuated over the years amounts to more than 330,000. Although relocation reduced the population's radiation dose, many considered it a traumatic experience, even after material compensation (such as new housing) (Chernobyl Forum 2005).

The social and socioeconomic impacts of the accident include large-scale restrictions to land use in previously arable land areas and consumers still shunning products grown in areas which have already been categorised as safe. This has had an impact on the total economy in areas which experienced the greatest radioactive fallout from the accident at Chernobyl (Chernobyl Forum 2005).

The population structure has also undergone significant changes, given that in the areas which suffered most from the accident, the elderly are abnormally overrepresented in the age distribution. Among other things, this is the result of migration, during which the younger population has gravitated elsewhere on their own initiative. In addition to an abnormal age distribution, this has also had psychological effects. In the areas in question, the mortality rate is higher than the birth rate, and various industries have difficulties finding a professional workforce. This has had an impact on many sectors, including social services. The people living in areas most contaminated by the accident have a more negative attitude towards their own health than people living in other areas. A certain type of victimisation and a culture which leans increasingly heavily on government-paid subsidies have also take hold (Chernobyl Forum 2005).

According to a study of the Fukushima accident (Hasegawa et al. 2016), the accident has caused mental problems such as post-traumatic stress disorder, chronic anxiety and feelings of guilt, an indeterminate feeling of loss, emotions related to families or communities set apart as well as feelings of shame. Increased deaths were observed particularly among the evacuated senior citizens in need of care. It has been suggested that these deaths are the result of the constant changes in nutrition, hygiene as well as medical and general care resulting from the multiple evacuations. In addition, the Fukushima accident caused what are referred to as lifestyle-related changes, given that many of the evacuees experienced changes in their eating habits, amount of exercise as well as the consumption of tobacco and alcohol. The changes are expected to lead to an increase in diseases related to these lifestyles, such as obesity (Hasegawa et al. 2016).

9.21.5 Comparison with the Fukushima accident

The Fukushima accident was well documented from the start, and the fallout and radiation doses, for instance, have been mapped across a large area right up to the present day. The Fukushima accident led to the meltdown of the reactor core of three power plant units and consequently, a significant release of radioactive substances and the resulting action aiming to protect the population. The Fukushima accident was categorised as an INES level 7 accident on the International Nuclear and Radiological Event Scale. Based on the activity released in the emission, the modelled fictitious severe reactor accident of Loviisa power plant is an INES level 6 accident.

Table 9-75. Comparison between the Fukushima accident and Loviisa power plant's modelled severe reactor accident (Extension Site of Distribution Map of Radiation Dose 2021; Unscear 2013; Unscear 2015).

	The Fukushima nuclear power plant accident		Loviisa power plant – modelled severe reactor accident	
Emission into air [TBq]				
I-131	151,000		1,040	
Cs-137	14,500		100	
The fallout in an area within approximately 100 km of the power plant [kBq/m²]				
I-131, min	0,4a (1340)		1.07	
I-131, max	7,400[b]		14,681	
Cs-137, min	< 300		0.1	
Cs-137, max	3,000 - 14,700		1,090	
Radiation dose [mSv]				
	One-year exposure period[c]	Lifelong exposure period[c]	One-year exposure period[d]	Lifelong exposure period[d]
One-year-old	2.0 - 7.5	2.1 - 18.0	0.3 - 8.0	0.4 - 14.5
10-year-old	1.2 - 5.9	1.4 - 16.0	0.3 - 5.4	0.4 - 13.9
Adult	1.0 - 4.3	1.1 - 11.0	0.3 - 4.8	0.4 - 15.2

a: The fallout in the direction of the emission trail approximately three months after the accident, when the half-life of I-131 has had a significant effect on the value. The value in parentheses has been scaled to the date of the accident, 12 March 2011, when the radiation levels were first detected as rising (Unscear 2013). The scaling factor 3357.341 is based on the half-life of I-131 (8.0252 d) and a 94-day period.
b: In the city of Namie, in the days following the accident.
c: The radiation doses reported in terms of the Fukushima accident correspond with the range estimated for the dose in the areas of Fukushima Prefecture in which the population was not evacuated, given in the reference (Unscear 2013)a. Initially, the evacuated area extended to a distance of 20 km from the power plant. Later, the area was expanded, particularly due northwest.
d: For the sake of comparison, the range of the radiation doses at a distance of 20–100 km from the power plant is shown in terms of Loviisa power plant's fictitious severe reactor accident.

Table 9-75 shows reference data on the Fukushima accident and the modelled Loviisa power plant's severe reactor accident. Based on the table, the emission of the Fukushima accident was approximately 150 times greater, in terms of both iodine and caesium, than the severe reactor accident of Loviisa power plant in the case example would be. Despite this, the modelled I-131 fallout resulting from Loviisa power plant's severe reactor accident in the case example is, in places, up to twice that of the data published on the Fukushima accident, which is itself an indication of the calculation model's conservative nature. However, in terms of the Cs-137 radionuclide, the fallout observed in the Fukushima area is significantly greater. The radiation doses are in the same range of magnitude, and in places, even extremely close to each other in all age groups.

In the assessment concerning a severe reactor accident at Loviisa power plant, the estimates of the fallout and the radiation doses were conservative, and the modelling did not account for the impact of protective actions as a factor reducing radiation doses. In a genuine accident situation, the protective actions would be implemented on a scale instructed by the authorities. Extensive protective action aiming to protect the population was taken in the Fukushima accident. In addition, some of the emissions resulting from the Fukushima accident were carried east, towards the sea, meaning that the emission as a whole did not result in a deposition over land areas. This means that the fallout deposited on the ground and measured from the environment of Fukushima does not, as a whole, correspond with the amount of activity released into the atmosphere in the accident. The comparison between a severe reactor accident at Loviisa power plant and the Fukushima accident is therefore not straightforward in every respect.

9.22 OTHER INCIDENTS AND ACCIDENTS

9.22.1 Baseline data and assessment methods

Incidents and accidents and their environmental impacts were reviewed on the basis of the requirement for nuclear facilities set by the authorities and on the investigations carried out. Among other things, the existing safety and risk analyses drawn up for Loviisa power plant were reviewed to identify incidents and accidents.

The incidents and accidents discussed are related to the power plant's internal and external events in which there is no need to initiate safety measures involving the reactor and the storages for spent fuel, or in which they work as planned. In other words, the event does not directly cause an incident or accident pursuant to the Nuclear Energy Decree (161/1988), or the approval criteria in accordance with the event category are met. Incidents and accidents could have an impact on functions and safety functions during normal operation and thereby impair the power plant's safety level. The categorisation of a nuclear power plant's incidents and accidents, preparing for them as well as their management and emergency preparedness operations are described in Chapter 7.

Some external events could lead to the power plant's temporary shutdown, at which point commercial electricity production would be suspended and the power plant would be shifted to a shutdown state. Work would also be stopped if necessary. Examples of such events include an oil accident in the sea area, a high air or seawater temperature, or a high or low level of seawater. The power plant's shut down would aim to ensure that the power plant's state was as safe as possible, should the situation be exacerbated for some reason.

In disturbances of the electricity network, the electricity produced by the plant cannot be transmitted to the national grid, due to which the power plant would be left at houseload operation power or be shut down, in which case the diesel generators in the power plant area would be used for the production of the electricity needed in the area.

If the measures related to the management of incidents and accidents fail, or if the systems needed for their performance are out of order, the situation could deteriorate. The measures and systems are presented in more detail in Chapter 7.5.2. At its most extreme, the situation could, as a result of numerous failures and errors, escalate into a severe reactor accident, the consequences and impacts of which are discussed in Chapter 9.21. Nevertheless, the probability of such a situation is extremely low.

In extended operation, the estimate concerning the radiation doses was prepared for a milder case, in which the safety functions worked as planned. The case pertains to a major leak from the primary system to the secondary system during operation. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. In accordance with the categorisation of the Nuclear Energy Decree (161/1988), the accident falls under the event category B – design extension condition. Based on the activity released in the emission, the event is an INES level 4 event according to the international categorisation.

In addition, the review in terms of extended operation and decommissioning covers other potential incidents and accidents in which a small quantity of radioactive substances could spread into the environment. Such situations have been deemed possible in the plant's safety analyses when, for example, handling spent nuclear fuel or radioactive waste, or if there is a leak in a system containing radioactive substances. Situations causing minor radioactive emissions may occur at all stages of the plant's lifecycle until the plant has been decommissioned. For example, fires may cause a radioactive emission, but also an impairment of the safety level by damaging part of the safety system.

The estimates on the radiation doses were prepared with the Tuulet programme. Instead of 1,000 km, the impacts of the emissions' dispersal are reviewed up to a distance of 1–100 km from the power plant, because the emissions are significantly smaller than the emission of a severe reactor accident would be, due to which the impact area of the emissions would not extend as far. The assessment employed conservative postulations, and the doses were estimated by employing an overshoot probability of 0.5% over a one-year integration period.

The impact assessment also reviewed conventional incidents and accidents which have no material impacts on the plant's safety level in principle. Such incidents and accidents do not cause radioactive emissions, and they are related to the transports, loading and unloading, storage and use of oils and other chemicals, for example. The reasons for the accidents could include equipment failure and human error.

9.22.2 Extended operation

9.22.2.1 Radioactive emissions

The worst-case scenario in terms of radiation doses would be a severe reactor accident at Loviisa power plant, which is discussed in Chapter 9.21. This chapter deals with an accident which would involve a major leak from the primary system to the secondary system. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. These also include fires and explosions occurring in the power plant's premises, which could result in radioactive emissions into the environment.

It is possible in pressurised-water plants, such as Loviisa power plant, for the water cooling the reactor to enter the secondary system as a result of damage occurring in the steam generators. Should such a leak be big, some of the water and steam would be blown into the atmosphere until the pressures of the systems level off. The primary system's water contains radioactive substances. At its greatest, such an accident would cause residents in the power plant's environment (at a distance of one kilometre from the power plant) a radiation dose of 3.3. mSv at a one-year exposure period. Of this dose, 1.5 mSv would be the result of an emission into the air and 1.8 mSv of a discharge into the sea.

The radiation dose resulting from this accident would be around 55% of the average annual radiation dose of a person residing in Finland, 5.9 mSv. Table 9-76 shows the estimated radiation doses resulting from an emission into the air at different distances from Loviisa power plant.

The systems of Loviisa power plant contain radioactive substances during normal operation. Leaks from the systems lead to only minor radioactive emissions. Such an event would cause residents in the power plant's environment (at a distance of one kilometre from the power plant) a radiation dose significantly below 0.1 mSv at a one-year radiation dose exposure period. This radiation dose would be around 1 % of the average annual radiation dose of a person residing in Finland, 5.9 mSv. An emission from a system containing radioactive substances could occur as a result of some of the events presented in Chapter 9.22.2.2 or an earthquake.

Incidents and accidents related to the handling and storage of waste, including spent nuclear fuel, are discussed in Chapter 9.22.4.

Table 9-76. The greatest distance-specific radiation doses [mSv] of an adult at a distance of 1–100 km from Loviisa power plant, resulting from an emission into air that forms in the secondary system due to a major leak in the primary system.

Distance [km]	Radiation dose estimated for an adult [mSv]
1	1.5
5	0.78
15	0.16
20	0.11
50	0.02
100	0.005

9.22.2.2 Fires, explosions, oil and chemical accidents

The reasons for the accidents discussed in this chapter include equipment failures, human error and earthquakes. Table 9-77 shows in more detail how fires, explosions and oil and chemical accidents are prepared for, and the impacts they may have. In some cases, they could also result in radioactive substances spreading into the environment. The events are prepared for in the power plant's design and instructions. The impacts of individual events are limited to a small area, and the emissions of radioactive substances are minor. In events of a larger scale, which could occur if some of the preparedness measures fail, the emission could be greater. Even in this case, the emission and its impacts are nevertheless expected to remain significantly below category B of the postulated accident's design extension condition. The radiation doses specified above in Chapter 9.22.2.1 therefore also cover the radiation doses of residents in the power plant's environment in the events covered in this chapter.

In addition to fire protection, the tasks of the plant fire brigade include protection against chemical and oil accidents. The plant fire brigade maintains firefighting equipment and machinery and material preparedness of the kind that allow it to handle small incidents and start damage control in big events before the regional fire service arrives.

9.22.2.3 Preparing for climate change

Climate change has an impact on the intensity 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, and 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, while 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 (Bolle et al. 2015).

In accordance with what is presented in Chapter 7.5.6, one of the threats posed by climate change from the perspective of the operation of Loviisa power plant is a rise in sea levels. According to the Intergovernmental Panel on Climate Change (IPCC 2018), the global rise in sea levels would be roughly 0.3 m in 2050 compared to the average level in 1986–2005, even according to the worst climate change scenario. At the location of the power plant, the impact would be less than half of this due to the rising landmass. The temporarily high level of seawater is attributable to weather phenomena, which are monitored and forecast continuously at Loviisa power plant. In the event of a high level of seawater, the plant will be shut down at an early stage, and flood control will be installed for some systems.

In the future, the increase in the temperature of the air and seawater may result in power restrictions or the need for temporary shutdowns 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 sources of backup power.

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.

Table 9-77. Impacts of incidents and preparing for them.

Incident	Impact	Preparedness
Fires and explosions	- Property damage and bodily injury - Damage to structures - In a major fire, the spread of combustion gases into the environment - In a major fire, the run off of firewater into the environment - Minor spread of radioactive substances into the environment possible	- Structural fireproofing (the separation and location of systems to be protected as well as fire compartmentalising). - Instructing the plant's controllers in how to manage the situation. - Minimising fire loads and appropriate storage. - The appropriate treatment of flammable gases generated in the process systems. - The pressure relief devices of pressure vessels. - The application of ATEX equipment and condition regulations. - Fire detection system. - Fire extinguishing systems. - Hydrogen leak alarms. - The plant's own fire brigade with 24-hour standby readiness. - The personnel's training and qualification requirements. - The fire and rescue plan, and cooperation with other operators and the authorities. - Filtered ventilation system.
Transport accident or spill of light fuel oil	- Oil spill into the soil or waterway	- Transports are carried out according to regulations applicable to the transport of dangerous goods. - Transports within the power plant area are carried out along guided and paved transport routes. - The fuelling of the diesel generators' engines relies on the plant area's distribution pipes. - Unloading areas are paved, and the rainwaters of the unloading places of the diesel buildings, in which the largest oil stock is located, are treated in the oil separator before the cooling water is conducted into the discharge tunnel. - All storage tanks are equipped with level meters and overfill prevention devices, and unloading events are supervised by both the driver of the tank truck and a representative of the power plant. - The storage tanks for fuel oil are located in their own separate rooms, the volume of which is at least equal to the volume of the storage tank. The rooms are not equipped with drainage. The day and usage tanks, which are smaller than the storage tanks, are located in spaces with drainage either to a collector tray or the cooling water discharge tunnel, via oil separation. - The storage and day tanks are monitored daily for the detection of any leaks. The condition of the tanks is also covered by regular inspections. - All oil separators are equipped with oil sensors which, when oil is detected, close the separator's discharge valve and send an alert to the control room. The condition and functioning of the oil separators and sensors are covered by regular inspections, and records are kept on the inspections. - Absorbents for spills are available in the plant area. - The security personnel monitor the surrounding waterbody, the mouths of drainage pipes and drainage ditches for any signs of oil. - An action plan has been drawn up for any oil spills. - The plant fire brigade is responsible for the oil pollution response.
Oil spill in the yard area	- Oil spill into the soil or waterway	- Absorbents for spills from machinery are available in the plant area. - Any oil spills occurring in the generator transformer area are collected in the collector for drain oil under the transformers. A collector under each transformer can hold the transformer's entire volume of oil. - The emergency generator transformer is located in the catchment basin, which collects smallish oil spills.
Chemical ransport accident or chemical spills	- Bodily injuries (e.g. corrosive chemical splashes) - Chemical spill into the soil or waterway	- Transports are carried out according to regulations applicable to the transport of dangerous goods. - Transports within the power plant area are carried out along guided and paved transport routes. - Chemical spills occurring indoors are directed into a collector system. - The chemical's entry into the environment is prevented according to separate spill instructions. - The transfers of chemicals within the power plant comply with the applicable safety guidelines and regulations. A manual for the transport of hydrazine barrels has been drawn up, for example.

9.22.3 Decommissioning

During the preparation phase of decommissioning, the power plant will still be in operation or in a shutdown state. The actual dismantling operations can be started once the spent nuclear fuel has been moved from the reactor buildings to the storages for spent fuel. At the same time, a great many of the power plant's systems will become obsolete, given that there will longer be a risk of an accident involving the reactor or the reactor building's fuel pools. Any extra chemicals, fuel oil and oil will be removed, after which the risks related to them will also disappear.

The dismantling, packing and transport of the systems and structures will create risks which are prepared for in largely the same way as during the power plant's operation. This is discussed in Chapter 9.22.2. Incidents and accidents related to the transport, handling and storage of waste, including spent nuclear fuel, are discussed in Chapters 9.22.4 and 9.22.5. The nature and scale of the operations will nevertheless differ from what they are during the plant's operation. The prevention and extinguishing of fires, for example, plays an important role in managing these risks.

Special attention will be paid to the personnel's radiation protection when planning the dismantling measures and other decommissioning phases. The careful selection of individual ways of working and the tools used has a significant impact on the personnel's radiation doses. A radiological protection plan, which will be further specified before the dismantling work begins, has been drawn up for the dismantling of each piece of equipment or set of systems. Some of the radiological protection measures employed in the implementation of the decommissioning are listed below:

- the radiological protection measures already employed during electricity production and annual outages;
  - active monitoring of radiation and contamination levels;
  - minimising the duration of radiation work with good planning;
  - orthodox use of personal protective equipment (respirator, gloves, etc.);
  - the construction of temporary radiation shelters;
  - decontamination of equipment;
  - the dismantling and packing of strongly radiating waste under water;
- optimising the order of the work phases in the decommissioning;
- optimising work methods, such as the cutting of pipes;
- the use of remote-controlled chipping and sawing robots;
- sawing concrete structures under water;
- filtered local exhaust ventilation (local suction/dust removal) to be installed at individual work sites;
- barriers preventing the spread of dust to be installed at individual work sites or a larger area;
- a dimensioned radiation shield around the reactor pressure vessel's core zone;
- a radiation protection cylinder modified for the transport of the reactor's inner parts during decommissioning;
- control of the crane from a separate radiation-shielded control location;
- manual remote control of the crane from outside the reactor building with the help of a video link;
- additional radiation shielding to be installed in the vehicle transporting the most active waste.

Despite the measures listed above, situations in which a small quantity of radioactive substances end up in the environment may occur during decommissioning. The dose estimate of 0.1 mSv presented in Chapter 9.22.2.1 also applies to these situations.

In addition to what is presented above, the dismantling activities related to the decommissioning involve risks similar to those involved in any kind of dismantling activity. These risks are life and health risks, which are prepared for with good planning and execution. No possible incidents will have an impact on the environment. Part of the work, such as asbestos removal, complies with the required protective measures.

9.22.4 Spent nuclear fuel as well as low and intermediate-level waste generated at the power plant

9.22.4.1 Handling, storage and transport of spent nuclear fuel

Situations causing minor radioactive emissions may occur during the operation of the fuel storages in the same manner as during the power plant's operation, which is discussed in Chapter 9.22.2.1. Even so, there are only a few systems, which means that the likelihood of such situations is also smaller than it is in connection to the power plant units. The 0.1 mSv specified in Chapter 9.22.2.1 also covers the loss of the recovery of the residual heat of the spent fuel stored in the interim storages for spent nuclear fuel.

The transports of spent fuel between the reactor buildings and the storages for spent fuel are not subject to the IAEA's safety requirements (IAEA 2018) or the Act on the Transport of Dangerous Goods (719/1994), because the transports take place within the power plant area. For all intents and purposes, the requirements are nevertheless accounted for; for example, the dose rate of the radiation on the surface of a transfer cask meets the requirements set for transports outside the power plant area. Several of these transfers take place each year during operation – and will take place during the initial phase of decommissioning – in a transfer cask designed for the purpose. No disruptions or accidents occurring during transfer are expected to cause radioactive emissions, given that the cask will be transported at a low height, which means that even if the cask topples over, it will not break. Thus an exceptional incident would result in radiation doses for the personnel. The magnitude of the doses would be equal to what it is expected below in connection with an accident occurring in a transport to Olkiluoto, in which the cask does not break.

The transports of spent nuclear fuel for encapsulation and final disposal at Olkiluoto are transports of dangerous goods, subject to, among other things, the IAEA's safety requirements (IAEA 2018) and the Act on the Transport of Dangerous Goods (719/1994). According to these requirements, the transfer cask must be able to withstand a drop from a height of nine metres, fire and submersion in water. The dose rate of external radiation may not exceed the value of 2 mSv per hour on the transport device's (vehicle's) outer surface or the value of 0.1 mSv at a two-metre distance from it. A transport plan and preparedness plan will be drawn up for transports. In the event of an accident, the rescue personnel could be required to work in the vicinity of the transfer cask, in which case eight hours of working at a distance of two metres from the cask would result in a maximum radiation dose of 0.8 mSv. This radiation dose would be around 14% of the average annual radiation dose of a person residing in Finland, 5.9 mSv. At a distance of approximately 30–50 metres from the transfer cask, its radiation dose rate would be equal to natural background radiation. Should the transfer cask's integrity be lost in more serious accidents involving traffic, the consequence could be a radioactive emission formed by noble gases or other volatile substances which would expose an individual to a negligibly small radiation dose (Posiva 2012, Appendix 18).

Table 9-78. The impacts of incidents and accidents related to the handling of operational and decommissioning waste, and preparing for them.

Incident	Impact	Preparedness
Waste handling and transport accidents	- Bodily injuries - Minor spread of radioactive substances into the environment possible	- Lifting and transport plans - Transport equipment and waste packaging methods suitable for the waste type and conditions - Radiation control - Maintenance of passageways and transport routes

9.22.4.2 Handling of operational and decommissioning waste

During the power plant's operation, radioactive waste is handled, transported and stored in relatively small amounts at a time, due to which any incidents or accidents are expected to generate only minor radioactive emissions. During decommissioning, the amounts are larger, but the occurrence of incidents and accidents can be prevented in the detailed planning of the decommissioning by the selection of the methods for handling radioactive waste and packaging as well as logistics arrangements. This also applies to reducing the consequences of any incidents or accidents.

The estimates of the radiation doses (less than 0.1 mSv from the leakage of systems containing radioactive substances and 3.3 mSv from an improbably large fire) also include waste handling accidents. The potential impacts of incidents and accidents related to the handling of operational and decommissioning waste, and the preparedness measures involved, are explained in Table 9-78. The general principles of preparing for fire also apply to the handling of waste. These are dealt with in Table 9-77.

9.22.4.3 L/ILW repository

Emissions of radioactive substances from the L/ILW repository into the environment occur solely as a result of incidents or accidents. The worst-case scenario involves an intense transport vehicle fire, which could result in a maximum radiation dose of 0.2 mSv at a one-year exposure period to a resident in the power plant's environment. This radiation dose would be around 3% of the average annual radiation dose of a person residing in Finland, 5.9 mSv.

Table 9-79. Incidents and accidents identified as possible during the final disposal facility's operational phase.

Incident	Impact	Preparedness
The flooding of the final disposal halls due to a rise in sea level or a failure of the seepage water system.	- The waste containers are exposed to water and radioactive substances could be dissolved in the water. - A minor spread of radioactive substances into the environment in connection with the water being pumped out is possible.	- A rise in sea level to the L/ILW repository's access tunnel and the mouths of the shafts is extremely unlikely, given that the mouth of the access tunnel is at a level of three metres (N2000). - The L/ILW repository has a seepage water tank which collects the seepage water from the bedrock. The seepage water tank can hold roughly a week's worth of seepage water, during which time the system can be repaired, or an alternative pumping method can be arranged.
Fires (e.g. the fire of a transport vehicle)	- Minor spread of radioactive substances into the environment possible	- Fire detection system. - Fire extinguishing systems. - The plant's own fire brigade with 24-hour standby readiness. - The personnel's training and qualification requirements. - The fire and rescue plan, and cooperation with other operators and the authorities. - Filtered ventilation system.
The mechanical damage of waste containers or release barriers.	- No impact on the environment. - Bodily injuries.	- The condition of the bedrock and rock reinforcements is regularly monitored and maintained to avoid rocks falling on top of the containers. - Transports and transfers are planned, and they are implemented according to the instructions provided so that the likelihood of damage is small. - Monitoring the condition of and supporting waste containers when necessary. - The probability of seismic phenomena that could damage the structures or waste containers is extremely low.

Incidents and accidents identified as possible during the L/ILW repository's operational phase are shown in Table 9-79. In most incidents and accidents, the impacts would be confined to the L/ILW repository. The L/ILW repository's long-term safety and situation after closing are discussed in Chapters 7.9.3 and 9.10.5.2.

9.22.5 *Radioactive waste generated elsewhere in Finland and its impact*

The handling and final disposal of radioactive waste generated elsewhere in the Loviisa power plant area is subject to incident and accident measures corresponding to those described in Chapter 9.22.4. Radioactive waste generated elsewhere would not alter the situation to any significant degree.

The only incident or accident identified as specific to radioactive waste generated elsewhere in Finland is a disruption related to the transport of such waste. These transports would be subject to the Act on the Transport of Dangerous Goods (719/1994) and the IAEA's safety requirements (IAEA 2018). Transports in general are described in 9.10.6. The transport safety of a radioactive substance is ensured primarily with the package, which must be protective and sufficiently strong to allow transport in the manner of conventional goods. The package must keep the adverse effects caused by the radioactive substance minor, both during transport and in a possible accident. The packages used in the transport of radioactive substances are subject to various requirements according to the radioactivity and other properties of the transported substance, for example, considering the impacts that the damaging of the packages could have in the event of a traffic accident, for example. Among other things, the regulations specify the activity limits which, if exceeded, require the package to withstand a fall from a height of nine metres onto a hard surface and a 30-minute incineration test at a temperature of +800 °C. The packages must be marked appropriately, and the consignment notes must describe the content of the packages as precisely as necessary in light of the waste's radioactivity and other properties. The party performing the transport must ensure that the driver is sufficiently qualified, and that the standard safety instructions for accidents, for example, are readily available in the cabin.

The aforementioned measures ensure that the driver and rescue authorities can account for the radioactive substance being transported during a disruption or in an accident. The radiation shielding of the radioactive substances being transported must be dimensioned so that it does not restrict any possible rescue measures (STUK 2012).

9.23 COMBINED IMPACTS WITH OTHER PROJECTS

No new projects are being planned or are currently underway in the power plant area or its vicinity that could contribute to a combined impact in the event that Loviisa power plant's operation is extended or the plant is decommissioned.

However, in the future, the project may have an interface with the potential recovery of thermal energy or the further use of transmission lines, but there is still insufficient information about these possibilities, due to which their review is not included in this EIA Procedure. The energy production alternatives at the power plant, such as the utilisation of thermal energy generated in the processes, may become topical in the future. The decision on the further use of the transmission lines in the event of the power plant's decommissioning will be made by Fingrid Oyj, the owner of the transmission lines.

9.24 TRANSBOUNDARY IMPACTS

9.24.1 Impacts of a severe reactor accident

The transboundary impacts were assessed by modelling the dispersion of a radioactive emission resulting from a severe reactor accident, the consequential fallout and the population's radiation doses up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The modelling reviewed an extremely improbable severe reactor accident, in which a 100 TBq emission of the radionuclide caesium-137 (Cs-137), corresponding to the limit value provided in section 22 b of the Nuclear Energy Decree (161/1988), and other radionuclides of the reactor inventory to a proportionate degree, are released into the environment. Based on the activity released, the accident would be an INES level 6 accident.

The modelling methods and the impacts of the modelled fictitious reactor accident are described in more detail in Chapter 9.21. The analyses made for Loviisa power plant served as the starting point for the modelling, and the postulations of the modelling ensure the conservative nature of the estimated fallout and radiation doses. The actions aiming to protect the population, for example, and the restrictions on the use of foodstuffs, which would allow the radiation doses to be reduced in both the short and long run, were not accounted for in the modelling.

Figure 9-84 illustrates the distances to other countries up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The distances shown are the counting points employed in the modelling on which the estimate of the fallout and radiation doses caused by a severe reactor accident, including beyond the borders of Finland, is based.

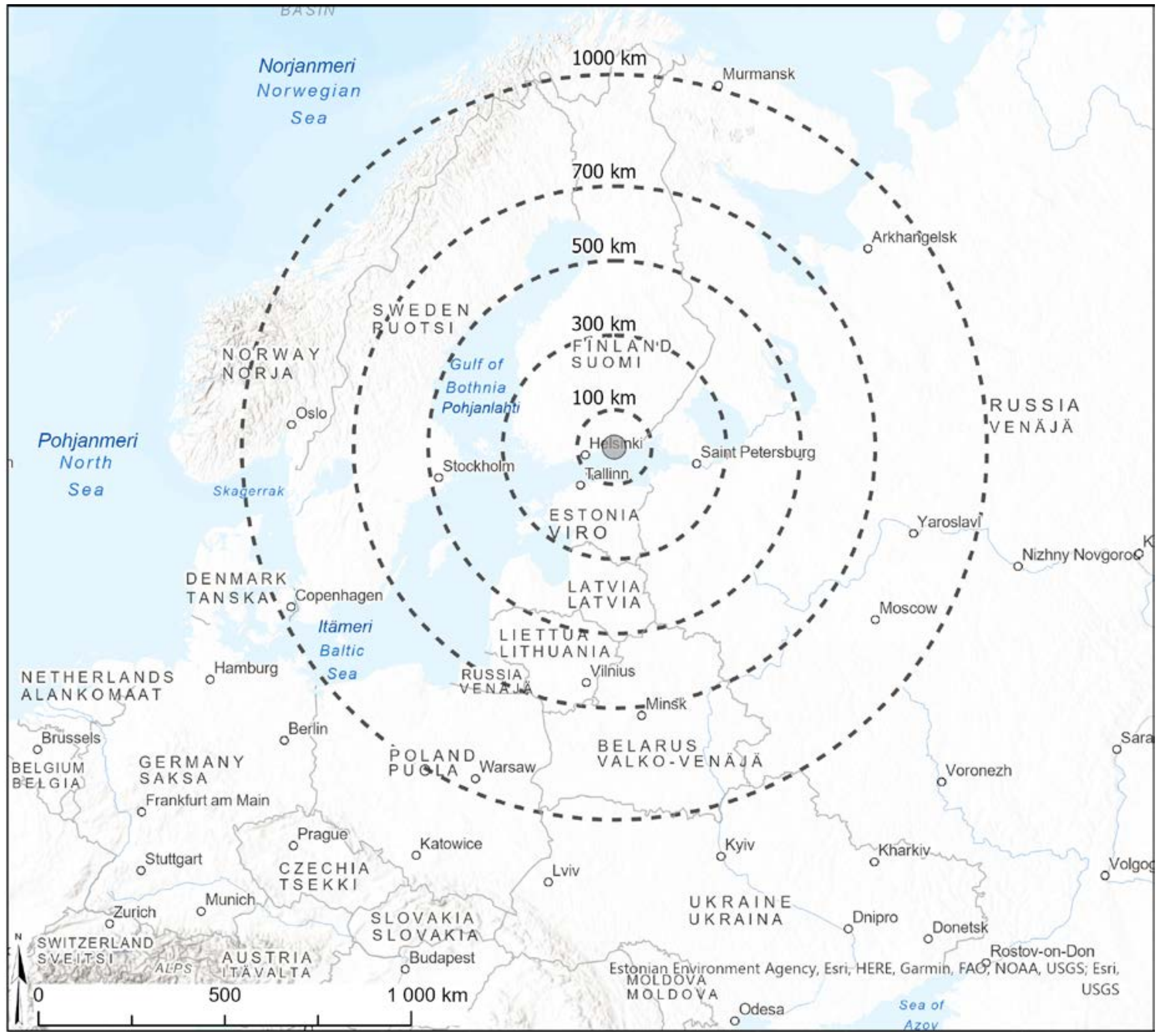


Figure 9-84. Indicative distances from Loviisa nuclear power plant, up to 1,000 km.

Table 9-80. The estimated magnitudes of the country-specific radiation doses of children and adults resulting from a severe reactor accident. The range of the radiation doses corresponds to the approximate distance to Loviisa power plant from areas within a state's borders.

Country	The approximate distance of the state's areas from Loviisa power plant (maximum, minimum) [km]	Range of one-year-old's lifelong dose [mSv]	Range of 10-year-old's lifelong dose [mSv]	Range of adult's lifelong dose [mSv]
Estonia	300, 100	≤0.16–0.41	≤0.16–0.40	≤0.17–0.43
Russia	1,000, 100	≤0,.03–0.41	≤0.03–0.40	≤0.04–0,.43
Sweden	1,000, 300	0.03–0.16	0.03–0.16	0.04–0.17
Latvia	500, 300	0.09–0.16	0.09–0.16	0.10–0.17
Lithuania	700, 500	≤0.06–0.09	≤0.06–0.09	≤0.06–0.10
Belarus	1,000, 500	≤0.03–0.09	≤0.03–0.09	≤0.04–0.10
Norway, Poland, Ukraine, Denmark	1,000, 700	≤0.03–0.06	≤0.03–0.06	≤0.04–0.06
Germany	1,000	≤0.03	≤0.03	≤0.04

Based on the results of the modelling, a severe reactor accident would not have direct health effects on the residents of the power plant's nearby areas or beyond the borders of Finland. At a distance of five kilometres from the power plant, the radiation dose during two days attributable to the modelled severe reactor accident would be 3.8–4.5 mSv, depending on the group reviewed. Based on the dose criteria set in Finnish legislation and official requirements (Table 9-72), the dose criteria are exceeded in the precautionary action zone extending to a distance of less than five kilometres from the power plant. The need to protect the population is therefore not transboundary.

Table 9-80 shows the country-specific radiation doses resulting from the radioactive emission of a severe reactor accident up to a distance of 1,000 kilometres from Loviisa nuclear power plant. The radiation doses attributable to natural background radiation in the European area are 1.5–6.2 mSv a year (European Commission 2019). Compared to this, the radiation doses attributable to the emission of the severe reactor accident beyond Finland's borders remain small enough to be negligible from a general statistical perspective. Table 9-80 shows the rough level of radiation doses' magnitude in various countries, based on the counting points employed in the modelling and shown in Figure 9-83. The estimated lifelong radiation doses for an adult are a maximum of 0.43 mSv and a minimum of ≤0.04 mSv. Children's estimated lifelong radiation doses are basically of an equivalent size.

The greatest transboundary radiation doses focus on the vicinity of Estonia and Russia, whose borders are, at their shortest, a distance of roughly 100 km from Loviisa nuclear power plant. When the distance grows, the radiation doses decrease. The Swedish coast is around 400 kilometres from Loviisa nuclear power plant. Based on a conservative estimate, the lifelong dose in the area of the state of Sweden is a maximum of 0.16 mSv for children and 0.17 mSv for adults (the doses are shown at the counting point of 300 km). In northern and southern Sweden, at a distance of roughly 1,000 km, the lifelong radiation doses of children and adults are in the region of 0.03–0.04 mSv.

At distances of more than 1,000 km, the radiation doses have not been reviewed in more detail computationally, but based on the results of the modelling and an expert assessment, they are expected to be smaller or no greater than 0.03–0.04 mSv for children and adults in places like eastern/northeast Germany and southern/southwest Poland.

9.24.2 Other impacts

In addition to the impacts of a severe reactor accident, neither extended operation nor decommissioning is expected to have other transboundary impacts.

10. Significance of environmental impacts and comparison of options

10.1 SUMMARY OF THE SIGNIFICANCE OF ENVIRONMENTAL IMPACTS

The operational phases following the current licence periods, which include either extended operation or decommissioning, are compared in Table 10-1. The handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland is also reviewed separately. The review accounted for the significance of the impacts impact-specifically, based on the affected aspects' sensitivity and the magnitude of the change (see Chapter 9.1.4). The table focuses on comparing the operations that would take place in the Loviisa power plant area after the current licence periods and the resulting environmental impacts. The impacts of the operational phase of extended operation were assessed until 2050 at the furthest. In the operational phase of decommissioning, the assessment accounted for the operations falling under its scope (including the expansion of the L/ILW repository, the first and second dismantling phase and the operation of the plant parts to be made independent), all the way up to the closure of the L/ILW repository. The assessment focused on assessing the impacts of normal operation. Incidents and accidents are described in Chapters 9.21, 9.22 and 9.24.

Table 10-1. Summary of the impacts' significance in terms of the different operational phases. The colours indicate the level and nature of the significance (white: no impact; green: positive; red: negative).

Negative impact — Positive impact

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

	Extended operation	Decommissioning	Radioactive waste generated elsewhere in Finland
Land use, land use planning and the built environment	Minor negative	Minor positive	No impact
Landscape and cultural environment	Minor negative	Minor positive	No impact
Traffic	Minor negative	Moderate negative	No impact
Noise	No impact	Minor negative	No impact
Vibration	No impact	Minor negative	No impact
Air quality	No impact	Minor negative	No impact
Emissions of radioactive substances and radiation exposure	Minor negative	Minor negative	Minor negative
Use of natural resources	No impact	Minor positive	No impact
Waste and waste handling (Loviisa)	Minor negative	Minor negative	Minor negative
Waste and waste handling (Finland as a whole)	No impact	No impact	Moderate positive
Energy markets and security of supply	High positive	Major negative	No impact
Greenhouse gas emissions and climate change	Moderate positive	Moderate negative	No impact

	Extended operation	Decommissioning	Radioactive waste generated elsewhere in Finland
Regional economy (the Loviisa sub-regional area)	Very high positive	High positive	No impact
Regional economy (Finland as a whole)	Minor positive	Minor positive	No impact
Soil and bedrock	No impact	Minor negative	No impact
Groundwater	No impact	Minor negative	No impact
Surface waters (Hästholmsfjärden, in the Klobbfjärden body of water)	Moderate negative	Moderate positive	No impact
Surface waters (rest of the nearby sea area)	Minor negative	Minor positive	No impact
Surface waters (Lappomträsket lake)	No impact	Minor negative	No impact
Fish fauna	Moderate negative	Moderate positive	No impact
Fishing industry	Minor negative	Minor positive	No impact
Flora, fauna and conservation areas	Minor positive	Minor negative	No impact
People's living conditions and comfort	Minor negative	Moderate negative	Minor negative
Health	No impact	No impact	No impact

10.10.1 Extended operation

10.1.1.1 Positive impacts

In the operational phase of extended operation, the impacts with the greatest positive significance involve the regional economy (Table 10-1). Loviisa power plant's impacts on the regional economy are extremely high at the level of the Loviisa sub-regional area and also visible at 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 terms of their significance in the event that operation is extended. The use of nuclear energy in electricity production supports Finland's objective of being carbon neutral by 2035. The operation of the nuclear power plant 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 will maintain, in the event of extended operation, Hästholmsfjärden's significance as regionally important wintering grounds for waterfowl.

10.1.1.2 Negative impacts

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 ruled out.

The impacts on the icthyofauna are expected to be moderate and negative. The continuation of the power plant's thermal effect maintains a situation in the sea area that favours fish species adapted to warm water, such as pike-perch and cyprinids. The warmer waters may also allow the non-native species round goby to become more abundant in the area, which is nevertheless not expected to have an impact on the area's stock of pike-perch. The impact on fishing is expected to be minor and negative.

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 at 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.

10.1.2 Decommissioning

10.1.2.1 Positive impacts

Once the power plant is no longer in operation, its very high positive impacts on the regional economy will end (Table 10-1). 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 significance. The impacts on the regional economy will come to an end once the decommissioning ends.

The impacts on surface waters will be moderate and positive significance in the Klobbfjärden body of water, 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.

10.1.2.2 Negative impacts

The power plant's decommissioning will have a major and negative impact on the energy markets and security of supply. 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 require the construction of new electricity production capacity in Finland and the increased electricity imports. The possibilities for exporting electricity from Finland would also reduce.

The impact on greenhouse gas emissions and climate change is expected to be moderate and negative. The decommissioning of Loviisa power plant would 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 temporarily increase 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 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 waste handling 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.

10.1.3 Radioactive waste generated elsewhere in Finland

The reception, handling, interim storage and final disposal of any radioactive waste generated elsewhere in Finland within the Loviisa power plant area would not have an impact for the most part (Table 10-1).

Yet 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, on waste and waste handling, given that radioactive waste generated in different sources is provided with a safe and cost-effective final disposal solution at Loviisa power plant. 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 which will amount, due to the small volume of the waste, to a mere fraction of the already small radiation impact of the operational waste. The waste handling and final disposal will be executed so that their impact on the radiation doses of the personnel and members of the public in the environment will be minor and the long-term safety requirements will be met. Minor negative impacts may still result from the concern raised by the radioactive waste generated elsewhere in Finland.

10.2 COMPARISON OF OPTIONS

10.2.1 Extended operation VE1 and decommissioning VE0/VE0+

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:

- In extended operation (VE1), the power plant's operation would be extended by roughly 20 years, starting from when the current operating licences expire, in 2027 and 2030. The phases related to decommissioning would be carried out around 2045–2090.
- In the decommissioning option (VE0/VE0+), the power plant's operation will end as the current operating licences expire in 2027 and 2030, in which case preparation for the power plant's decommissioning will be begun in the next few years. The phases related to decommissioning would be carried out around 2025–2065.
- Radioactive waste generated elsewhere in Finland can be received at Loviisa power plant in both the option of extended operation (VE1), until 2090, and in the option of decommissioning (VE0+), until 2065.

The significance of the environmental impacts differs in the different operational phases (Table 10-1). In all options, the final situation will ultimately be the same, in that the current operations 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 most negative impacts of extended operation will be attributable to the cooling water's thermal load on the sea area. Extended operation would also involve significant positive impacts on the regional economy, energy markets and greenhouse gas emissions.

Once the power plant's operation comes to an end, these impacts will no longer be generated. Positive impacts on the regional economy will still be generated during decommissioning, but they will be smaller than during operation and concern different industries until the impacts end entirely once the decommissioning has concluded. The decommissioning will have its greatest positive impacts on the status of the sea area, given that the thermal load on the sea area attributable to the power plant's cooling water will end. Decommissioning will nevertheless result in negative impacts, particularly in relation to dismantling activities. If the power plant's decommissioning is carried out when the current licence periods end (VE0/VE0+), the positive and negative impacts related to extended operation (VE1) will not materialise.

The reception of radioactive waste generated elsewhere in Finland would not have significant environmental impacts. The power plant has existing competence, technology and spaces for its handling, interim storage and final disposal. The reception of this waste at Loviisa nuclear power plant would be in the interest of the entire society, as radioactive waste generated by various sources would be provided with a safe and cost-effective final disposal solution.

The operations of Fortum Power and Heat Oy's nuclear power plant in Loviisa is highly established and their environmental impacts are well known. The techniques, processes and the means by which to mitigate the impacts are well known. In the option of extended operation, the plant's ageing management is considered; the related measures are presented in Chapter 4.1. 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. The risks of incidents and accidents have been and are prepared for, accounting for any changes in the operating environment or legislation. In option VE1, the risk of accidents would continue for some 20 years longer than in options VE0 and VE0+.

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 adverse effects presented in the assessment report will allow the potential environmental impacts to be mitigated, provided that they are accounted for in the project's further planning and implementation insofar as possible.

10.2.2 Differences in decommissioning in Options VE1 and VE0/VE0+

In option VE1, decommissioning would be carried out, barring some exceptions (see Chapter 5.9), largely in a manner corresponding to that in option VE0, described in Chapter 5. The environmental impacts of decommissioning, presented in Chapter 9, are largely the same in both options. The most significant difference concerns the time of the decommissioning and the environmental impacts attributable to it. In option VE0, the environmental impacts related to the decommissioning phases would take place around 2025–2065, and in option VE1, around 2045–2090, provided that the power plant's commercial operation is extended by a maximum of 20 years. The most large-scale work related to the decommissioning of the power plant units will take place, for the most part, during the first 10 years following the end of the plant's operation. The differences in the environmental impacts of the decommissioning in options VE1 and VE0 are explained in Table 10-2.

Table 10-2. Differences of decommissioning carried out after extended operation (VE1) compared to the option in which the decommissioning would be carried out after the current licence periods (VE0).

	VE0 decommissioning	VE1 decommissioning	Summary of the differences between the environmental impacts
First dismantling phase of decommissioning	The operation of the power plant units will end in 2027 and 2030. They will be dismantled at different times.	The operation of the power plant units can be ended simultaneously around 2050 or with a shorter delay than in option VE0.	In option VE1, the decommissioning could be carried out simultaneously for both power plant units or with a shorter delay than in option VE0. In this case, the first dismantling phase can be carried out slightly more quickly, which could increase traffic, noise and vibration impacts compared to the overlapping decommissioning in option VE0. Option VE1 would also allow experience of the decommissioning of nuclear power plants from other countries to be accumulated. The techniques used in the decommissioning could also be developed, which could reduce the impacts on the environment.
Low- and intermediate-level operational waste	Low-level waste during operation approximately 2,700 m³ and intermediate-level waste during operation approximately 4,900 m³.	Low-level waste during operation approximately 3,300 m³ and intermediate-level waste during operation approximately 7,300 m³.	In option VE1, the total volume of the low and intermediate-level operational waste to be handled would increase as a result of the 20 additional years of operation. The current expansion plan concerning the L/ILW repository is also expected to be sufficient in option VE1, because the accumulation rate of the operational waste has been successfully reduced, and because the extension of the operating life would not significantly increase the volume of decommissioning waste.
Radioactivity of decommissioning waste	The radioactivity of the decommissioning waste is approximately 22,000 TBq.	The radioactivity of the decommissioning waste is approximately 33,000 TBq.	In option VE1, the amount of radioactivity contained by some types of decommissioning waste will increase as a result of the 20 additional years of operation. Due to the targeted dose constraints set for decommissioning and the effective radiation shielding in the handling of the waste types in question, this would not have a significant impact on the personnel's radiation doses. In both options, the personnel's collective radiation dose accumulated during the decommissioning is estimated to be roughly 10 manSv, while the annual dose of a member of the public will remain below the limit value of 0.01 mSv set for decommissioning. Despite the increase in radioactivity, the long-term safety impacts would remain below the limit values set for them; the radiation dose of the most exposed individuals would remain below 0.1 mSv a year, for example.

	VE0 decommissioning	VE1 decommissioning	Summary of the differences between the environmental impacts
Interim storage of spent nuclear fuel	Total amount approximately 7,700 bundles. Interim storage in the existing storage for spent nuclear fuel within the power plant area.	Total maximum amount approximately 12,800 bundles. Increasing the interim storage capacity within the power plant area.	In option VE1, the total amount of spent nuclear fuel would grow as a result of the 20 additional years of operation, which would increase the need for the power plant area's capacity for the interim storage of spent nuclear fuel. 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 possible increase of storage capacity by expanding one of the existing interim storages (KPA2) would nevertheless not increase the volume of decommissioning waste in option VE1. The ways in which the storage capacity would be increased would not have differing impacts on radiation doses. In normal operation, the interim storage and treatment of spent nuclear fuel within the power plant area would not cause abnormal radiation or emission impacts on the environment in either option. Nor would the personnel's legal limit values be exceeded.
Transports of spent nuclear fuel	Roughly 6–8 road transports of spent nuclear fuel a year (one cask at a time) or two transports by sea a year (3–4 casks at a time).	Roughly 6–8 road transports of spent nuclear fuel a year (one cask at a time) or two transports by sea a year (3–4 casks at a time).	In option VE1, the increase in the total volume of operational waste would increase the total number of the transports of nuclear fuel, but at an annual level, the number of transports would be the same in both options. In option VE1, the transports could begin later and be spread over a longer timespan. In both options, the radiation to which humans and the environment would be exposed as a result of the transport of spent nuclear fuel would be very low.
Final disposal of spent nuclear fuel	Eurajoki, Olkiluoto (Posiva Oy). Total amount approximately 7,700 bundles.	Eurajoki, Olkiluoto (Posiva Oy). Total maximum amount approximately 12,800 bundles.	Posiva Oy 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 that would be accumulated in option VE1 would be included in this amount and would have no effect on the safety of the final disposal.

10.2.3 Radioactive waste generated elsewhere in Finland in the event of extended operation (VE1) and decommissioning (VE0+)

Options VE1 and VE0+ include the reception of radioactive waste generated elsewhere in Finland at Loviisa nuclear power plant. The difference between the options is the overall schedule of the waste to be received. Radioactive waste originating from elsewhere in Finland can be received 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. In extended operation (VE1), this would be possible until around 2090, and in decommissioning (VE0+), until around 2065.

In both options, the maximum volume of the waste to be received would be 2,000 m^3. However, the duration for which the waste is in interim storage could be longer in the option of extended operation (VE1). Even in this case, due to the small volume of the waste, the radiation impact would amount to only a fraction of the already quite small radiation impact of operational waste.

10.3 CONCLUSIONS ON THE MOST SIGNIFICANT ENVIRONMENTAL IMPACTS

All the project's options (VE1, VE0/VE0+) are feasible from the environmental perspective.

10.3.1 Option VE1

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 at the local and regional levels. 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. The warming impact of the cooling water would be extended by roughly 20 years following the current operating licence period (2027/2030).

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. Significantly more than half 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 at the level of the entire country. This would benefit the interests of society as a whole by providing a safe and cost-effective final disposal solution for radioactive waste originating from various sources.

10.3.2 Option VE0/VE0+

In the decommissioning option (VE0/VE0+), Loviisa nuclear power plant's commercial operation would 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. The major negative impact on the energy markets and security of supply would furthermore 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 an amount of roughly EUR 300 million and value added in excess of EUR 170 million, and a labour requirement 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 the labour requirement. 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. While this will not have a significant environmental impact, the reception of radioactive waste generated elsewhere in Finland will have a moderate positive impact at the level of the entire country. This would benefit the interests of society as a whole by providing a safe and cost-effective final disposal solution for radioactive waste originating from various sources.

11. 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. Chapter 11 focuses on regular monitoring and observations.

11.1 OBSERVING RADIOACTIVE EMISSIONS AND RADIATION MONITORING

During extended operation, the operation of the power plant would be similar to its current level, which is why the observation and monitoring is expected to continue in much the same manner as it currently does. The following chapters provide a summary of the monitoring of radioactive emissions and radiation control at Loviisa nuclear power plant in the case of extended operation.

Once the power plant's operations have ended, the environmental radiation monitoring will be carried out in a manner approved by STUK. During and also after the decommissioning, until the end of the interim storage of spent fuel and the closing of the L/ILW repository, the radiation monitoring is likely to continue according to the current materially identical procedures. The impact that a reduction in the emissions of radioactive substances and the change in emission routes and the nuclide breakdown of emissions will have on the monitoring needs will be assessed at a later date. The assessment is likely to lead to some changes to the programme for environmental radiation monitoring.

11.1.1 Emission measurements

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 remain below the limits specified in section 22 b and section 22 d of the Nuclear Energy Decree. The results are reported to STUK at regular intervals. A nuclear power plant's emissions are monitored specific to power plant units and emission routes and with continuous measurement instruments and by sampling. Emissions into air take place in a controlled manner through the ventilation stack and possibly, to a minor extent, through the turbine building's ventilation. Activity into the sea is discharged in a controlled manner from the inspection tank. If the water is not clean enough, it is returned to treatment. The auxiliary facilities, such as the final disposal facility for operational waste, the storage and the solidification plant for liquid waste are covered by the power plant's emission monitoring.

11.1.2 Environmental radiation monitoring

Fortum monitors the environment of Loviisa power plant in accordance with the environmental radiation control programme. The status of radioactive substances in the surroundings of Loviisa power plant has been monitored for a long time. The baseline studies began as early as 1966, before the construction of the power plant began. The environmental radiation control is based on sampling, the identification of radionuclides in the samples and the determination of their levels. 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.

The environmental radiation control programme of Loviisa focuses on measurements of external radiation, the routes through which people are exposed to radioactivity and the indicator organisms that enrich radioactive substances, such as fern. The current monitoring in the environment of Loviisa power plant in line with the radiation control programme is shown in Figure 11-1.

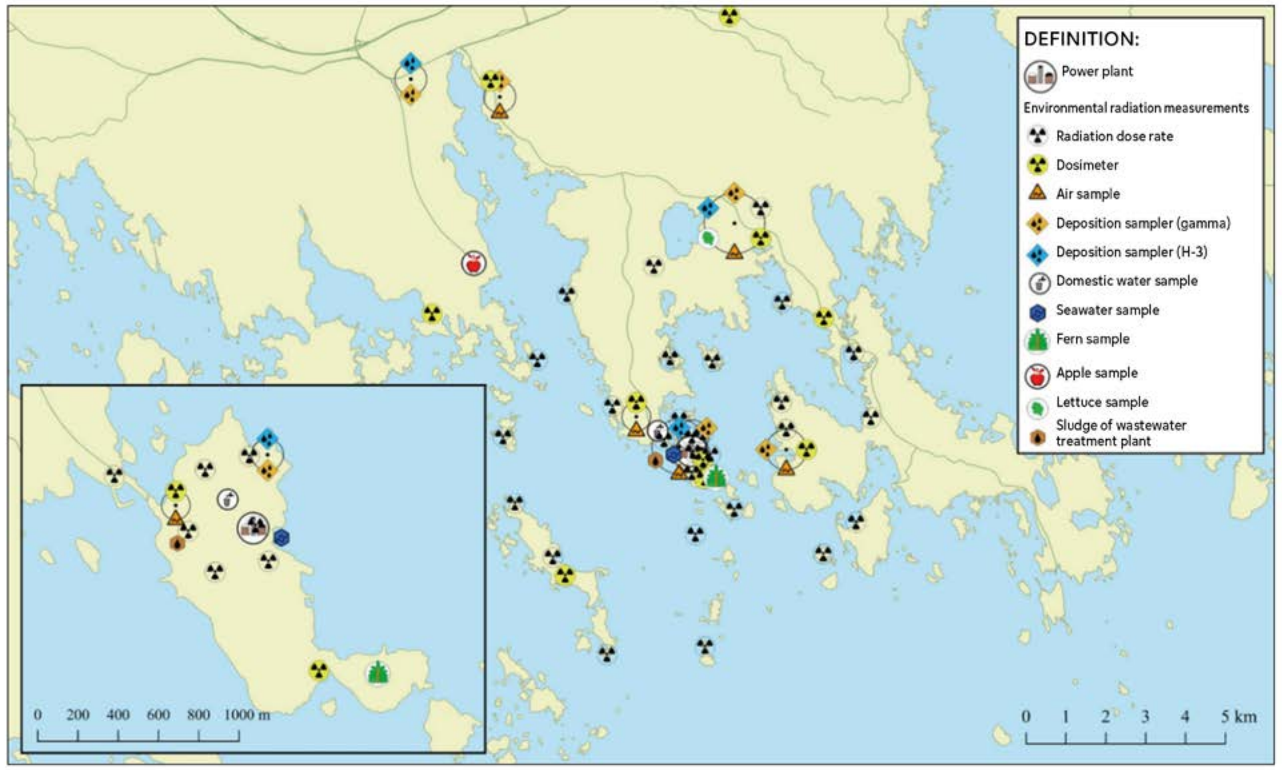


Figure 11-1. The measurement and sampling sites of Loviisa power plant's environmental radiation control programme. If there is more than one monitoring target in a particular location, the location is marked with a black dot, and the monitoring targets are represented with an arc drawn around the dot.

STUK also carries out its own independent monitoring in the environment of Loviisa power plant. STUK regularly takes samples from the air in connection with plants' annual outages and collects samples from the soil and sea environment within the framework of STUK's environmental radiation monitoring programme. The sampling focuses primarily on sample types related to food chains, such as milk, agricultural products, domestic waters, fish, game and other foodstuffs (STUK 2020c; STUK 2021c and STUK 2021d).

External radiation is measured continuously. These measurements yield real-time information on changes in the radiation level in the environment. To measure external radiation, there is a total 21 radiation dose ratemeters at distances of two and five kilometres from, and seven dose ratemeters within, the power plant area (Figure 11-1). The ratemeters are part of the national radiation metering network, and thereby also serve regional monitoring. In addition to the power plant, the results of the measurements are available to the Ministry of the Interior and the Radiation and Nuclear Safety Authority in real time. Ten dosemeter stations have also been placed at 1–10-kilometre distances from the power plant, in the most important directions.

The methods employed in the environmental radiation monitoring detect radioactive substances inherent in nature and even small emissions originating from Finland and beyond, which indicates the system's good detection sensitivity. Extended operation would not result in any material changes to the power plant's operations in relation to radiation monitoring.

11.1.3 Meteorological measurements

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 meteorological measurements. The meteorological data is provided by Loviisa power plant's weather observation system, which includes two measurement locations: the main observation point, located in the power plant's vicinity, and the additional observation point, which is located at a distance of around 12 km from the power plant. Both measurement locations are equipped with a weather mast and a measuring station on the ground. The observations of the weather observation system are available in real time at the power plant, the Finnish Meteorological Institute and STUK. The measured variables include the wind speed and direction, atmospheric pressure, relative humidity, the time and volume of precipitation as well as temperature.

11.1.4 Radiation dose estimates

During the power plant's operation, the population's radiation exposure in the environment is estimated annually on the basis of the meteorological measurements and emissions. The results are reported to STUK. In a possible accident, the radiation doses of people in the environment are estimated in real time on the basis of the meteorological measurements and emission data. The estimates serve the rescue and emergency services, and they are compared to the results provided by the dose ratemeters. The radiation dose calculation software used for the estimates are described in Loviisa power plant's preparedness instructions, approved by STUK.

11.2 MONITORING OF COOLING WATER AND WASTEWATERS

The volume and quality of the cooling water and wastewaters conducted from the power plant to the sea is monitored in a manner approved by the Uusimaa ELY Centre. The volume of cooling water is monitored on the basis of the seawater pumps' operating times and output. The temperature of the cooling water taken from and conducted to the sea is measured continuously. The measurements are used to calculate the rise in the cooling water temperature in the condensers, the flow of the cooling water and the amount of heat conducted into the waterway. The monitoring of the wastewater volume is based on the measurements of the wastewater treatment plant. The wastewater monitoring follows the amounts of nutrients and solids as well as oxygen-consuming substances conducted into the waterway.

During decommissioning, the monitoring of the cooling water and wastewaters will be carried out in a manner approves by the Uusimaa ELY Centre.

11.3 IMPACT MONITORING

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 biological monitoring covers the phytoplankton, benthic fauna and aquatic vegetation monitoring carried out every three years.

The temperature of the seawater at different sampling depths is measured in connection with the monitoring of the seawater's quality and biological monitoring. In addition to the sea area's temperature monitoring, the forming of the ice cover is monitored in the sea area surrounding Hästholmen approximately once a month, starting from the beginning of December, until the ice cover in the surrounding sea area has melted completely.

Loviisa power plant's monitoring related to fishery economics is composed of the catch accounting and fishing inquiries of commercial fishermen and the fishing inquiries of leisure-time fishermen. In addition, test fishing is conducted in the power plant's nearby sea area during scheduled years.

During decommissioning, waterway monitoring will be carried out in a manner approved by the Uusimaa ELY Centre.

11.4 MONITORING OF FLUE GAS EMISSIONS

The emissions of the emergency diesel generators and the diesel-powered emergency power plant are calculated according to the consumption of light fuel oil, the fuel's quality data and emission factors. The emissions are reported annually to the environmental protection authorities. Given that the emergency diesel generators and diesel-powered emergency power plant serve as the power plant's emergency power supply, their use is limited to test runs and is therefore extremely minor.

The monitoring of carbon dioxide emissions subject to the Emissions Trading Act is carried out according to the conditions of the approved emissions permit. The emissions report verified by an external party and required by the emissions permit is delivered to the Energy Authority every year.

11.5 NOISE MONITORING

Noise measurements in line with the conditions of the environmental permit are conducted in the power plant's environment. These measurements ensure that the noise generated by the power plant complies with the guideline values set by the authorities. The measurements are performed by an external expert in accordance with the relevant instructions issued by the Ministry of the Environment in January 1995 ("Ympäristömelun mittaaminen"). The plans concerning the measurements are submitted to the Uusimaa ELY Centre for approval no later than three months prior to the measurements.

The sound power level (LWA) of fixed sound sources, which have a significant impact on the environment's noise level, is measured by an external expert whenever a piece of equipment is renewed.

During decommissioning, noise measurements will be carried out in a manner approved by the Uusimaa ELY Centre.

11.6 WASTE RECORDS

The formation, volumes, waste types and locations of radioactive and conventional waste are monitored at the power plant both continuously and as larger-scale summaries. The records on radioactive waste detail the activities as well as waste volumes and types of both individual waste packages and storage and final disposal facilities. The records on conventional waste detail the waste types and volumes of the waste batches as well as the recipient and handling method of the waste.

A summary of the radioactive waste is drawn up each year and delivered to STUK for reference. The annual summary of conventional waste is delivered to the ELY Centre.

11.7 MONITORING IMPACTS ON HUMANS

Impacts in people can be monitored by organising discussion events, conducting resident surveys or interviews, and collecting information through electronic feedback channels, for example. Especially during decommissioning, residents and other stakeholders can be shown a contact person from the power plant whom they can contact if they detect any disturbing effects.

The project owner regularly publishes topical information on the plant's operations on its website, and two or three times a year in a supplement delivered to residents of the nearby area in the local paper.

11.8 L/ILW'S REPOSITORY'S MONITORING PROGRAMME

The L/ILW repository is subject to the regular monitoring of rock mechanics, hydrology and groundwater chemistry. These are described in Chapters 9.14 and 9.15. The monitoring programmes were reviewed in the L/ILW repository's periodic safety review drawn up in 2020, in which they were deemed sufficiently extensive and comprehensive. The scope and comprehensiveness of the monitoring programmes is reviewed when necessary, such as before the excavation related to the L/ILW repository's expansion begins.

12. Project's licence and permit process and project's relation to plans and programmes

Once the environmental impact assessment procedure has concluded, the project progresses to the licence and permit phases. The coordinating authority's reasoned conclusion on the EIA Report will be appended to the various licence and permit applications when the applications are submitted. The following provides a general description of the permits, licences and decisions the project's different options may require. It also outlines the project's relation to various plans and programmes pertaining to the use of natural resources and environmental protection.

12.1 DECISIONS AND LICENCES PURSUANT TO THE NUCLEAR ENERGY ACT

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 final disposal facility for low and intermediate-level waste (the L/ILW repository) is valid until the end of 2055.

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.

In the case of both extending the operation and the decommissioning of the power plant, the L/ILW repository is operated longer than the validity of the current operating licence, which is why a new operating licence must be sought for the L/ILW repository. In addition, the current operating licence of the L/ILW repository does not cover all planned purposes of use, and they can be taken into account in the potential licence application. These uses are the final disposal of radioactive waste generated elsewhere in Finland, decommissioning waste and waste containing uranium. The waste containing uranium does not refer to spent nuclear fuel, but rather a measuring instrument containing uranium, for example.

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.

The project's implementation may also require other licences in accordance with the Nuclear Energy Act.

12.1.1 Operating licence

The licence to operate a nuclear facility may be issued provided that the prerequisites listed in section 20 of the Nuclear Energy Act are met. The prerequisites include the following:

- the nuclear facility and its operation meet the safety requirements laid down in the Nuclear Energy Act, and appropriate account has been taken for the safety of workers and the population;
- the methods available to the applicant for arranging nuclear waste management, including disposal of nuclear waste and decommissioning of the facility, are sufficient and appropriate;
- the applicant has sufficient expertise available, and especially the competence of the operating staff and the operating organisation of the nuclear facility are appropriate;
- the applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations.

Operation of the nuclear facility may not be started on the basis of the licence granted for it until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the safety requirements set, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the nuclear facility operator has arranged, in the manner provided, indemnification regarding liability in the event of nuclear damage. In addition, it is required that the Ministry of Economic Affairs and Employment has ascertained that provision for the cost of nuclear waste management has been arranged in accordance with the provisions of the Act.

12.1.2 Decommissioning licence

When the operation of a nuclear facility has been terminated, the holder of the operating licence is obligated to undertake measures to decommission the nuclear facility in accordance with the plan and the requirements set for decommissioning referred to in section 7g of the Nuclear Energy Act. For this purpose, the holder must apply for a decommissioning licence which will enter into force after the operating licence. The licence must be applied for well in advance so that the authorities have adequate time to assess the application before the termination of the operating licence of the nuclear facility.

A licence for the decommissioning of a nuclear facility may be granted if the prerequisites listed in section 20 a of the Nuclear Energy Act are met. The prerequisites include the following:

- the nuclear facility and its decommissioning meet the requirements related to safety in accordance with the Nuclear Energy Act, and the safety of the employees and the population, as well as environmental protection, have been duly taken into account;
- the methods available to the applicant for the decommissioning of the nuclear facility as well as other nuclear waste management are adequate and appropriate;
- the applicant has the necessary expertise and especially the competence of the nuclear facility personnel and the organisation of the nuclear facility available, and they are appropriate and suitable for decommissioning;

- the applicant has the financial and other necessary requirements to carry out the decommissioning safely and in accordance with Finland's international contractual obligations.

The decommissioning of a nuclear facility may not be started before the granting of the related licence unless otherwise provided in the other licences of the licence holder. The decommissioning of a nuclear facility may not be started on the basis of the licence granted for it until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the safety requirements for decommissioning, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that the nuclear facility operator has arranged, in accordance with the related provisions, indemnification regarding liability in the event of nuclear damage. In addition, it is required that the Ministry of Economic Affairs and Employment has ascertained that provision for the cost of nuclear waste management has been arranged in accordance with the provisions of the Act.

12.1.3. Other licences in accordance with the Nuclear Energy Act

In addition to the operating licence and decommissioning licence, the project options may require other licences in accordance with the Nuclear Energy Act. Section 21 of the Nuclear Energy Act provides the prerequisites for granting a licence for other use of nuclear energy, such as the possession, manufacturing, production, transfer, handling, use, storage, transport and import of nuclear substances and nuclear waste, as well as final disposal on a smaller scale than extensive final disposal (the operating licence). In accordance with section 16 subsection 2 of the Nuclear Energy Act, STUK grants a licence for the aforementioned operations by application.

A licence can be granted for other use of nuclear energy when so required by the operation if the prerequisites set in section 21 of the Nuclear Energy Act are met: The prerequisites include the following:

- the use of nuclear energy meets the safety requirements laid down in the Nuclear Energy Act, and appropriate account has been taken of the safety of the workers and the population, and environmental protection;
- the applicant has possession of the site needed for the use of nuclear energy;
- nuclear waste management has been arranged appropriately, and provision for the cost of nuclear waste management has been made in accordance with the provisions of the Nuclear Energy Act;
- the applicant's arrangements for the implementation of control by the Radiation and Nuclear Safety Authority as referred to in the Nuclear Energy Act are sufficient;
- the applicant has sufficient expertise available, and the operating organisation and competence of the operating staff are appropriate;
- the applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations;
- the authorisations required under the Council Directive on the supervision and control of shipments of radioactive waste and spent fuel (2006/117/Euratom) have been obtained from foreign states, and the said
- provisions can also be observed in other respects;
- the use of nuclear energy otherwise meets the principles laid down in Sections 5–7 of the Nuclear Energy Act and does not conflict with the obligations under the Euratom Treaty.

The use of nuclear energy may not be initiated on the basis of a granted licence until the Radiation and Nuclear Safety Authority has ascertained, when required by the operations, that the use of nuclear energy is in accordance with the safety requirements set, that the security and emergency arrangements are sufficient, that the control necessary to prevent the proliferation of nuclear weapons has been arranged appropriately, and that indemnification regarding liability in the event of nuclear damage in connection with the operations has been arranged in compliance with the relevant provisions.

12.2 LICENCES PURSUANT TO THE RADIATION ACT

Loviisa power plant's radiation practice other than the operation of nuclear energy requires a safety licence pursuant to the Radiation Act. Fortum Power and Heat Oy is the undertaking in the radiation practice pursuant to the safety licence in terms of the use of unsealed sources, X-ray equipment and sealed sources in industry and research.

Unsealed sources used for the performance of radiochemical analyses, for instance, are handled in Loviisa power plant's laboratory. X-ray equipment, such as XRF analysers, are used in materials inspections. Sealed sources are used in the power plant units to check the calibrations of measuring instruments and operational tests, among other things.

The safety licence for radiation practice is valid until further notice. The safety licence is a document that must be kept up-to-date in terms of any amendments, such as the addition of any new radiation sources or their removal from use. The supervisory authority is STUK.

The radiation practice in industry and research will be continued to an extent deemed necessary in the event of both the extended operation of the power plant or its decommissioning. The safety licence will be amended if necessary.

12.3 RADIOACTIVE WASTE GENERATED ELSEWHERE IN FINLAND

Small amounts of radioactive waste originating from some place other than Loviisa power plant may be stored under the L/ILW repository's current operating licence. When a new operating licence for the L/ILW repository is applied for, the amount of the waste generated elsewhere in Finland will be specified. An account on the quality and maximum quantity of nuclear materials or nuclear waste manufactured, produced, handled, used or stored in the nuclear facility, including radioactive waste generated elsewhere in Finland, will be included in the power plant's and L/ILW repository's applications for a licence.

VTT's FiR 1 research reactor has an operating licence pursuant to the Nuclear Energy Act which will remain valid until the end of 2023. VTT Technical Research Centre of Finland Ltd has submitted an application addressed to the government with which VTT applied for a licence referred to in section 20 of the Nuclear Energy Act for decommissioning the FiR 1 research reactor in such a way that the amount of radioactive substances remaining in facility's area, located in Otaniemi, Espoo, meets the requirements issued by virtue of the Nuclear Energy Act. The applied for licence would be valid until the end of 2038. As part of the licence process, VTT carried out an environmental impact assessment on the decommissioning of the FiR 1 research reactor. VTT has a safety licence pursuant to the Radiation Act for the decommissioning of the Otakaari 3 research laboratory.

VTT has made an agreement with Fortum Power and Heat Oy on the decommissioning services and nuclear waste management of the FiR 1 research reactor and the Otakaari 3 research laboratory. VTT has noted to the ministry that the services under the agreement between Fortum and VTT meet the VTT's nuclear waste management needs. As the licence holder of a nuclear power plant, Fortum has the expertise and operating system required to fulfil the contractual obligations. The same agreement also applies to the management of the OK3 laboratory's radioactive decommissioning waste in its entirety. The agreement's implementation is conditional upon Fortum being able to secure the permits and licences required for handling the waste at Loviisa power plant and placing it in final disposal in the L/ILW repository.

The radioactive waste generated elsewhere in Finland which may be handled at Loviisa power plant or be deposited in final disposal in Loviisa's L/ILW repository is either nuclear waste as referred to in the Nuclear Energy Act or radioactive waste as referred to in the Radiation Act, depending on whether the practice in which it was generated is subject to the Nuclear Energy Act or the Radiation Act. The decommissioning waste of VTT's research reactor is an example of nuclear waste pursuant to the Nuclear Energy Act, whereas the waste of VTT's materials research lab is primarily radioactive waste as referred to in the Radiation Act, as is any waste generated elsewhere in industry, research facilities and in healthcare.

While the transport of nuclear waste is basically subject to a transport licence, the Nuclear Energy Decree states that the transport licence is not required in the event that the maximum activity of nuclear waste not containing nuclear material and to be transported at one time is 1 TBq. Preliminary estimates suggest that the decommissioning waste of VTT's research reactor will need a maximum of two transports requiring a licence. Other transports are reported to STUK.

A safety licence pursuant to the Radiation Act is not required for the transport of radioactive substances, with the exception of the transport of high-activity sealed sources by road or by rail. Even the transports which do not require a safety licence must nevertheless be reported to STUK. The activity of most of the future transports of radioactive waste generated elsewhere in Finland is likely to be of the kind which does not require a safety licence. The transport are nevertheless reviewed case-specifically, and the procedure is determined according to the radioactivity of the substance to be transported.

To summarise, one can conclude that 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. Regardless of the notification or permit procedure, the transports are subject to the aforementioned acts and any other regulations issued by virtue of them, such regulations including orders pertaining to transport packages, their marking, the equipment of the means of transport, the driver's qualifications and transport documents.

12.4 LICENCES REQUIRED FOR THE TRANSPORT OF RADIOACTIVE SUBSTANCES

Transports of radioactive substances and waste are subject to the Act on the Transport of Dangerous Goods (719/1994), the Radiation Act (859/2018) and, in terms of nuclear materials and waste, the Nuclear Energy Act (990/1987), and the regulation issued pursuant to the above.

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. The permit authority in transport licence matters is STUK. In the event of extended operation, fresh fuel will continue to arrive to the power plant and in terms of this, the licence process will remain the same as it currently is. Posiva is responsible for the transports of spent fuel for encapsulation and final disposal in Eurajoki, Olkiluoto. The transports require a transport licence pursuant to the Nuclear Energy Act.

12.5 LAND USE PLANNING

The valid local detailed plan makes it possible to carry out modification work in the power plant area, construct additional structures and buildings, and decommission the power plant. Needs to change land use plans may become topical after decommissioning if existing limitations to the use of land in the power plant area and its surroundings caused by the power plant's operation are lifted. The local detailed plan contains information on the L/ILW repository's location. In respect of this, it must be ensured that the plan notations are also retained in the future. Any changes to the local detailed plan are approved by the Loviisa town council. Information about the restrictions pertaining to the area's further use can also be included in the land use registers, if necessary.

12.6 PERMITS IN ACCORDANCE WITH TH LAND USE AND BUILDING ACT

In accordance with the Land Use and Building Act (132/1999), the construction of power plant buildings related to the required modification work, the necessary infrastructure and facilities requires a building permit. In Loviisa, the town's building and environmental board is responsible for the duties and decision- making of the building inspection authorities.

In areas covered by a local detailed plan, a building permit is granted under the following conditions:

- the building project is in keeping with the valid local detailed plan;
- construction meets the requirements laid down in the Act and other requirements prescribed in or under the Act;
- the building is appropriate for the location concerned;
- a serviceable access road to the building site exists or can be arranged;
- water supply and wastewater management can be organised satisfactorily and without causing environmental harm; and
- the building will not be located or constructed in a way that causes unwarranted harm to neighbours or hinders appropriate building on a neighbouring property.

Separate action permits may be required for smaller structures, such as containers of temporary warehouses if they are not included in the building permit application. The dismantling permits required by the Land Use and Building Act are applied for in connection to the decommissioning and the dismantling of buildings. The necessary notifications are also filed at this point.

12.7 ENVIRONMENTAL AND WATER PERMIT

The operation of a nuclear power plant requires an environmental permit in accordance with the Environmental Protection Act (527/2014) (annex 1 Activities subject to a permit, Table 2 Other installations, section 3 Energy production, b) nuclear power plant).

Loviisa power plant has an environmental permit and a water permit granted by the environmental permit agency of Western Finland on 8 April 2009 (decision numbers 23/2009/2 and 24/2009/2). The permit became legally valid by the decision issued by the Supreme Administrative Court on 19 June 2012. The permit applies to the operation of the power plant, cooling water intake, emissions of the power plant and monitoring. The power plant has a service water abstraction permit in accordance with the Water Act, 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.

A permit is required for any change in an activity that increases emissions or their impact, or for any other substantial change in an activity requiring an environmental permit. However, no permit is required if the change does not increase the environmental impact or risks, and if the change in the activity does not require the permit to be reviewed (section 29 of the Environmental Protection Act). The need for changes to the existing environmental and water permits will be assessed in cooperation with the authorities if an operating licence for continuing operations after 2027/2030 is applied for (and issued). According to the current assessment, the impacts of Loviisa nuclear power plant will remain much the same as they are today.

The operator must inform the environmental protection authority without delay of the termination of the activity. The authority issuing the environmental permit may issue orders on the termination of the activity, if necessary.

The issue of a new environmental permit requires that the operations, considering the permit provisions to be set and the location of the activity, do not alone or together with other functions:

- cause harm to health;
- cause other
    - harm to the environment and its functions;
    - prevent or materially hinder the use of natural resources;
    - cause a loss of general amenity of the environment or of special cultural values;
    - reduce the suitability of the environment for general recreational use;
    - cause damage or harm to property or impairment of use;
    - constitute a comparable violation of the public or private interest;
- result in the violation of the prohibition of soil or groundwater contamination;
- cause the deterioration of special natural conditions, present a risk to the water supply or affect other potential uses important to the public interest within the area impacted by the activity;
- create the unreasonable burden referred to in the Adjoining Properties Act.

Permit provisions that prevent and limit emissions are set for the operations in the permit by considering the nature of the operations and local environmental conditions.

The water abstraction and discharge structures require a permit pursuant to the Water Act (587/2011). If water abstraction from Lappomträsket lake is discontinued, the removal of the structures made for the abstraction requires that a permit pursuant to the Water Act be applied for.

Should the undertaking apply for a new water permit, the application should include a project description and a report on the impact of the project in accordance with the Government Decree on the management of water resources (1560/2011). A permit for a water resources management project will be granted if:

- the project does not significantly violate public or private interests;
- the benefit gained from the project to public or private interests is considerable compared with the losses incurred for public or private interests.

The water resources management project may not jeopardise public health or safety, cause considerable detrimental changes in the natural state of the environment or the aquatic environment and its functions, or cause considerable deterioration in the local living or economic conditions.

The environmental permit authority is either the Southern Finland Regional State Administrative Agency or the environmental protection authority of the town of Loviisa, depending on the operation subject to the permit application. In water permit matters, the permit authority is the Southern Finland Regional State Administrative Agency. The environmental permit application and the permit application in accordance with the Water Act concerning the same operation shall be processed jointly and decided by a single decision unless this is considered unnecessary for a specific reason.

The ELY Centre must generally be notified of the groundwater pumped out of the repository, if the minimum water volume is 100 m^3 a day. If the volume of water pumped is 250 m^3 a day or more, the activity is subject to a permit in accordance with the Water Act. If a concrete crushing plant or a crushing plant for the quarry material with a minimum total operating time of 50 days is established in the area for the decommissioning and dismantling activities, the activity requires an environmental permit.

12.8 PERMITS AND DOCUMENTS IN ACCORDANCE WITH THE CHEMICALS ACT

Facilities engaged in extensive industrial handling and storage of chemicals require a permit granted by the Finnish Safety and Chemicals Agency (Tukes). The extent of the industrial handling and storage of chemicals is determined based on the quantity and dangers of the chemicals stored in the facility. The permit sets conditions for the activities, and a commissioning inspection is conducted at the facility after the permit is granted. Fortum's 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 Act on the Safe Handling of Dangerous Chemicals and Explosives (390/2005, the "Act on Chemical Safety") excludes radioactive substances and products containing radioactive substances from its area of application. Changes in the handling, storage and quantities of radioactive materials do not therefore as a rule result in changes to the chemicals permit.

However, changes in the operation may, in accordance with the Act on Chemical Safety, invoke an obligation to apply in writing for a permit for a production facility change if the planned change is an expansion comparable to the establishment of a production facility or another essential change. Changes categorised as essential include a significant increase in the quantity of hazardous chemicals, a significant change in the hazardous chemicals being handled or stored, or in their properties or state, a significant change in the manufacturing or handling method, or another change that may significantly affect the accident risk. The notification of the change in the operation submitted to Tukes should include the essential information on the change and a report on the safety impact of the change. The institutions subject to a safety assessment should also update the essential parts of the safety assessment.

The Tukes regulatory authority should be notified of the decommissioning of Loviisa power plant in accordance with the Act on Chemical Safety. The notification concerning the decommissioning of the operation must include a plan for how the structures and areas of the production facility and its parts to be decommissioned are cleaned if required after the operations are discontinued, and the measures that are taken to ensure that hazardous chemicals and explosives do not cause personal injuries or damage to the environment or property.

12.9 OTHER PERMITS AND PLANS

The Government Decree on areas restricted for aviation (VNa 930/2014) has defined the surroundings of the power plant as a no-fly zone. The no-fly zone covers the power plant surroundings within a four-kilometre radius and at an altitude of up to 2,000 metres. On a general level, the Aviation Act (864/2014) requires a permit for air navigation obstacles to set up a facility, building, structure or sign of a certain height. The party responsible for maintaining the air navigation obstacle must notify the Finnish Transport and Communications Agency Traficom or an instance designated by it of any changes concerning the obstacle (such as the removal of the air navigation obstacle) and its contact information.

Conventional dismantling requires a dismantling plan. In this connection, a contractor who has a work permit for asbestos demolition granted by the permit authority carries out the required survey concerning asbestos and harmful substances. The demolition method, protection and reuse possibilities of waste are determined based on the survey.

If there is reason to expect the noise or vibration to be particularly disturbing, the undertaking must notify the local environmental protection authority of a measure causing temporary noise or vibration (section 118 of the Environmental Protection Act).

12.10 PROJECT'S RELATION TO PLANS AND PROGRAMMES PERTAINING TO THE USE OF NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION

Table 13-1 describes the project's relation to the most important plans and programmes pertaining to the use of natural resources and environmental protection. These include both international commitments and national target programmes which, while not being directly binding upon the undertaking, may concern the undertaking through various permits and licences, for example.

Table 13-1. Project's relation to plans and programmes pertaining to the use of natural resources and environmental protection.

Name of programme/plan	Content	Relation to project
Paris Agreement	A new legally binding international treaty on climate change was adopted at COP 21 in Paris, on 12 December 2015. The Paris Agreement entered into force on 4 November 2016 and became binding on Finland on 14 November 2016. The Paris Agreement aims to limit global warming to well below 2 degrees Celsius, compared to pre-industrial times, and to pursue measures which would limit the warming to 1.5 degrees Celsius. The objective is to achieve the peak of global greenhouse gas emissions as soon as possible and to reduce emissions quickly after that in such a way that human-derived greenhouse gas emissions and sinks are in balance by the second half of this century. In addition to the objectives of emission reduction, the agreement sets the long-term target of adapting to climate change and the target of adjusting financing flows toward low-carbon and climate-resilient development. The global stocktakes held at five-year intervals review the parties' joint progress in relation to the agreement's goals. The first global stocktaking will take place in 2023.	Electricity production based on nuclear power does not generate greenhouse gas emissions. Therefore, the extended operation of Loviisa nuclear power plant would support emission reduction targets in line with the Paris Agreement.
The EU's climate and energy policy 2020 and 2030	The European Council agreed on the EU's energy and climate objectives for the 2021–2030 period in 2014. The new objectives are a continuation of the 2020 framework agreed on in 2007. The goal by 2030 is to reduce greenhouse gas emissions on the EU level by 40% compared to the level in 1990. The goal has been divided into a 43% emission reduction in the emissions trading sector (big industrial and energy production plants) and a 30% emission reduction in industries outside the emissions trading, compared to 2005.	Electricity production based on nuclear power does not generate greenhouse gas emissions. Therefore, the extended operation of Loviisa nuclear power plant would support the goals of the EU's climate and energy policy.
Finland's national energy and climate strategy	Finland's long-term goal is a carbon-neutral society. The Energy and Climate Roadmap 2050 report published in 2014 by the Parliamentary Committee on Energy and Climate Issues functions as a strategic guideline towards this goal. The roadmap assessed the means by which to build a low-carbon society and for reducing Finland's greenhouse gas emissions by 80–95% from the 1990 level by 2050. The energy and climate policy has three main dimensions the balance of which must be managed continuously whilst shifting towards a carbon neutral society. The energy system must be i) cost-effective and enable the growth of the national economy and the competitiveness of Finnish companies on the global market, ii) sustainable from the perspective of greenhouse gas emissions and the environment, and iii) sufficiently secure in terms of supply.	Electricity production based on nuclear power does not generate greenhouse gas emissions. Therefore, the extended operation of Loviisa nuclear power plant would support the goals of Finland's national energy and climate strategy. In addition, nuclear energy supports the continuity of supply in Finland's electricity production.

Name of programme/plan	Content	Relation to project
New climate and energy strategy	The government is preparing the climate and energy strategy in line with Prime Minister Sanna Marin's Government Programme under the leadership of the Ministry of Economic Affairs and Employment. Sanna Marin's Government Programme aims to achieve carbon neutrality in Finland by 2035 and a zero carbon level soon after. The strategy is being prepared in coordination with the intermediate-term climate plan, which is coordinated by the Ministry of the Environment and defines the new policy measures of the "effort sharing" sector outside the EU's emissions trading scheme. The strategy covers all sources of greenhouse gas emissions (the emissions trading sector, the effort sharing sector, the land use sector) and sinks (the land use sector). It also includes reviews in accordance with the five dimensions of the EU's Energy Union (low-carbon, including renewable energy, energy efficiency, the energy markets, energy security and RDI measures), adapting to climate change, energy and greenhouse gas balances, and comprehensive impact assessments on the selected set of policy measures (environmental impacts, gender equality, national economy, fiscal economy as well as social and regional impacts). In addition, the strategy may highlight other topical energy and climate policy themes, such as energy's security of supply. The main focus in both the policy measures outlined in the strategy and the scenarios based on them is on achieving the climate and energy goals for 2030 set by the EU and the government programme's carbon neutrality 2035 goal.	The use of nuclear power in electricity production supports Finland's goal, pursuant to 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.
National Air Pollution Control Programme 2030	The National Air Pollution Control Programme 2030, approved by the government in March 2019, is a key instrument in the implementation of EU obligations and the objectives of national air pollution control. The programme includes the measures needed to implement the emission reduction obligations set by the EU's NEC Directive (2016/2284) and other actions needed to improve air quality.	The production of nuclear energy does not generate emissions restricted by the NEC Directive. The extended operation of the nuclear power plant supports the achievement of Finland's goals, given that energy production based on incineration processes would be replaced by nuclear power.
Water Framework Directive **Water resources management plans and programmes of measures**	The EU's Water Framework Directive (2000/60/EC) was adopted in 2000. The Directive aimed to define the framework for the protection of inland surface waters, estuaries, coastal waters and groundwaters. According to the Water Framework Directive, member states must identify the river basins within their territories and assign them to individual river basin districts. A water resources management plan must be prepared for each river basin district. Each plan includes a programme of measures which must fulfil the Directive's goals. On the national level, the EU's Water Framework Directive is implemented with the Act on the Organisation of River Basin Management and the Marine Strategy (1299/2004), the Government Decree on Water Resources Management Regions (1303/2004), the Government Decree on Water Resources Management (1040/2006), the Government Decree on the Organisation of the Development and Implementation of the Marine Strategy (980/20119 and the Government Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006). The water resources management plans and the programmes of measures complementing them provide information on the status of the waters and the factors impacting them, as well as on the measures needed to achieve and maintain a good status of waters. The valid plans and programmes of measures cover the years 2016–2021. The hearings on the water resources management plans and programmes of measures for 2022–2027concluded in May 2021 and the plans will be adopted by the end of 2021.	The water resources management plan for the river Kymijoki-Gulf of Finland river basin district covers the Gulf of Finland's coastal areas and the programme of measures of Uusimaa's water resources management covers the coastal area of Loviisa. The power plant's most significant impact is the thermal load carried to the waterways, which has had an adverse effect mainly on the status of the Klobbfjärden body of water. The proposal on the programme of measures for Uusimaa's water resources management mentions the planning and implementation of the eutrophied bay's rehabilitation as Klobbfjärden's measure. Measures for the operation, maintenance and increased efficiency of plants are also presented to the industrial sector for the third water resources planning period.

Name of programme/plan	Content	Relation to project
Marine Strategy Framework Directive **Finland's Marine Strategy**	The Marine Strategy Framework Directive (2008/56/EY) is a directive on the framework for a marine environmental policy creating a framework and objectives for the preservation of the marine environment and its protection from the noxious activity of humans and for the prevention of noxious activity by humans. Finland's Marine Strategy implements the EU's marine policy and the relevant directive on the national level. The planning of the Marine Strategy is divided into three parts and progresses in six-year cycles. The initial stage of Finland's Marine Strategy involved an assessment of the sea's present state and the setting of the objectives needed for the attainment of a good status as well as indicators for monitoring the status. The Marine Strategy covers Finland's territorial waters and exclusive economic zone. The Marine Strategy's programme of measures includes suggested measures that would improve the status of the sea. The valid programme of measures covers the years 2016–2021. Hearings on the Marine Strategy's programme of measures for 2022–2027 and its background materials concluded in May 2021. The government is set to adopt the new programme of measures in December 2021.	This EIA Report includes an assessment of the impacts on the status of the sea area. According to the assessment, the thermal effect of the cooling water is local and has contributed to a local increase in eutrophication over the long term. In the proposal concerning the Marine Strategy's programme of measures, the thermal effect of the cooling water is deemed local enough not to have impact on the status of the sea.
Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM) **Baltic Sea Action Plan (BSAP; HELCOM)**	The Convention on the Protection of the Marine Environment of the Baltic Sea Area (1974, 1992), also referred to as the Helsinki Convention, obligates the participating countries to reduce input from all emission sources, protect the marine nature and preserve biodiversity. The convention's key principles are the use of the best available technology from the perspective of environmental protection, applying the practices best in terms of the environment and compliance with the principle of prudence and the 'polluter pays' principle. The Helsinki Commission (HELCOM) is an intergovernmental organisation established by the signatories (contracting parties) to the Helsinki Convention. The commission monitors and promotes the application of the Helsinki Convention and gives recommendations to the governments of the contracting parties. HELCOM's Secretariat approved the Baltic Sea Action Plan in 2007. The action plan's objective was the good ecological status of the Baltic Sea by 2021. The action plan covers the worst environmental problems of the Baltic Sea and actions related to eutrophication, harmful and dangerous substances, biodiversity and nature protection. HELCOM and its signatories have decided to update the action plan, given that it seems unlikely that the objective of a good status will be attained by the end of 2021.	According to the environmental impact assessment, the thermal effect of the cooling water is local and has, in the long run, contributed to a local increase of eutrophication, among other things. The thermal effect does not have an impact on the ecological status of the Baltic Sea in a wider sense, as was concluded in the Marine Strategy's programme of measures.
Natura 2000 network	The European Union aims to stop the loss of biodiversity in its area. The Natura 2000 network is one of the most important means by which to attain this goal. The network safeguards the environments of the natural habitats and species defined in the Habitats Directive. These areas pursuant to the Habitats Directive are called Sites of Community Importance (SCI). The Habitats Directive applies to wild fauna, flora and natural habitats. It aims to i) attain and maintain a favourable level of conservation in terms of some species and natural habitats, ii) preserve species in their natural environments so that their natural range does not shrink, and iii) preserve a sufficient number of a species' natural habitats to ensure its survival in the future, too. The netwrok also includes Special Protection Areas (SPA) pursuant to the Birds Directive. The Birds Directive applies to Europe's wild birds. The Directive's general objective is to maintain certain bird populations on a level that meets ecological, scientific and educational requirements.	The Natura 2000 network site closest to the power plant area is the Källaudden–Virstholmen area, located approximately 1.3 km to the southwest. According to the impact assessment, the power plant's extended operation or decommissioning would not have impacts that would impair the Natura area in question.
National policy and programme for spent fuel and radioactive waste management	The most recent national policy and programme for spent nuclear fuel and other radioactive waste was published in 2015. The policy and programme is currently being updated. The national programme is a comprehensive plan aimed at ensuring that all spent fuel and radioactive waste generated in Finland is managed safely and in a way that all waste management measures from the generation of waste to its final disposal are carried out without undue delay. The national programme ensures the implementation of the national policy for spent nuclear fuel and radioactive waste. The policy can be seen as a strategy for the management of spent nuclear fuel and radioactive waste generated in Finland. The policy consists of several principles included in the Nuclear Energy Act and the Radiation Act. The principles are therefore mandatory on the undertakings and authorities. The national programme applies to all spent nuclear fuel and radioactive waste generated in Finland. One of the objectives of the updated national programme will be to develop a safe and cost-effective final disposal solution for all spent nuclear fuel and radioactive waste generated in Finland. Among other things, the attainment of this objective requires the licence and permit conditions of the plants and final disposal facilities intended for the treatment and handling of the radioactive waste generated at existing nuclear power plants to also allow the handling and final disposal of radioactive waste generated outside of their own operations.	The management of spent nuclear fuel and radioactive waste will be implemented in accordance with the national programme in the event of both extended operation and decommissioning. The reception of radioactive waste generated elsewhere in Finland at Loviisa nuclear power plant would support the objectives of the national programme currently being updated.
National Waste Plan	The National Waste Plan to 2023 sets the objectives for waste management and for preventing the generation of waste as well as the measures needed to achieve the objectives. It was adopted by the government in December 2017. The National Waste Plan will be updated during 2021. At the same time, the plan's validity will be extended to 2027. The updated Waste Plan implements the following entry in the government programme: "Create a vision for the waste sector that supports the objectives of recycling and the circular economy and extends to the 2030s. The aim is to increase the recycling rate at least to the level of the EU's targets for recycling." The renewed Waste Framework Directive and the Single-Use Plastics Directive also require new content to be incorporated into the Waste Plan. The principle in the waste management of conventional waste is what is referred to as prioritisation: 1) minimising waste 2) the reuse of waste 3) recycling as material 4) recovery as energy 5) landfill.	The power plant generates conventional waste in a manner similar to any other industrial activity. Waste containing radioactivity can be cleared from regulatory control if the activity of the waste batch falls below the limit values set by authorities. The further treatment of waste cleared from regulatory control can be identical with that of conventional industrial waste. Attention will be paid, in the event of both extended operation and decommissioning, to the minimisation of conventional waste, the appropriate handling of the waste and on final disposal in accordance with the principles of waste management and the Waste Act.

List of references

Aalto, J., Pirinen, P. & Jylhä, K. 2016. New gridded daily climatology of Finland — Permutation-based uncertainty estimates and temporal trends in climate. Journal of Geophysical Research — Atmospheres, doi:10.1002/2015JD024651.

Ahokas, T., Nylander, E., Olin, S., Vähä-Vahe, A. & Mäntykoski, A. (eds) 2020. Ehdotus Uudenmaan vesienhoidon toimenpideohjelmaksi vuosille 2022–2027. p. 115

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M.Wairiu, and K. Zickfeld. 2018. Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

An, N., Hemmati, S. & Cui, Y-J. 2017. Assessment of the methods for determining net radiation at different time-scales of meteorological variables. Journal of Rock Mechanics and Geotechnical Engineering 9: 239–246.

Andrejev, O., Myrberg, K., Alenius, P. & Lundberg, P. A. 2004. Mean circulation and water exchange in the Gulf of Finland — a study based on three-dimensional modelling. Boreal Environment Research 9: 1–16.

Anttila, P. 1988. Engineering geological conditions of the Loviisa power plant area relating to the final disposal of reactor waste. Voimayhtiöiden ydinjätetoimikunta, Raportti YJT-88-11.

Anttila, P., Ahokas, H., Front, K., Hinkkanen, H., Johansson, E., Paulamäki, S., Riekkola, R., Saari, J., Saksa, P., Snellman, M., Wikström, L. & Öhberg, A. 1999. Final disposal of spent nuclear fuel in Finnish bedrock – Hästholmen site report.

Anttila-Huhtinen, M 2018. Pohjaeläintutkimukset merialueella Pyhtää-Kotka-Hamina vuosina 2014-2018 ja vertailua aikaisempiin tuloksiin. Kymijoen vesi ja ympäristö ry:n julkaisu no 279/2018. p. 33 http://www.kymijoenvesijaymparisto.fi/julkaisut/

Anttila-Huhtinen, M. & Raunio, J. 2018. Fortum Power and Heat Oy:n Loviisan voimalaitos ja Oy Loviisan Smoltti Ab: Merialueen yhteistarkkailun laaja vuosiraportti 2017. Kymijoen vesi ja ympäristö ry:n julkaisu no 272/2018. p. 52 http://www.kymijoenvesijaymparisto.fi/julkaisut/

M. Anttila-Huhtinen, & J. Raunio. 2019. Fortum Power and Heat Oy:n Loviisan voimalaitos ja Oy Loviisan Smoltti Ab: Merialueen yhteistarkkailun vuosiraportti 2018. Kymijoen vesi ja ympä-ristö ry:n julkaisu no 280/2019. http://www.kymijoenvesijaymparisto.fi/julkaisut/

M. Anttila-Huhtinen, & J. Raunio. 2020. Fortum Power and Heat Oy:n Loviisan voimalaitos ja Oy Loviisan Smoltti Ab: Merialueen yhteistarkkailun vuosiraportti 2019. Kymijoen vesi ja ympä-ristö ry:n julkaisu no 291/2020.http://www.kymijoenvesijaymparisto.fi/julkaisut/

APL Systems 2020a. Mittausraportti Fortum Power and Heat Oy Loviisan ydinvoimalaitoksen ympäristömelumittauksista 23.7.–16.10.2020. https://www.fortum.com/loviisaeia

APL Systems 2020b. Mittausraportti Fortum Power and Heat Oy Loviisan ydinvoimalaitoksen varoventtiilikoestusten ympäristömelumittauksista 31.7., 28.8. ja 16.10.2020. https://www.fortum.com/loviisaeia

BACC II Author Team 2015. Second assessment of climate change for the Baltic Sea basin. SpringerOpen. p. 245. https://link.springer.com/book/10.1007/978-3-319-16006-1

Balkuvienė, G. & Pernaravičiūtė, B. 1994. Growth Rates of Roach (*Rutilus rutilus* (L)) in a Cooling Water Reservoir under Different Thermal Conditions, Internationale Revue der gesamten Hydrobiologie und Hydrographie, Volume 79, Issue 1, pp. 139–142, 1994.

Benviroc Oy, 2018. Loviisan kasvihuonekaasupäästöt 2009–2016, ennakkotieto vuodelta 2017. Viewed 5 January 2021. https://www.loviisa.fi/wp-content/uploads/2018/05/CO2-raportti_2017.pdf

Bolle, H-J., Menenti, M. and Rasool, S. I., 2015. Second Assessment of Climate Change for the Baltic Sea Basin.

Borg J., Mitikka V. and Kallasvuo M. 2012. Menetelmäohjeisto rannikon taloudellisesti hyödyntä-mättömien kalalajien lisääntymis- ja esiintymisalueiden kartoittamiseen. Riista- ja kalatalous. Tutkimuksia ja selvityksiä 4/2012. Riista- ja kalatalouden tutkimuslaitos, Helsinki.

Bruckner, T., Fulton, L., Hertwich, E., McKinnon, A., Perczyk, D., Roy, J. Schaeffer, R., Schlömer, S., Sims, R., Smith, P. & Wiser, R., 2014. Technology-specific Cost and Performance Parameters (Table A.III.2) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 2014. IPCC.

Bruun, J.-E., Hällfors, S. & Leppänen, J.-M. 2010. Variation in the composition and the amount of particles at the entrance of the Gulf of Finland and the eastern Gotland Basin. SYKE Marine Research Centre. p. 41

Chernobyl Forum 2005. Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts ans Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. The Chernobyl Forum: 2003–2005. Second revised version. Viewed 19 February 2021. https://www.iaea.org/sites/default/files/chernobyl.pdf

Cross, E. E. & Rawding, R. S. 2009. Acute thermal tolerance in the round goby, *Apollonia melanostoma (Neogobius melanostomus)*. Journal of Thermal Biology 34, 85–92.

DHI 2017. Hydrodynamic Module, User Guide. https://manuals.mikepoweredbydhi.help/2017/Coast_and_Sea/MIKE_FM_HD_3D.pdf https://manuals.mikepoweredbydhi.help/2017/Coast_and_Sea/MIKE3HD_Scientific_Doc.pdf

Finnish Energy 2020. Electricity statistics. Electricity balance 1970–2019. Viewed 5 February 2021. https://energia.fi/en/newsroom/publications/electricity_balance_1970-2019.html#material-view

Finnish Energy 2021. Electricity statistics. Viewed 10 February 2021. https://energia.fi/en/statistics/electricity_statistics

Energy Authority 2021. Sähkön odotetaan riittävän talvipakkasilla Suomessa - vanhojen voimalaitosten sulkeminen on pienentänyt tuotantokapasiteettia. Published on 3 December 2020. Viewed 2 February 2021. https://energiavirasto.fi/-/sahkon-odotetaan-riittavan-talvipakkasilla-suomessa-vanhojen-voimalaitosten-sulkeminen-on-pienentanyt-tuotantokapasiteettia

ENTSO-E & ENTSOG 2020. TYNDP 2020 Scenario Report. Viewed 2 February 2021. https://2020.entsos-tyndp-scenarios.eu/

European Commission 2019. European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (eds), European Atlas of Natural Radiation, Publication Office of the European Union, Luxembourg, 2019, https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation/Download-page. Viewed 6 May 2021.

European utility requirements for LWR nuclear power plants 2016. EUR Rev E, Vol 2, Ch. 1, App. A13, Dec 2016.

Extension Site of Distribution Map of Radiation Dose 2021. Viewed 19 February 2021. https://ramap.jmc.or.jp/map/eng/#lat=37.286773249029125&lon=140.58585758198276&z=9&b=std&t=air&s=28,0,0,0&c=largezone,20110429_cs137

Fingrid 2021. Network Vision. Viewed 18 January 2021. https://www.fingrid.fi/globalassets/dokumentit/fi/kantaverkko/kantaverkon-kehittaminen/fingrid_network_vision.pdf

Fleming, V. & Kaitala, S. 2006. Phytoplankton spring bloom intensity index for the Baltic Sea estimated for the years 1992 to 2004. Hydrobiologia 554:57–65.

Fontell, E., Lehtonen, H. & Lappalainen, J. 2004. Influence of temperature and depth on spawning site selection of pikeperch (*Sander lucioperca* (L.)) in the Helsinki sea area. Percis III. The third International Percid Fish Symposium. July 20-24, 2003. Madison, Wisconsin USA. pp. 103–104.

Fortum Power and Heat Oy 2008. Expansion of Loviisa nuclear power plant with a third power plant unit. Environmental impact assessment report.

Fortum Power and Heat Oy 2019a. Loviisa power plant's report on seawater temperatures and their impact on the state of the sea area in the summer of 2018. Internal report LO1-K873-00107.

Fortum Power and Heat Oy 2019b. Report on environmental impacts 2019. Internal report LO1-K870-00141.

Fortum Power and Heat Oy 2019c. Julkinen tiedote, maaliskuu 2019. Toimintaohje säteilyvaaran varalle. Viewed 24 February 2021. https://www.fortum.fi/sites/default/files/documents/toimintaohje_sateilyvaara_fi_2019.pdf

Fortum Power and Heat Oy 2021. Fortumin Loviisan ydinvoimalaitoksella hyvä tuotantovuosi 2020. Viewed 10 February 2021. https://www.fortum.fi/media/2021/01/fortumin-loviisan-ydinvoimalaitoksella-hyva-tuotantovuosi-2020

Gabi database 2021. Thermal energy from light fuel oil (LFO), EU-28.

Gasum Oy 2019. Gasum Oy Environmental impacts of natural gas lifecycle from Russia to Finland. Report. October 2019. Viewed 20 January 2021. https://www.gasum.com/globalassets/pdf-files/vuosiraportointi/green-finance/final_gasum_environmental-study_october2019.pdf

Hakala, T., Viitasalo, M., Rita, H., Aro, E., Flinkman, J. & Vuorinen, I. 2003. Temporal and spatial variation in the growth rates of Baltic herring (*Clupea harengus membras* L.) larvae during summer. Marine Biology 142: 25–33.

Hakanen, P. 2018. Loviisan edustan tarkkailu 2017. kasviplankton – lajisto ja biomassat. Raportti nro 2018/10. Menetelmäkuvaus, määritysten tulokset ja tulosten tarkastelu. Tmi Zwerver. p. 12

Hasegawa, A., Ohira, T., Maeda, M., Yasumura, S. & Tanigawa, K. 2016. Emergency Responses and Health Consequences after the Fukushima Accident. Evacuation and Relocation. Clinical Oncology. Volume 28, Issue 4. 2016. Pages 237–244. ISSN 0936-6555. https://doi.org/10.1016/j.clon.2016.01.002

City of Helsinki. Helsingin kaupungin työmaavesiohje. Website. http://dev.hel.fi/paatokset/media/att/5a/5af25e9c60eb7b4f0a8f24dd374a92e7869b4906.pdf (Viewed 29 March 2021)

Hempel M., Neukamm R. and Thiel R. 2016. Effects of introduced round goby *(Neogobius melanostomus)* on diet composition and growth of zander *(Sander lucioperca)*, a main predator in European brackish waters. Aquatic Invasions (2016) Volume 11, Issue 2: 167–178.

Herlevi H., Aarnio A., Puntila-Dodd R. and Bonsdorff E. 2018. The food web positioning and trophic niche of the non-indigenous round goby: a comparison between two Baltic Sea populations. Hydrobiologia (2018) 822:111–128. Springer.

Hiilitieto 2021. Hiilidioksidin talteenotto ja varastointi (CCS). Viewed 20 January 2021. https://www.hiilitieto.fi/kestava-kehitys/ccs/

Hokkanen, J., Virtanen, Y., Savikko, H., Känkänen, R., Katajajuuri, J-M., Sirkiä, A., Sinkko, T. 2015. Alueelliset resurssivirrat Jyväskylän seudulla. Sitran selvityksiä 91. ISBN 978-951-563-909-7. Available: https://media.sitra.fi/2017/02/27174807/Selvityksia91-2.pdf

Hyvärinen, E., Juslén, A., Kemppainen, E., Uddström, A. & Liukko, U-M. (eds.) 2019. The 2019 Red List of– Finnish Species. Ministry of the Environment & Finnish Environment Institute. Helsinki. p. 704

IAEA 2008. INES. The International Nuclear and Radiological Event Scale. User's Manual 2008 Edition. Viewed 24 February 2021. https://www-pub.iaea.org/MTCD/Publications/PDF/INES2013web.pdf

IAEA 2013. Safety Standards for protecting people and the environment. Specific Safety Guide. No. SSG-25. Viewed 24 February 2021. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1588_web.pdf

IAEA 2018. International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. SSR-6 (Rev.1), IAEA, Vienna (2018). http://www-pub.iaea.org/MTCD/Publications/PDF/PUB1798_web.pdf

ICPR 2006. Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a. Ann. ICRP 36 (3), 2006.

ICPR 2007. ICRP 103, Table 1, http://www.icrp.org/publication.asp?id=ICRP%20Publication%20103

Climate Guide 2021a. Finland's changing climate. Viewed 1 March 2021. https://ilmasto-opas.fi/fi/ilmastonmuutos/suomen-muuttuva-ilmasto/-/artikkeli/74b167fc-384b-44ae-84aa-c585ec218b41/ennustettu-ilmastonmuutos-suomessa.html

Climate Guide 2021b. Finland's changing climate. Viewed 1 March 2021. https://ilmasto-opas.fi/fi/ilmastonmuutos/videot-ja-visualisoinnit/-/artikkeli/a7ea17da-f0a5-4651-8f72-6214dc2f437a/ipcc-meri-lumi-jaa-infografiikat.html.

Climate Guide 2021c. Baltic Sea ice conditions. Viewed 17 February 2021. https://ilmasto-opas.fi/fi/ilmastonmuutos/suomen-muuttuva-ilmasto/-/artikkeli/63e8e231-2d68-45cb-97c8-6bbdd9b5bae5/itameren-jaaolot-muuttuvat.html

Finnish Meteorological Institute 2020. Website. https://www.ilmatieteenlaitos.fi/vuosi-2011

Finnish Meteorological Institute 2021. Website. Open data. Viewed 21 January 2021. https://www.ilmatieteenlaitos.fi/havaintojen-lataus

Ilus, E. 2009. Environmental effects of thermal and radioactive discharges from nuclear power plants in the boreal brackish-water conditions of the northern Baltic Sea. STUK – Radiation and Nuclear Safety Authority University of Helsinki, Faculty of Biosciences Department of Biological and Environmental Sciences, Aquatic Sciences. Academic dissertation.

IPCC 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, p. 151

IPCC 2018. Special report: Global Warming of 1.5°. Viewed 12 February 2021. http://www.ipcc.ch/report/sr15/

Irannezhad, M., Chen, D. & Kløve, B. 2015. Interannual variations and trends in surface air temperature in Finland in relation to atmospheric circulation patterns, 1961–2011. International Journal of Climatology, 35, 3078–3092, doi:10.1002/joc.4193.

Itä-Uudenmaan liitto 2007. Itä-Uudenmaan maisematyypit.

Jaale, M. & Norkko, A. 2008. Pohjaeläimet. In the publication: Raateoja, M. (ed). Itämeri 2008 – Merentutkimuslaitoksen Itämeriseurannan vuosiraportti. – Meri, Report Series of the Finnish Institute of Marine Research no 64: 49–51.

Jauhiainen, T., Vuorinen, H. S., Heinonen-Guzejev, M. 2007. Ympäristömelun vaikutukset (Effects of noise). Ympäristöministeriön julkaisuja. The Finnish Environment 3/2007.

Karonen, M., Mäntykoski, A., Nylander, E. & Lehto, K. (eds.) 2015. Vesien tila hyväksi yhdessä. Kymijoen-Suomenlahden vesienhoitoalueen toimenpidesuunnitelma vuosiksi 2016–2021. ELY-keskuksen raportteja 132/2015. p. 216

Kauppinen, T. and Nelimarkka, K. 2007. Ihmisiin kohdistuvien vaikutusten arvioiminen. Oppaita / Stakes: 68 http://urn.fi/URN:NBN:fi-fe2016100324788

Keskinen, T., Pulkkanen, M., Huttula, T. & Karjalainen, J. 2011. Vulnerability assessment of ecosystem services for climate change impacts and adaptation (VACCIA). Action 10: Assessment of impacts and adaptation of fisheries production and wash off effects in Lake Päijänne.

Kokkonen V. 2018. Statistics Finland, Enterprise statistics, Establishments of enterprises by industry and municipality, email 23 November 2018.

Kornis M. S., Mercado-Silva N. and Vander Zanden J. M. 2011. REVIEW PAPER. Twenty years of invasion: a review of round goby *Neogobius melanostomus* biology, spread and ecological implications. Journal of Fish Biology (2012) 80, 235–285.

Association of Finnish Municipalities 2020. Kuntien vuoden 2020 veroprosentit. Viewed 12 February 2020. https://www.kuntaliitto.fi/sites/default/files/media/file/Liite%203_kuntakohtaiset%20prosentit%202020_1.xlsx

Laamanen, M. (ed.) 2016. Programme of measures for the development and implementation of the marine strategy in Finland 2016–2021. Reports of the Ministry of the Environment 5/2016. p. 198

Laamanen, M. (ed.) 2020. Ehdotus Suomen merenhoitosuunnitelman toimenpideohjelmaksi vuosiksi 2022–2027. p. 252

Lahti, M. 2021. Impact of Loviisa power plant's intake and discharge of cooling water on sea area. Version 1. 19 March 2021. p. 65. Shown in Appendix 4.

Lappalainen J., Kurvinen L. and Kuismanen L. (eds.) 2020. The Finnish ecologically significant marine underwater areas (EMMA). Reports of the Finnish Environment Institute 8/2020. Finnish Environment Institute, Marine Research Centre.

Lappalainen, J., Malinen, T., Rahikainen, M., Vinni, M., Nyberg, K., Ruuhijärvi, J., & Salminen, M. 2005. Temperature dependent growth and yield of pikeperch, *Sander lucioperca*, in Finnish lakes. Fisheries Management and Ecology, 12, 27–35.

Launiainen, J., 1975. On the physical effects of cooling water discharges by nuclear power stations and their investigation. Meri 2: 45 – 59. ISSN 0356-0023. Finnish Institute of Marine Research. (In Finnish)

Launiainen, J. 1979. Studies of energy exchange between the air and the sea surface in the coastal area of the Gulf of Finland. Finnish Marine Research, 246, 3–110. ISSN 0357-1076. Finnish Institute of Marine Research. Leino 2012

Lee, V. A. & Johnson, T. B. 2005. Development of a bioenergetics model for the round goby *(Neogobius melanostomus)*. Journal of Great Lakes Research 31, 125–134.

Leino K. 2011. Jäähdytysveden mukana Loviisan voimalaitokselle vuosina 1977–1997 kulkeutunut kala ja levä. Report LO1-C2-00652, 29 November 2011. Fortum Power and Heat Oy.

Leino, K. 2012. Nutrient load in the sea area near Loviisa power plant. 6 November 2012. LO1-C2-00717.

Leivo, M. & Lehtiniemi, T. 2019. Porvoon seudun maakunnallisesti tärkeät lintujen muutonaikaiset kerääntymisalueet. Vuoden 2019 uudistettu MAALI-selvitys. Online publication. Viewed 28 February 2021. https://asiakas.kotisivukone.com/files/psly.kotisivukone.com/tiedostot/MAALI_Raportti_Final.pdf

Ministry of Transport and Communications 2012. Vaarallisten aineiden kuljetus Suomessa. Strategy for Transport of Dangerous Goods 2012–2020. Ohjelmia ja strategioita 5/2012.

Finnish Transport Agency 2018. National transport forecasts. Research reports of the Finnish Transport Agency 57/2018. Viewed 3 February 2021. https://julkaisut.vayla.fi/pdf8/lts_2018-57_valtakunnalliset_liikenne-ennusteet_web.pdf

Lindfors, A., Huttunen, O., Kiirikki, M. 2012. Lämpötila- ja virtausmittaukset Loviisan voimalaitoksen edustan merialueella avovesikaudella 2011. Luode Consulting Oy 24 February 2012. LO1-C2-00670.

Lindfors, A., Meriläinen, H. & Kronholm, H. 2020. Sedimenttien haitta-aineselvitys Loviisan voimalaitoksen edustan merialueelta. Luode Consulting Oy 31 December 2020. LO1-C2-01316. https://www.fortum.com/loviisaeia

Town of Loviisa 2020. Lausunto Uudenmaan ELY-keskukselle tienpidon ja liikenteen suunnitelmasta 2021–2024. Viewed 12 January 2021. http://julkaisu.loviisa.fi/FIN/kuulutus/6373473507159559111.1599127470972.PDF

Town of Loviisa 2021a. Master plans and local detailed plans of the town of Loviisa.

Town of Loviisa 2021b. Layout. Saaristotie between Mannerheiminkatu and Ramsayntie.

Town of Loviisa 2021c. Asuminen ja ympäristö. Ilmastonmuutos. Viewed 5 January 2021. https://www.loviisa.fi/asuminen-ja-ymparisto/ymparisto-ja-luonto/ymparistonsuojelu/ilmastonmuutos/

Luomaranta. A., Haapala, J., Gregow, H., Ruosteenoja, K., Jylhä, K., Laaksonen, A. 2010. The changes in the Baltic Sea ice cover by 2050. Reports 2010:4. Finnish Meteorological Institute.

Natural Resources Institute Finland 2019a. Riistahavaintopalvelu. Viewed 19 December 2019. http://riistahavainnot.fi/19 December 2019.

Natural Resources Institute Finland 2019b. Viewed 9 January 2020. https://www.luke.fi/uutinen/itameren-hyljekannat-jatkavat-kasvua-–-laskenta-tehtiin-hyvissa-olosuhteissa/

Natural Resources Institute Finland 2021. Viewed 23 March 2021. https://kalahavainnot.luke.fi/kartta.

Nationalparks.fi 2021. Svartholma Sea Fortress. Viewed 1 February 2021. https://www.luontoon.fi/svartholma

Ministry of Agriculture and Forestry 2018. Memo concerning the special season hunting of the ringed seal 2018 – 2019, reg. no. 1186/1 March 2018.

National Land Survey of Finland 2021a. Open map and geographical location data by the National Land Survey of Finland. Viewed 1 February 2021. https://www.maanmittauslaitos.fi/en/maps-and-spatial-data

National Land Survey of Finland 2021b. Land uplift. Viewed 1 March 2021. https://www.maanmittauslaitos.fi/en/research/interesting-topics/land-uplift

Marjamäki, M. & Lahti, M. 2012. Selvitys Kirmosundin tiepenkereen aiheuttamista virtausten muutoksista. 17 December 2012. LO1-C2-00735.

Marjamäki, M. 2012. Selvitys Loviisan voimalaitoksen jäähdytys- ja jätevesipäästöistä rantakiinteistöille ja purkualueen vesialueille aiheutuvista vahingoista, 17 December 2012, LO1-C2-00736.

Marttila, V., Granholm, H., Laanikari, J., Yrjölä, T., Aalto, A., Heikinheimo, P., Honkatuki, J., Järvinen, H., Liski, J., Merivirta, R. and Paunio, M. 2005. Finland's National Strategy for Adaptation to Climate Change. Ministry of Agriculture and Forestry. Publications of the Ministry of Agriculture and Forestry 1/2005.

Metsänen, T. 2021. Loviisan ydinvoimalaitoksen linnustoselvitykset 2020. Linnustoseuranta. Report 24 February 2021. Luontoselvitys Metsänen. https://www.fortum.com/loviisaeia

Mikkonen, S., Laine, M., Mäkelä, H., Gregow, H., Tuomenvirta, H., Lahtinen, M. & Laaksonen, A. 2015. Trends in the average temperature in Finland, 1847–2013. Stochastic Environmental Research and Risk Assessment, 29, 1521–1529, doi:10.1007/s00477-014-0992-2.

Ministry of Agriculture and Forestry 2014. Kansallinen vesiviljelyn sijainninohjaussuunnitelma. Ministry of Agriculture and Forestry, Ministry of the Environment. Helsinki.

Monivesi Oy 2018. Fortum Power and Heat Oy Loviisa power plant and Oy Loviisan Smoltti Ab. Merialueen yhteistarkkailu: vesikasvillisuuden ja kovan pohjan eliöstön tutkimukset vuona 2017. 2 March 2018.

Moskal'kova, K. I. 1996. Ecological and morphophysiological prerequisites to range extension in the round goby *Neogobius melanostomus* under conditions of anthropogenic pollution. Journal of Ichthyology 36, 584–590.

Finnish Heritage Agency 2021. Kulttuuriympäristön palvelukuna. Viewed 19 January 2021. https://www.kyppi.fi/palveluikkuna/portti/read/asp/default.aspx

Mäntykoski, A., Nylander, E., Ahokas, T., Olin, S. Vähä-Vahe, A. (eds.) 2020. Vaikuta vesiin. Ehdotus Kymijoen-Suomenlahden vesienhoitoalueen vesienhoitosuunnitelmaksi vuosiksi 2022–2027. Osa 1. p. 167 https://www.ymparisto.fi/fi-fi/vesi/vesiensuojelu/Vesienhoidon_suunnittelu_ja_yhteistyo/Vesienhoitoalueet/KymijokiSuomenlahti/Osallistuminen_vesienhoitoon

Niiranen & Hagman 2012. Fortum Power and Heat Oy, Lappominjärven turvelauttojen kartoitus ja poistaminen. 24 October 2012. LO1-K879-00024. Ramboll Finland Oy.

NOAA 2020. HYSPLIT. Viewed 15 December 2020 https://www.ready.noaa.gov/HYSPLIT.php

Nord Pool 2021. Production. Viewed 10 February 2021. https://www.nordpoolgroup.com/Market-data1/Power-system-data/Production1/Production1/ALL1/Hourly/?view=table

Nummi 2019. Safety case for Loviisa LILW repository 2018 – Main report. Fortum Power and Heat Oy, Espoo.

OECD/NEA & IAEA 2020. Uranium 2020: Resources, Production and Demand.

OECD/NEA 2014. Managing Environmental and Health Impacts of Uranium Mining, OECD/NEA, Nuclear Development 2014.

Pekcan-Hekim, Z., Lauri, U., Auvinen, H., Heikinheimo, O., Lappalainen, J., Raitaniemi, J. & Söderkultalahti, P. 2011. Climate Warming and Pikeperch Year-Class Catches in the Baltic Sea. A Journal of the Human Environment 40(5):447–456.

Perus, J., Bonsdorff, E., Bäck, S., Lax, H.-G., Villnäs, A. & Westberg, V. 2007. Zoobenthos as indicators of ecological status in coastal brackish waters: a comparative study from the Baltic Sea. Ambio 36(2–3): 250–256.

Posiva 2008. Expansion of the repository for spent nuclear fuel. Environmental impact assessment report. Posiva Oy.

Posiva 2012. Construction permit application for the Olkiluoto encapsulation plant and final disposal facility. Posiva Oy.

Pöyry 2009. Fish breeding area surveys in Pyhäjoki, Ruotsinpyhtää and Simo. Fennovoima Oy. Nuclear power plant project. 60K30029.25. October 2009.

Raateoja, M. & Setälä O. (eds.) 2016. The Gulf of Finland assessment. Reports of the Finnish Environment Institute 27/2016. p. 362

Ramboll Finland Oy 2012. Lappominjärven turvelauttojen kartoitus ja poistaminen. Esiselvitys.

Ramboll Finland Oy 2013. Loviisan voimalaitoksen ympäristömelumittaukset 2013. https://www.fortum.com/loviisaeia

Ramboll Finland Oy 2017. Loviisan voimalaitoksen ympäristömelumittaukset 2017. https://www.fortum.com/loviisaeia

Ramboll Finland Oy 2021. Accidents on map. Viewed 7 January 2021 https://mobilityanalytics.ramboll.com/onn/poliisi/

RIL 253-2010. Rakentamisen aiheuttamat tärinät. p. 122

Roikonen, T. & Kangas, H. 2021. Loviisan voimalaitos. Kalastotutkimukset voimalaitoksen lähimerialueella vuonna 2020. Ramboll 25 January 2021. p. 20 https://www.fortum.com/loviisaeia

Ruosteenoja, K., Jylhä, K. & Kämäräinen, M. 2016. Climate projections for Finland under the RCP forcing scenarios. Geophysica 51(1):17–50.

Räty, A. 2019. FiR 1 -tutkimusreaktorin ja OK3 laboratorion aktiivisuusinventaarit loppusijoituksen turvallisuusanalyysia varten. VTT-R-00739-19.

Sandström O. 1990. Environmental monitoring at the Forsmark nuclear power plant. Cooling water effects. Swedish Environmental Protection Agency, Environmental Impact Assessment Department. Coastal Laboratory. Report 3868. Öregrund.

Ministry of the Interior 2016. Säteilytilanneohje, Sisäministeriön julkaisu 10/2016. Viewed 2 February 2021. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/74874/Sateilytilanneohje.pdf?sequence=1

Ministry of Social Affairs and Health 1999. Ympäristövaikutusten arviointi, Ihmisiin kohdistuvat terveydelliset ja sosiaaliset vaikutukset. http://urn.fi/URN:NBN:fi-fe201504225515

State of the Baltic Sea – holistic assessment: non-indigenous species. Website. Viewed 12 March 2021 http://stateofthebalticsea.helcom.fi/pressures-and-their-status/non-indigenous-species/

Strömmer, H. 2019. Vaarallisten aineiden kuljetukset vuonna 2017. Traficomin julkaisuja 4/2019.

STUK 2002. Säteilyn terveysvaikutukset. Paile W (ed.). Säteily- ja ydinturvallisuus -kirjasarja, osa 4.

STUK 2004. Kokemukset onnettomuuksista ja poikkeuksellisista tapahtumista ydinlaitoksilla. Säteily- ja ydinturvallisuus -kirjasarja, luku 6. Viewed 24 February 2021. https://www.stuk.fi/julkaisut/sateily-ja-ydinturvallisuus-kirjasarja/ydinturvallisuus

STUK 2009. Säteilyn terveysvaikutukset. Säteily- ja ydinturvallisuus -kirjasarja. Säteilyturvakeskuksen julkaisu. https://www.julkari.fi/bitstream/handle/10024/125172/katsaus-sateilyn-terveysvaikutukset-8-2009.pdf?sequence=1&isAllowed=y

STUK 2012. Radioaktiivisten aineiden kuljetus. Advice from STUK. September 2012.

STUK 2015. Säteilyturvakeskuksen turvallisuusarvio Posivan rakentamislupahakemuksesta. Viewed 5 February 2021. https://www.stuk.fi/documents/12547/131539/stukin-turvallisuusarvio-posivan-rakentamislupahakemuksesta.pdf/a8c45d8c-f354-4817-947b-7375624bca7d

STUK 2019a. Stuklex. Limitation and monitoring of radioactive releases from a nuclear facility, 15/03/2019. YVL C.3. Viewed 9 February 2021. https://www.stuklex.fi/fi/ohje/YVLC-3

STUK 2019b. Eeva Salmisen esitys säteilyn terveysvaikutuksista. STUKin järjestämä Syventävä säteilysuojelukoulutus-kurssi 3.12.2019.

STUK 2020a. Stuklex. Suojelutoimet säteilyvaaratilanteessa, 1.9.2020. VAL 1. Viewed 9 February 2021. https://www.stuklex.fi/fi/ohje/VAL1

STUK 2020b. Suomalaisten keskimääräinen efektiivinen annos vuonna 2018. STUK-A263. Huhtikuu 2020. Siiskonen Teemu (toim.). Viewed 19 February 2021. https://www.julkari.fi/bitstream/handle/10024/139611/Suomalaisten_keskima%20a%20ra%20inen_efektiivinen_annos_vuonna_2018.pdf?sequence=6

STUK 2020c. Ydinvoimalaitosten ympäristön säteilyvalvonta Suomessa. Vuosiraportti 2019. STUK-B 253. Toukokuu 2020. Viewed 17 March 2021. https://www.julkari.fi/bitstream/handle/10024/139992/Ydinvoimalaitosten_ymp%C3%A4rist%C3%B6n_s%C3%A4teilyvalvonta_Suomessa_Vuosiraportti_2019.pdf?sequence=1&isAllowed=y

STUK 2021a. STUK supervises. Regulatory oversight of radiation safety. Viewed 10 February 2021. https://www.stuk.fi/web/en/stuk-supervises/nuclear-safety/stuk-s-duties-in-the-supervision-of-nuclear-safety/regulatory-oversight-of-radiation-safety

STUK 2021b. STUK supervises. Employee radiation exposure in nuclear power plants. Viewed 10 February 2021. https://www.stuk.fi/web/en/stuk-supervises/nuclear-safety/stuk-s-duties-in-the-supervision-of-nuclear-safety/regulatory-oversight-of-radiation-safety/employee-radiation-exposure-in-nuclear-power-plants

STUK 2021c. STUK supervises. Discharge of radioactive substances into the air. Viewed 10 February 2021. https://www.stuk.fi/web/en/stuk-supervises/nuclear-safety/stuk-s-duties-in-the-supervision-of-nuclear-safety/regulatory-oversight-of-radiation-safety/discharge-of-radioactive-substances-into-the-air

STUK 2021d. STUK supervises. Discharge of radioactive substances into the sea. Viewed 10 February 2021. https://www.stuk.fi/web/en/stuk-supervises/nuclear-safety/stuk-s-duties-in-the-supervision-of-nuclear-safety/regulatory-oversight-of-radiation-safety/discharge-of-radioactive-substances-into-the-sea

STUK 2021e. STUK supervises. Estimating the population's exposure. Viewed 10 February 2021. https://www.stuk.fi/web/en/stuk-supervises/nuclear-safety/stuk-s-duties-in-the-supervision-of-nuclear-safety/regulatory-oversight-of-radiation-safety/estimating-the-population-s-exposure

STUK 2021f. Säteilyn käyttäjälle. Radioaktiivisten aineiden kuljetus. Viewed 19 February 2021. https://www.stuk.fi/stuk-valvoo/sateilyn-kayttajalle/toiminnan-valvonta/radioaktiivisten-aineiden-kuljetus

STUK 2021g. Radioactivity in sold natural produce. Radiation and Nuclear Safety Authority. Viewed 4 March 2021. https://www.stuk.fi/web/en/stuk-supervises/stuk-monitors-the-radiation-safety-of-the-environment/continuous-regulatory-control-programme/radioactivity-in-food/radioactivity-in-sold-natural-produce

STUK 2021h. What is radiation. Health effects of radiation. Viewed 10 March 2021. https://www.stuk.fi/web/en/topics/what-is-radiation/health-effects-of-radiation

STUK 2021i. Emergencies. Examples of radiation doses and external dose rates. Viewed 26 November 2020. https://www.stuk.fi/web/en/topics/emergencies/examples-of-radiation-doses-and-external-dose-rates

STUK 2021j. Use of radiation in health care. Radiation doses of radiographic examinations. Viewed 14 January 2021. https://www.stuk.fi/web/en/topics/use-of-radiation-in-health-care/radiographic-examinations/radiation-doses-of-radiographic-examinations

STUK 2021k. Emergencies. The International Nuclear and Radiological Event Scale INES. Viewed 24 February 2021. https://www.stuk.fi/web/en/topics/emergencies/the-international-nuclear-and-radiological-event-scale-ines

STUK 2021l. The average radiation dose in Finland. Viewed 2 February 2021. https://www.stuk.fi/web/en/topics/what-is-radiation/the-average-radiation-dose-in-finland

Suolanen, V., Lautkaski, R., Rossi, J., Nyman, T., Rosqvist, T. & Sonninen, S. 2004. Käytetyn ydinpolttoaineen kuljetusriskitarkastelun päivitys. Posiva Oy. Raportti 2004-04.

The Finnish Wildlife Agency 2019. Taantuvien riistavesilintujen toimenpideohjelma.

Finnish Environment Institute 2018. Viewed 15 March 2021. Merilintujen pesimispopulaatioiden koko. https://www.ostersjon.fi/fi-FI/Luonto_ja_sen_muutos/Itameren_tila/Meriluonnon_tila/Merilinnut

Finnish Environment Institute 2020. The Finnish ecologically significant marine underwater areas (EMMA). Reports of the Finnish Environment Institute 8/2020.

Finnish Environment Institute 2021. Open data geographical location data service of the environmental administration.

OSF 2020. Official Statistics of Finland. Goods transport by road. e-publication, ISSN=2342-3617. Helsinki: Statistics Finland [referred: 14 January 2021. http://www.stat.fi/til/kttav/index_en.html

OSF 2021. Official Statistics of Finland. Greenhouse gases. e-publication, ISSN=1797-6065. Helsinki: Statistics Finland [referred: 5 January 2021. Available at: http://www.stat.fi/til/khki/index_en.html

SYKE 2018. TARKKA service. Viewed 1 June 2018. Available at: https://wwwi4.ymparisto.fi/i4/eng/tarkka/index.html?type=RGB&date=2021-06-27&datespan=1&name=DEFAULT&lang=en&zoom=5.31&lat=64.23000&lon=26.00000

SYKE 2020. Ghg emissions of Finnish municipalities and regions Viewed 21 December 2020. Available at: https://paastot.hiilineutraalisuomi.fi/

Talja, A. 2011. Ohjeita liikennetärinän arviointiin [Instructions for assessment of traffic vibrations]. VTT Tiedotteita – Research Notes 2569. Espoo, Finland. 35 p. + app. 9 p. Viewed 1 February 2021. http://www.vtt.fi/inf/pdf/tiedotteet/2011/T2569.pdf

VTT Technical Research Centre of Finland Ltd. 2017. LIPASTO Transport unit emissions database. Updated on 6 July 2017.

Statistics Finland, 2019a. Municipal key figures. Viewed 28 November 2019. https://www.stat.fi/tup/alue/kuntienavainluvut.html#?year=2019&active1=SSS

Statistics Finland, 2019b. The PX-Web databases of Statistics Finland, establishments of enterprises by municipality and establishments of enterprises by industry and region. Viewed 28 November 2019. http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__yri__alyr/?tablelist=true

Statistics Finland, 2021a. Statistics Finland's PX-Web databases. Population structure. Population according to age and sex by area. Viewed 28 March 2021. https://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__vrm__vaerak/

Statistics Finland, 2021b. Municipal key figures. Viewed 28 March 2021. https://www.stat.fi/tup/alue/kuntienavainluvut.html#?year=2019&active1=SSS

MEAE 2019. Final report of the National Nuclear Waste Management Cooperation Group. Publications of the Ministry of Economic Affairs and Employment. Energy. 2019:39. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161762/TEM_39_2019_KansallisenYdinjatehuollon.pdf?sequence=1

MEAE 2020a. Summary of sectoral low-carbon road maps. Publications of the Ministry of Economic Affairs and Employment. Energy. 2020:52. https://julkaisut.valtioneuvosto.fi/handle/10024/162851

MEAE 2020b. Report of the Ministry of Economic Affairs and Employment on the Environmental Impact Assessment Programme of Loviisa Nuclear Power Plant. Statement of Liaison Authority. VN/16076/2020.

MEAE 2020c. Energy and climate strategy. Viewed 5 January 2021. https://tem.fi/en/energy-and-climate-strategy

UNSCEAR 2000. United Nations Scientific Committee on the Effects of Atomic Radiation. "Sources and Effects of Ionizing Radiation". Report vol. II.

UNSCEAR 2013. Sources, effects and risks of ionizing radiation. UNSCEAR 2013 report, volume I, scientific annex A. "Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami". Accessed on 09/03/2021. https://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

UNSCEAR 2015. Developments since the 2013 UNSCEAR Report on the levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami. Accessed on 09/03/2021. https://www.unscear.org/unscear/en/publications/Fukushima_WP2015.html

Uusimaa Centre for Economic Development, Transport and the Environment 2015. Uusimaa Centre for Economic Development, Transport and the Environment 2015. Raportteja 109/2015. Uudenmaan ilmanlaadun bioindikaattoriseuranta vuonna 2014.

Uusimaa Centre for Economic Development, Transport and the Environment 2020. Uusimaa Centre for Economic Development, Transport and the Environment 2020. Raportteja 20/2020. Ilmanlaatu Uudellamaalla 2019.

Helsinki-Uusimaa Regional Council 2016. Missä maat on mainiommat. Uudenmaan kulttuuriympäristöt. Uudenmaan liiton julkaisuja E 176.

Helsinki-Uusimaa Regional Council 2019. Aineistot: Väestö. Viewed 17 March 2021. https://www.uudenmaanliitto.fi/tietopalvelut/uusimaa-tietopankki/aineistot/vaesto

Helsinki-Uusimaa Regional Council 2020a. The Helsinki-Uusimaa Land Use Plan 2050. Land use plan map, symbols and regulations as well as reports.

Helsinki-Uusimaa Regional Council 2020b. Hiilineutraali Uusimaa 2035 -tiekartta. Uudenmaan liiton julkaisuja B 61–2020.

Government 2021. Marin's government, Government Programme. 3.1 Carbon neutral Finland that protects biodiversity. (Accessed on 2 February 2021) https://valtioneuvosto.fi/en/marin/government-programme/carbon-neutral-finland-that-protects-biodiversity

VELMU map service 2019. VELMU map service data. Viewed 19 December 2019. https://paikkatieto.ymparisto.fi/velmu/index_eng.html

Vieraslajiportaali. Website. Viitattu 18.2.2021 https://vieraslajit.fi/

Vieraslajit.fi. Viewed 24 March 2021. Round goby. https://vieraslajit.fi/lajit/MX.53000

Visit Loviisa 2021. Svartholma Sea Fortress. Accessed on 01/02/2021. https://www.visitloviisa.fi/en/attractions-and-experiences/svartholma-sea-fortress/

VTT 2014. Environmental impact assessment report. Decommissioning of the FiR 1 research reactor. VTT Technical Research Centre of Finland Ltd. October 2014.

VTT 2021. News, Press release, 10 February 2021. https://www.vttresearch.com/en/news-and-ideas/used-fuel-vtts-research-reactor-set-further-use-usa

Vuolio, R. 1999. Räjäytystyöt. Suomen Maarakentajien Keskusliitto r.y.

Vuori, S., Lautkaski, R., Lehtilä, A., Suolanen, V. 2002. Katsaus eri energiatuotantomuotojen ympäristövaikutuksiin". VTT Tiedotteita - Research Notes 2127. VTT Prosessit, 2002.

Finnish Transport Infrastructure Agency 2020. TMS Data. Viewed 3 February 2021. https://vayla.fi/en/transport-network/data/open-data/road-network/tms-data

Ministry of the Environment 2015. Sedimenttien ruoppaus- ja läjitysohje. Ympäristöhallinnon ohjeita 1/2015. Available at: https://helda.helsinki.fi/bitstream/handle/10138/154833/OH_1_2015.pdf?sequence=1&isAllowed=y

ÅF-Consult Oy 2018. Loviisa power plant. Monitoring of cooling water and waste water in 2017.

ÅF-Consult Oy 2019. Loviisa power plant. Monitoring of cooling water and waste water in 2018.

Glossary and abbreviations

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Activation products	Radioactive substances generated as a result neutron radiation (e.g. from impurities carried to the reactor within water, the materials of the reactor's internals and the pressure vessel, or the materials of external structures in the reactor's vicinity). Activation products carried within water may migrate from the reactor to other systems and contaminate them.
Sub-criticality	A state in which the chain reaction maintained by the neutrons released in fission does not occur.
AVI	Regional State Administrative Agency
Becquerel (Bq)	The measurement unit of radioactivity, refers to the decay of one radioactive atom per second. The concentration of radioactive substances in foodstuffs is expressed in becquerels per unit of mass or volume (Bq/kg or Bq/l). Multiple units of becquerel include kilobecquerel (kBq), which is a thousand becquerels, megabecquerel (MBq), which is a million becquerels, and terabecquerel (TBq), which is a thousand billion becquerels.
dB	Decibel, or a unit of the sound pressure level, which has a logarithmic scale. An increase of 10 dB increases noise by tenfold.
Decontamination	The process of removing radioactive contaminants (contamination).
Dosimeter	A device that measures radiation doses.
Equivalent (e.)	Corresponding, equal in value.
Extensometer	A device for measuring, e.g. rock movements.
ELY centre	Centre for Economic Development, Transport and the Environment.
Espoo Convention	The UNECE Convention on Environmental Impact Assessment in a Transboundary Context. 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. Https://www.finlex.fi/fi/sopimukset/sopsteksti/1997/19970067 (in Finnish)
FiR 1	A TRIGA Mark II-type research reactor owned by VTT and located in Otaniemi, Espoo.
Fission products	Radioactive substances generated when fissile atomic nuclei (such as U-235, Pu-239) split into lighter substances. Fission products remain primarily in spent nuclear fuel. However, they may migrate from the reactor to other process systems as a result of a fuel leak, and thereby contaminate the other systems.
Fissurometer	A device for measuring rock mechanics. It measures changes in the distance between anchor points and allows the movements of a rock fissure to be monitored.
Diffuse source input	Chemical input entering an environment the exact origin of which is unknown. Examples include the nutrient input caused by agriculture in a catchment area.
Project area	The project area refers to the Hästholmen area, which is the location of the current functions of the power plant and the changes planned for them in the project.
Project owner	Fortum Power and Heat Oy, or the operator responsible for the implementation of the project to be reviewed in the EIA procedure.
Moderator	A substance used for the moderation of the neutrons generated in the nuclear reaction. The purpose of the moderator is to maintain the chain reaction. In a light water reactor, regular water (light water) is used as the moderator.
HP/CORD UV decontamination method	A method which can be used for the wide-scale chemical decontamination of the primary system to lower the plant's radiation levels and the activities of components. HP = permanganic acid, CORD = Chemical Oxidation Reduction Decontamination, UV = UV light.
Maintenance waste	Waste accumulated in the maintenance and repair of the nuclear power plant. Among other things, maintenance waste consists of contaminated protection and insulation materials, defective components and used tools. For the most part, maintenance waste is low-level waste.
Maintenance waste hall	A hall in the L/ILW repository in which low- or intermediate-level waste is stored. There are three maintenance waste halls in Loviisa power plant's L/ILW repository (HJT1, HJT2 and HJT3).

IAEA	International Atomic Energy Agency
IBA and FINIBA areas	IBA areas are internationally significant bird areas, and FINIBA areas are nationally significant bird areas in Finland. The parties responsible for mapping the areas are the Finnish Environment Institute and BirdLife Finland.
INES	The International Nuclear and Radiological Event Scale (INES) is a scale used for the classification of various events related to nuclear power plants or the use of radiation. It describes the severity of an emission of radioactive material and radiation exposure.
Plant parts to be made independent	The nuclear power plant's plant parts to be made independent are the interim storage for spent nuclear fuel, the liquid waste storage and the solidification plant, the operation of which will continue after the operation of the power plant units. In addition to the above, the use of the L/ILW repository will continue. 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.
Cooling water	Cooling water is seawater used to cool the steam from the turbines back into water in a condenser. The water is then pumped back to the steam generators. Cooling water does not come into contact or mix with the process waters or primary and secondary system waters of the nuclear power plant.
International hearing	A hearing procedure in accordance with the Espoo Convention on the assessment of the transboundary environmental impacts, in which different countries can participate.
Intermediate-level waste	Nuclear waste with an activity level sufficiently high to require effective radiation shielding during the handling of the waste. The waste's activity concentration is usually between 1 MBq/kg and 10 GBq/kg. Intermediate-level waste is generated during both the operation and decommissioning of the power plant.
Light water reactor	A reactor type in which regular water is used for cooling and as a moderator. Most nuclear power plant reactors in the world are light water reactors.
Solidified waste	Liquid radioactive waste rendered into solid form by mixing it with a suitable binder (such as cement and other components).
Solidified waste hall	A hall in the L/ILW repository in which solidified waste is stored.
Solidification plant	A plant in which liquid radioactive waste is rendered into solid form by mixing it with a suitable binder. At Loviisa power plant's solidification plant, liquid waste is mixed with cement and other components.
Kilovolt (kV)	A volt (symbol V) is a derived unit of voltage in the SI system. 1 kV = 1,000 V.
Collective radiation dose	A collective (radiation) dose refers to the combined effective radiation dose of individuals exposed to radiation.
Contamination	Radioactive impurity.
Conventional	Normal, not related to radioactivity.
Conventional waste	Conventional and hazardous waste that is not radioactive.
Convergence measurement	The measurement of changes in the distance between fixed points. Often used to measure transformations in rock caverns.
Criticality	Criticality refers to a state in which the production and loss of the neutrons generated in fission and maintaining a chain reaction is in equilibrium so that the chain reaction continues smoothly.
Criticality safety	Criticality safety refers to the means and restrictions employed to control the criticality of a nuclear reactor and the prevention of super-criticality. The goal is to prevent the emergence of a geometric order of criticality or super-criticality.
Dry silo	A structure in the floor of the reactor hall consisting of 153 steel pipes. The steel pipes of the dry silo serve as a storage space for intermediate-level dry waste, such as any control rods' connection rods removed from use.
Dry waste handling facility	Areas in Loviisa power plant in which radioactive waste other than liquid radioactive waste is handled and packed.
Spent nuclear fuel	Nuclear fuel removed from the nuclear reactor after operation. Spent nuclear fuel contains fission products and is highly radioactive.

Interim storage for spent nuclear fuel	A water pool storage in the Loviisa power plant area in which high-level spent nuclear fuel removed from the reactor is stored. The interim storage consists of two water pool storages, KPA1 and KPA2. The spent nuclear fuel is transported from the interim storage to Posiva for encapsulation and final disposal.
Decommissioning	Dismantling a completely closed nuclear facility so that no special measures are needed in the plant area due to radioactive substances originating from the dismantled nuclear facility. Decommissioning also includes the handling, interim storage and final disposal of the low- and intermediate-level waste (decommissioning waste) accumulated in the dismantling of the plant. In addition, conventional dismantling waste may be generated in decommissioning.
Decommissioning waste	Waste generated in the decommissioning of a power plant or other nuclear facilities after operation that contains radioactivity and is deposited in the L/ILW repository for final disposal. See "dismantling waste".
LAeq	The midrange sound level over a particular period used to estimate the strength of fluctuating noise.
Littoral	The shore area.
Final disposal	The permanent disposal of radioactive waste in such a manner that the repository site does not need supervision, and the radioactivity of the waste does not pose a hazard to humans or the environment.
Final disposal facility	A nuclear facility designed for the final disposal of radioactive waste. Examples include the L/ILW repository.
Final disposal hall	A hall in the final disposal facility in which radioactive waste is stored/deposited for final disposal. In the L/ILW repository of Loviisa power plant, final disposal halls include maintenance waste halls and the solidified waste hall.
Loviisa nuclear power plant/ power plant	The nuclear power plant located on the island of Hästholmen in Loviisa, Finland, and the related functions and operations.
Mansievert (manSv)	The unit of a collective radiation dose.
Low-level waste	Nuclear waste with an activity level sufficiently low to allow its handling without any special radiation shielding measures. The waste's maximum activity concentration is usually 1 MBq/kg. Low-level waste is generated during both the operation and decommissioning of the power plant.
Millisievert (mSv)	A thousandth of the radiation dose unit sievert (see "sievert").
MW	Megawatt. A watt (W) is the unit of power and radiant flux in the SI system. 1 MW = 1,000,000 W.
Natura 2000	A nature protection programme of the European Union aiming to protect the core areas of the species and habitats listed in the Habitats Directive and Birds Directive.
Liquid waste storage	A hall at Loviisa power plant where liquid radioactive waste is stored.
Pressurised water plant	A light water reactor type in which water is used as a coolant and a moderator. The pressure of the water is kept so high that the water will not boil despite the high temperature. The water that has passed through the reactor core releases its heat into the secondary system water in separate steam generators, where the secondary system water is vaporised and used to drive a turbine.
Long-term safety	The safety of the final disposal of radioactive waste with regard to the radiation exposure of people and the environment after the final disposal facility has been closed. Depending on the activity of the waste, the timespan of the review can be from hundreds to hundreds of thousands of years.
Long-term safety case	A set of documents that demonstrates how the requirements concerning the long-term safety of the final disposal of nuclear waste are met.
Fuel integrity	A situation in which a fuel rod remains intact and does not release any radioactive substances. Fuel failure refers to a situation in which a fuel rod loses its integrity.
PRA	Probabilistic Risk Assessment.
Primary system	A cooling system for removing heat from an energy source such as a reactor core.
Process wastewater	Wastewater generated in the power plant process.
Dismantling waste	An overall concept for waste generated in connection with the decommissioning and dismantling of nuclear facilities. Dismantling waste includes both decommissioning waste that contains radioactivity and non-radioactive conventional waste.

Radioactive substance	A substance that decays into other substances and concurrently emits ionising radiation.
Radioactive waste	Radioactive waste refers to radioactive substances and equipment, goods or materials contaminated by radioactivity that are not required and that must be rendered safe because of their radioactivity.
Reactor pressure vessel	A vessel able to withstand internal pressure in which the reactor is located. Text
SAC	A Special Area of Conservation related to the Natura 2000 programme.
SCI	A Site of Community Importance related to the Natura 2000 programme.
Secondary system	A cooling system for removing heat from the primary system.
Sievert (Sv)	The unit of radioactive dose that represents the effect of radiation on the human body. Fractions of it include a millisievert (mSv), which is a thousandth of a sievert, and a microsievert (μSv), which is a millionth of a sievert.
SPA	A Special Protection Area pursuant to the Birds Directive and related to the Natura 2000 programme.
STUK	The Radiation and Nuclear Safety Authority, which is the authority supervising safety in Finland, a research institution and an expert organisation.
Control rod **Control rod's absorber element** **Control rod's connection rod**	Control rod: A moveable component between the fuel bundles or fuel rods in the reactor core used to control the core's reactivity. The control capability of the control rods is based on their neutron-absorbing quality. Control rods are usually grouped into the control rods used for a reactor trip in the reactor and the rods used for the control of the reactor during operation. In big reactors, the controlling rods are further divided into several groups fulfilling a different role in the control. Absorber element (neutron absorber): A medium or object which absorbs free neutrons. Control rods are neutron absorbers, and their insertion into the reactor core reduces reactivity. The control rod of a VVER-440 reactor is composed of an absorber element and fuel extension connected to one another with a connection rod. The absorber is located on top of the fuel extension. The absorber is tasked with absorbing neutrons and thereby reducing reactivity when a control rod's absorber element has been inserted into the reactor core.
Sanitary wastewater	Wastewater that originates from the toilets, kitchens, washrooms of residences, offices, buildings and institutions, as well as equivalent areas and equipment, and from business operations.
Targeted dose constraint	A nuclear power plant must have dose constraints in place that are lower than those provided in the Radiation Decree.
MEAE	The Ministry of Economic Affairs and Employment. The coordinating authority (liaison authority) in the environmental impact assessment procedure.
Thermocline	A layer in a body of water in which the water's temperature drops rapidly.
Terabecquerel	A unit of radioactivity; see "becquerel".
Transuranic elements	Transuranic elements, i.e. substances heavier than uranium, generated in U-238's neutron captures, for example. In normal situations, transuranic elements remain within the protective cladding of a fuel rod, but in connection with fuel rod leaks, they may be released into the plant's systems.
TWh	Terawatt-hour. A unit of energy used to express the amount of energy, electricity and heat produced.
Hazardous waste	Hazardous waste includes decommissioned substances or items that may cause special danger, or harm to health or the environment. Hazardous waste includes energy-saving lightbulbs and other fluorescent lights. The former term in Finnish was 'ongelmajäte'.
Clearance from regulatory control	If waste generated in the radiation controlled area does not exceed the limits set by the authorities, it can be cleared from regulatory control. Waste cleared from regulatory control can be handled as conventional waste.
Radiation controlled area	A radiation controlled area refers to a work area where special safety guidelines must be observed to ensure radiation protection. Access to radiation controlled areas is controlled. At a minimum, those rooms in the facility where the external dose rate can exceed 3 μSv/h or where a 40-hour weekly stay can cause an internal dose in excess of 1 mSv per year due to the radionuclides originating from a nuclear facility must be designated as controlled areas. (YVL Guide C.2)

Clearance limits	The limit value, expressed as an activity concentration, at the level of or below which materials generated in operations subject to a licence may be cleared from regulatory control.
Release barrier	A technical or natural structure or material that provides long-term safety functions – in other words, prevents radioactive substances from being released into the environment.
L/ILW repository	Loviisa power plant's final disposal facility for low- and intermediate-level waste. The abbreviation L/ILW stands for 'low- and intermediate-level waste'. The English translation 'operational waste' is used for both Finnish terms 'voimalaitosjäte' (an obsolete term) and 'ydinlaitosjäte'.
Power plant area	The area used by the nuclear power plant units and other nuclear facilities in the same area, or the area surrounding them, where moving and staying is restricted by a decree of the Ministry of the Interior issued by virtue of Chapter 9, section 8 of the Police Act (872/2011) (STUK Y/2/2018). The Loviisa nuclear power plant area covers the islands of Hästholmen and Tallholmen and their adjacent sea area, the Kirmosund causeway and the main gate building.
VTT	VTT Technical Research Centre of Finland Ltd.
Seepage water	Groundwater that accumulates in a shaft or tunnel built or excavated in the bedrock. At Loviisa power plant, seepage waters are generated in the L/ILW repository.
WANO	World Association of Nuclear Operators
Weser	What is commonly referred to as the Weser case (C-461/13) involves a ruling of the EU Court of Justice related to the river Weser in Germany, in which the Court adopted the view that the environmental objectives of water resources management were legally binding in licensing considerations concerning projects. According to the Weser ruling, licences may not be issued to projects which may have adverse effects on the state of a body of surface water.
Nuclear material	Specific fissionable materials suitable for generating nuclear energy, such as uranium, thorium and plutonium.
Nuclear waste	A generic term for the radioactive waste generated in connection with, or as a consequence of, the operation or decommissioning of a nuclear facility. Nuclear waste is low-level or intermediate-level waste or high-level spent nuclear fuel.
Nuclear facility	A nuclear facility refers to plants used to generate nuclear energy, including research reactors, facilities carrying out extensive final disposal of nuclear waste, as well as facilities used for the extensive production, use, handling or storage of nuclear material and nuclear waste. For example, at Loviisa nuclear power plant, once the power plant units have been decommissioned, the nuclear facility will consist of plant parts to be made independent.
Operational waste	Low- and intermediate-level waste generated in nuclear facilities, such as nuclear power plants. For example, operational waste is generated in the handling of radioactive liquids and gases, and in maintenance and repair work carried out in the radiation controlled area.
Nuclear fuel	Uranium (or plutonium) intended to be used in the reactors of nuclear power plants. Nuclear fuel does not burn in the sense that it would react with oxygen (as happens when coal or wood is burned); instead, heat is produced when the nuclei of uranium are split in chain reactions. The 'combustion products' are isotopes of lighter elements generated in the chain reaction. Most are radioactive. The uranium in the nuclear fuel used by Loviisa power plant is in the form of uranium oxide (UO_2).
Nuclear power plant	A nuclear power plant refers to a nuclear facility, equipped with a nuclear reactor, used to generate electricity or heat, or a plant complex formed by power plant units and other associated nuclear facilities in the same location. A nuclear power plant comprises one or more nuclear power plant units, each of which has one reactor, and one or two turbines and generators.
Nuclear power plant unit/ power plant unit/plant unit	Loviisa power plant consists of two nuclear power plant units, Loviisa 1 and Loviisa 2.
Coordinating/liaison authority	The Ministry of Economic Affairs and Employment is the coordinating/liaison authority in this EIA procedure.
ME	The Ministry of the Environment. Serves as the coordinating authority for the international hearing in Finland.
EIA	Environmental impact assessment
YVL Guides	Nuclear safety guides; regulatory guides published by the Radiation and Nuclear Safety Authority that specify the detailed safety requirements for the use of nuclear energy.

APPENDIX 1

EIA Report Experts

The Environmental Impact Assessment Report was prepared jointly by Ramboll Finland Oy and Fortum Power and Heat Oy, the project owner. The following experts took part in the preparation of the report:

Expert	Duties and qualification
Antti Lepola **Project director**	**M.Sc. (Agriculture and Forestry) (forestry planning)** Lepola has 30 years' experience in environmental research and planning. His core competence areas include the environmental impact assessment of projects, water, environmental and chemical permit applications, as well as related surveys. Lepola has long experience of environmental consulting related to energy production and the environmental impact of the industry. Lepola has participated in more than 70 EIA procedures and worked as a project manager in more than 30 EIA procedures.
Anna-Katri Räihä EIA project manager and expert (subconsultant)	**M.Sc. (Agriculture and Forestry) (environmental economics)** Räihä has more than 10 years' experience in environmental consulting and project management related to the environmental projects of several fields of industry. Her core competence includes environmental impact assessments, international hearings in the EIA, environmental legislation and greenhouse gas calculations. Räihä has worked as a project manager and project coordinator in several extensive EIA procedures, and as an expert in environmental issues in numerous EIA procedure impact assessments (including greenhouse gas emissions and their impact on the environment, traffic impact, impact of the use of natural resources). Her EIA competence also includes various areas of communication and stakeholder engagement.
Sanna Sopanen EIA coordinator, surface waters	**Ph.D. (aquatic ecology)** Sopanen has extensive experience of surveys related to the quality of surface waters and the aquatic environment, spanning 20 years. Her special expertise is related to the interactive relationships in the aquatic ecosystem, and the factors affecting them in both inland waters and sea areas. Sopanen has participated in numerous environmental impact assessments (EIA), licensing and land use planning projects, nature surveys, Natura assessments and various water system surveys as an expert on the impact on water systems.
Mikko Happo Health impacts	**Ph.D. (environmental health); docent (toxicology of combustion emissions)** Happo's job description includes expert tasks related to air quality as well as development tasks in air quality and health services. In addition, his duties include expert services related to the environmental and health sector and its reporting concerning air quality, emissions into the air, or other environmental and health impacts.
Anne Kiljunen Air quality	**M.Sc. (inorganic and analytical chemistry)** Kiljunen works as an environmental expert and has seven years' experience of various environmental expert tasks related to air quality. She has experience of various tasks in the field, the reporting of measurements, preparation of environmental permit applications and environmental impact assessments.
Kirsi Koivisto Vibration	**M.Sc. (Tech.) (foundation engineering and soil mechanics)** Koivisto has worked in the field of vibration inspections and studies for more than 10 years. She has extensive experience in the methods used in Finland to dampen vibration and in carrying out various vibration inspections. Koivisto's area of specialisation includes planning, studying and development of dampening methods, as well as assessing the impact of vibration.
Heini Koutonen Greenhouse gas emissions	**M.Sc. (Agriculture and Forestry) (environmental economics)** Koutonen works as an environmental consultant in diverse projects related to climate impact assessments, emission calculations, lifecycle assessments and material flow analyses. She specialises in the calculation of greenhouse gas emissions and carbon sinks, and in her previous jobs, has prepared carbon neutrality roadmaps, climate impact assessments and emission calculations at product, corporate, project and regional levels.
Timo Laitinen Landscape and land use	**M.Soc.Sc. (social and economic geography)** Laitinen has more than six years' experience of EIA procedures and related impact assessments. He has participated in approximately 30 EIA procedures as an appraiser of impacts (landscape and cultural environment, land use and land use planning) and worked as a coordinator in ten EIA procedures.
Otso Lintinen Ichthyofauna and fishing	**M.Sc. (Agriculture and Forestry) (fishing industry)** Lintinen works as a project manager in various projects related to water research. He has 11 years' experience of corresponding tasks. His area of specialisation is studies concerning the fishing industry.

Expert	Duties and qualification
Timo Metsänen Avifauna (subconsultant)	**Bachelor of Natural Resources, Environmental Planning, nature planner (special vocational qualification)** Metsänen has more than 20 years' experience of various avifauna surveys. He works as a subconsultant for Ramboll Finland in the project (Tmi Luontoselvitys Metsänen).
Juho Mäkelä waste management	**B.Sc. (Engineering) (environmental technology** Mäkelä has more than five years' experience of tasks related to material efficiency, waste management and earth construction. He works as a planner in projects related to the utilisation of materials. He has also worked as an independent quality controller in earth construction projects that require an environmental permit.
Jussi Mäkinen Nature and avifauna	**M.Sc. (environmental ecology)** Mäkinen has 16 years' experience of aligning natural values and the planning of land use in various land use planning and construction projects. Mäkinen specialises in the impact assessments of projects with considerable environmental impacts and the preparation of the required nature and environmental surveys. Mäkinen is one of Finland's leading experts in matters related to the Natura 2000 network (assessments, deviation procedures). His other areas of specialisation include ecological network surveys, ecological compensation, exemption permit applications, as well as various species surveys concerning avifauna especially.
Ville Mäntylä Dismantling operations	**Architectural drafter** Works as a project manager and harmful substance expert in projects related to construction. He has 18 years' experience of corresponding tasks. His areas of specialisation include dismantling consultation projects, as well as asbestos and harmful substance surveys.
Pekka Onnila Groundwater, soil and bedrock	**M.Sc. (soil science)** Onnila has extensive experience of the assessment of groundwater risks and impacts related, for example, to EIA projects, land use planning and environmental permits. In addition, Onnila is responsible for groundwater monitoring related to various functions and forms of land use.
Venla Pesonen Social impacts	**M.Sc. (environmental science); B.Sc. (Engineering) (environmental technology)** Pesonen works as an interaction designer in the interaction team of the land use unit. She has several years of diverse experience of the assessment of impacts targeting people, planning and implementation of stakeholder engagement, the facilitation of events, as well as methods of interactive information gathering, analysis and reporting in various projects.
Arttu Ruhanen Noise	**B.Sc. (Engineering) (environmental technology)** Ruhanen has more than 10 years' experience of the preparation of environmental studies. Every year, he works in several dozen projects as a planner or project manager studying noise. Ruhanen's special expertise in matters related to noise focuses on the industry, noise studies in the mineral aggregate operations and wind power, as well as various noise measurements.
Tiina Sainio Traffic	**M.Sc. (Engineering) (structural engineering)** Sainio has more than five years' experience in the preparation of traffic studies. She works as a principal planner in various projects involving traffic studies and planning. Sainio specialises in traffic safety as well as the transport and traffic planning of streets and various industrial and service sites.
Heikki Savikko Regional economy	**M.Sc. (Engineering) (materials technology, industrial economics)** Savikko has experience in impact and materiality assessments, the modelling of economic impacts as well as materials and resource efficiency, and of work related to lifecycle assessments. Among other things, he has modelled cash, resource and material flows at the national, regional and corporate levels, and formed links from resource flows to environmental and economic data. He has also participated in the development of indicators and assessment means for resource efficiency and the wise use of resources.

Expert	Duties and qualification
Jarkko Ahokas	**M.Sc. (Engineering) (energy technology)** Nuclear safety
Nici Bergroth	**M.Sc. (Engineering) (process technology)** Nuclear technology and safety
Tapani Eurajoki	**M.Sc. (Engineering) (nuclear and energy technology)** Nuclear waste, long-term safety, external waste
Mika Harti	**M.Sc. (Engineering) (energy technology)** Nuclear safety
Juha-Pekka Jurvanen	**M.Sc. (Meteorology)** Preparedness measures, dispersion of cooling water
Matti Kaisanlahti	**M.Sc. (Engineering) (energy technology)** External waste
Laura Kekkonen	**M.Sc. (Engineering) (nuclear technology)** Procurement of nuclear fuel, spent nuclear fuel
Pasi Kelokaski	**M.Sc. (Radiochemistry)** Decommissioning of the power plant
Markku Lahti	**D.Sc. (Technology) (water economy and hydrology)** Hydrology and environmental impacts, cooling water modelling
Jesse Lavonen	**Bachelor (Engineering; amk) (energy and environmental technology)** Decommissioning of the power plant, external waste
Maria Leikola	**D.Sc. (Technology) (materials technology)** Decommissioning of the power plant
Joni Niiranen	**Bachelor (Engineering; amk) (environmental technology)** Loviisa power plant's EHS expert, The power plant's environmental perspectives
Satu Ojala	**M.Sc. (Limnology)** The power plant's perspectives related to waterway
Maiju Paunonen	**Bachelor (Engineering; amk) (environmental technology)** Spent nuclear fuel, storage and final disposal
Anu Ropponen	**M.Sc. (Engineering) (environmental technology)** The power plant's environmental perspectives
Tommi Ropponen	**Ph.D. (Physics)** Radiation safety, accidents
Teemu Seitomaa	**M.Sc. (Engineering) (energy technology)** Decommissioning of the power plant

APPENDIX 2

Report of the Ministry of Economic Affairs and Employment on the environmental impact assessment programme of Loviisa nuclear power plant

On 13 August 2020, Fortum Power and Heat Oy submitted to the Ministry of Economic Affairs and Employment an assessment programme (EIA programme) in accordance with the Act on the Environmental Impact Assessment Procedure (252/2017). The assessment programme concerns the continuation of the operation of Loviisa Nuclear Power Plant for a maximum of approximately 20 years after the expiry of the current operating licences, after which the nuclear power plant would be decommissioned. Alternatively, Loviisa Nuclear Power Plant could already be decommissioned after the operating licences already in force have ended.

1. Environmental impact assessment procedure and project information

The aim of the Act on the Environmental Impact Assessment Procedure (EIA) is to promote the environmental impact assessment and the uniform integration of assessments into planning and decision-making, while also increasing access to information and participation for all.

The assessment programme is the plan of the party responsible for the project for the necessary studies and the organisation of an assessment procedure for the assessment of environmental impacts. The assessment programme shall contain information on the project, its options and a description of the current state of the environment. Section 3 of the Government Decree on the EIA procedure (277/2017, EIA Decree) lays down the information contained in the programme and the information presented therein.

In the next phase of the EIA procedure, the party responsible for the project shall prepare a report on the environmental impact assessments on the basis of the assessment programme and the statement of the liaison authority. The liaison authority shall communicate the statement by means of a public notification, inform at least one of the newspapers generally circulating in the area covered by the project, request opinions on the report and reserve the possibility for the expressing of opinions. After reviewing the adequacy and quality of the assessment report, the liaison authority shall prepare a reasoned conclusion on the significant environmental impact of the project and communicate it by means of a public notification. The environmental impact assessment report and reasoned conclusion shall be attached to any projects for authorisation under the Nuclear Energy Act (990/1987).

According to section 10 of the EIA Act, the Ministry of Economic Affairs and Employment acts as the joint authority for projects concerning nuclear facilities referred to in the Nuclear Energy Act.

1.1 PARTY RESPONSIBLE FOR PROJECT

The party responsible for the project is Fortum Power and Heat Oy (Fortum). Ramboll Finland Oy has acted as a consultant for Fortum Power and Heat Oy in the environmental impact assessment.

1.2 THE PROJECT AND ITS OPTIONS

The assessment programme concerns the continued operation and, alternatively, the decommissioning of Loviisa Nuclear Power Plant. The valid operating licences for the Loviisa 1 and Loviisa 2 Nuclear Power Plant units and their buildings and storages necessary for the management of nuclear fuel and nuclear waste will expire in 2027 and 2030. The programme also deals with the use of a low- and medium-level nuclear waste disposal facility (VLJ repository). The valid operating licence for the VLJ repository expires in 2055. The programme examines three different options for further operations.

Under option 1 (VE1), the company would continue to use the Loviisa 1 and 2 Nuclear Power Plant units for a maximum of approximately 20 years after the current operating licences have ended. The use of buildings and storages necessary for the maintenance of nuclear fuel and nuclear waste from the Loviisa 1 and 2 Nuclear Power Plant units would also continue with the necessary extensions. It would also be possible to process, intermediately store and dispose of small amounts of radioactive waste generated elsewhere in Finland at the nuclear power plant.

Under option 0 (VE0), the nuclear power plant would be decommissioned at the end of the existing operating licences. Buildings and storages necessary for the maintenance of nuclear waste from plant units would continue to be used until they become redundant and decommissioned.

Option 0+ (VE0+) is, otherwise, the same as option 0, but it would also be possible to process, intermediately store and dispose of small amounts of radioactive waste generated elsewhere in Finland at the nuclear power plant.

1.3 PROJECT RELATION TO OTHER PROJECTS

According to the assessment programme, the project is not directly related to other projects currently underway or planned at Loviisa Nuclear Power Plant.

The spent fuel of Loviisa Nuclear Power Plant is to be transferred to Posiva Oy's spent fuel disposal facility in Olkiluoto. The project will, therefore, have an impact on Posiva Oy's spent fuel disposal facility and the amount of spent nuclear fuel transferred there.

The assessment procedure examines various options that include the possibility of processing, intermediate storing and disposing of small amounts of radioactive waste generated elsewhere in Finland. In other words, the project is also related to projects in other parts of Finland that are typically carried out by industry, health care and research institutes, which result in the development of the aforementioned low- and medium-level waste.

The project is also related to decommissioning projects of VTT Oy's FiR 1 research reactor and the radioactive structural materials research laboratory located in Otakaari 3 (OK3). The assessment procedure takes into account the possible intermediate storage of low- and medium- level demolition waste from decommissioning projects at Loviisa Nuclear Power Plant and the final disposal in the VLJ repository. In addition, the procedure provides for the intermediate storage of spent and unused nuclear fuel from the FiR 1 research reactor at Loviisa Nuclear Power Plant. Intermediate storage would continue until VTT Technical Research Centre of Finland Ltd proceeds in the further preparation of nuclear fuel.

The project may relate to various plans and programmes for the use of natural resources and environmental protection, such as national target programmes and international commitments.

The programme states that, in the future, the project may have an impact on the further use of existing power lines and on the possible utilisation of thermal energy (waste heat) produced by the plants, but their examination has been excluded from the current assessment procedure.

2. Licence procedures

The operation and decommissioning of a nuclear facility requires a licence in accordance with the Nuclear Energy Act. The licences are issued by the Government. The project may also require other licences granted by the STUK Radiation and Nuclear Safety Authority in accordance with section 21 of the Nuclear Energy Act.

The valid operating licences for the plant units of Loviisa Nuclear Power Plant will expire in 2027 (Loviisa 1) and 2030 (Loviisa 2). The valid operating licences for buildings and warehouses and their extensions for nuclear fuel and nuclear waste needed for the management of nuclear fuel and nuclear waste in plant units will expire in 2030. The valid operating licence of the nuclear power plant waste disposal facility (VLJ repository) expires in 2055.

If the party responsible for the project wishes to continue using nuclear power plant units, new operating licences must be applied for said plant units. Otherwise, a licence must be sought for the decommissioning of the nuclear facility. If the party responsible for the project wishes to use the VLJ repository for a longer period of time than the valid licence allows, this also requires applying for a new operating licence. Due to the longer operating time than the VLJ nuclear power plant units, it is practical to separate the VLJ repository licence into a separate licence decision.

Other possible licences discussed in the assessment programme include permits in accordance with the Land Use and Building Act (132/1999), an environmental permit in accordance with the Environmental Protection Act (527/2014), a water management permit in accordance with the Water Act (587/2011) and permits in accordance with the Chemicals Act (390/2005). The above acts also involve different notification obligations.

The existing local detailed plan for the area makes it possible to implement the options set out in the assessment programme.

2.1 ENVIRONMENTAL IMPACT ASSESSMENT

Fortum Power and Heat Oy submitted the assessment programme to the Ministry of Economic Affairs and Employment on 13 August 2020. The submission of the assessment programme triggered the EIA procedure.

Fortum Power and Heat Oy shall prepare an environmental impact assessment report on the basis of an assessment programme and an opinion issued by the liaison authority. The company has estimated that it will submit the report to the liaison authority in the autumn of 2021.

The project is also subject to an intergovernmental assessment procedure for possible cross- border environmental impacts. In the procedure, the so-called Opportunity for States covered by the Espoo Agreement (67/1997) and their citizens to participate in the environmental impact assessment procedure is reserved. The Ministry of the Environment is responsible for the organisation of the international consultation.

2.2 OPERATING LICENCES

The use of nuclear power plant units and the buildings and warehouses necessary for their operation and the maintenance of nuclear waste, as well as the use of the VLJ repository, require government-issued operating licences as provided for in section 20 of the Nuclear Energy Act.

The licence to operate a nuclear facility requires due consideration of the safety requirements of the Nuclear Energy Act, the safety of workers and the population, as well as the protection of the environment. The applicant shall have, at their disposal, adequate and appropriate methods for arranging nuclear waste management and, at their disposal, the necessary expertise. The applicant is considered to have the financial and other necessary conditions to carry out operations safely and in accordance with Finland's contractual obligations. In addition, the nuclear facility and its use must meet, among other things, the principle of the overall interest of society.

2.3 DECOMMISSIONING LICENCE

After discontinuing the operation of a nuclear facility, the holder of a licence, in accordance with section 20 of the Nuclear Energy Act, is obliged to initiate measures to decommission the nuclear facility. Decommissioning is carried out in accordance with the plan and requirements referred to in section 7g of the Nuclear Energy Act. In addition, the licence holder must apply for a licence for the decommissioning of a nuclear facility. The licence shall be applied for in sufficient time so that the authorities have adequate time to evaluate the application before the end of the operating licence of the nuclear facility. The assessment programme provides two alternative times for decommissioning. In option 1, the decommissioning would take place between 2050 and 2060

In options 0 and 0+, decommissioning would take place already between 2030 and 2040.

The licence for the decommissioning of a nuclear facility requires, among other things, due account to be taken of safety requirements under the Nuclear Energy Act, the safety of workers and the population, as well as environmental protection.

3. Information and consultation on the assessment programme

The Ministry of Economic Affairs and Employment announced the assessment programme in accordance with the EIA Act and Decree in the areas affected by the project and organised a consultation on the matter. As of 27 August 2020, the consultation was announced on the websites of the Ministry and the municipalities of the affected area, as well as in the following newspapers: Helsingin Sanomat, Hufvudstadsbladet, Kymen Sanomat, Loviisan Sanomat, Uusimaa, Itäväylä, Östnyland and Nya Östis. The EIA programme was available to view during 27 August-26 October 2020 on the website of the Ministry of Economic Affairs and Employment.

Together with the responsible party to the project, the Ministry organised a public event in Loviisa on 3 September 2020. Six people attended the public event on site and about 50 people online.

The Ministry of Economic Affairs and Employment requested opinions on the assessment programme from the Ministry of the Environment, Ministry of the Interior, Ministry of 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, Regional State Administrative Agency of Southern Finland, Uusimaa ELY Centre, Helsinki-Uusimaa Regional Council, Finnish Safety and Chemicals Agency Tukes, Finnish Environment Institute, Eastern-Uusimaa Emergency Services Department, Eastern Uusimaa Police Department, City of Loviisa, Municipality of Myrskylä, Municipality of Pyhtää, City of Porvoo, Municipality of Lapinjärvi, City of Kouvola, AKAVA ry, Confederation of Finnish Industries EK, Finnish Energy ET, Geological Survey of Finland, Greenpeace, Fennovoima Oy, Fingrid Plc, The Central Union of Agricultural Producers and Forest Owners (MTK), Finnish Heritage Agency, Natur och Miljö rf, Posiva Oy, VTT Technical Research Centre of Finland, Teollisuuden Voima Oyj TVO, Finnish Confederation of Finnish Industries STTK, Finnish Association for Nature Conservation, Suomen Yrittäjät ry, Central Organisation of Finnish Trade Unions SAK ry and WWF.

In addition to those mentioned, other parties and citizens have also had the opportunity to express their views on the project. The opinions and considerations that were expressed concerning the EIA programme are summarised in section 4.

In a request for action sent on 25 August 2020, the Ministry of Economic Affairs and Employment asked the Ministry of the Environment to organise an international consultation in accordance with the Espoo Agreement in connection with the EIA procedure of Loviisa Nuclear Power Plant and to forward the feedback received to the EIA liaison authority (Ministry of Economic Affairs and Employment) for consideration in its opinion on the EIA programme.

On 27 August 2020, the Ministry of the Environment sent a notification of the project to Sweden, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Norway and Russia. In addition, all other parties to the Espoo Agreement were informed about the project's EIA procedure. Austria and the Netherlands replied that they wished to receive the notification provided to them under the Espoo Agreement.

The alert, the EIA programme and the statements and opinions received during the consultation period can be found on the website of the Ministry of Economic Affairs and Employment at https://tem.fi/en/loviisa-1-and-2-eia-programme.

4. Summary of statements and opinions

A total of 39 statements and opinions of the national consultation were submitted to the ministry. The Finnish Heritage Agency announced that it had forwarded the request for a statement to the regional museum of responsibility of Eastern Uusimaa (Porvoo Museum). The following organisations did not respond to a request for comment: the Ministry of Defence, Ministry of Transport and Communications, Ministry of Social Affairs and Health, Finnish Environment Institute, Municipality of Myrskylä, City of Kouvola, AKAVA ry, Confederation of Finnish Industries, Finnish Energy, The Central Union of Agricultural Producers and Forest Owners (MTK), Suomen Yrittäjät ry, WWF.

In the statements, the assessment programme is considered to be largely comprehensive. However, the parties behind the statements made some individual comments that should be taken into account and assessed in the EIA procedure. Comments were received, especially, on the water impacts of the nuclear power plant and accident modelling.

The statements also commented on the project options set out in the programme. Several agents behind the statements said they were in favour of continuing the use of the nuclear power plant based on climate objectives and economic factors, among other things. Support for decommissioning was generally justified by the abandonment of nuclear energy or by the fact that the Loviisa plants are already old. On the other hand, modernisations also appeared in the statements. In international consultation under the Espoo Agreement, Sweden, Estonia, Russia, Norway, Denmark, Lithuania, Germany and Austria have announced that they will participate in the EIA procedure for the project. Latvia and Poland do not consider themselves to be target parties and will not participate in the EIA procedure. However, the countries wish to be informed of the assessment report. A total of 20 statements were received from EU citizens and organisations. The international consultation highlighted the risks of a serious nuclear accident and its consequences.

Bulgaria, Canada, Greece, Romania and Hungary replied to the information sent on the pending employment of the EIA procedure. The countries do not consider themselves to be target parties and it is, therefore, not necessary to continue the procedure laid down in the Espoo Agreement. Romania and Hungary request to be notified of the assessment report.

The statements and opinions are available on the website of the Ministry of Economic Affairs and Employment.

4.1 REQUESTED STATEMENTS OF AUTHORITIES

4.1.1 Ministry of Agriculture and Forestry

The Ministry of Agriculture and Forestry states that the effects of climate change should have already been taken into account in the assessment programme. Taking climate change into account is especially relevant if operations in Loviisa are discontinued. The Ministry recalls that the taking into account of the risks of climate change must be continuously developed and promoted in projects that, due to the nature of the operations and the long life of the operations, involve specific climate risks.

The Ministry notes that the programme had only addressed flooding as a risk posed by climate change. However, Loviisa is already a significant flood risk area, which should be taken into account in the programme. In addition, according to the Ministry, the programme should examine the possible adverse effects on fish, fisheries and marine mammals in accordance with the precautionary principle. For example, activities should be avoided in spawning and occurrence areas important for fish stocks.

4.1.2 Geological Survey of Finland (GTK)

The Geological Survey of Finland (GTK) states that under the terms of the environmental permits, a maximum temperature for cooling water returning to the sea has been set, which must not be exceeded. According to GTK, the assessment procedure should examine how an extension of 20 years of use, combined with the warming of seawater caused by climate change, will affect compliance with the permit conditions. This may have an impact on the production of the power plant and on any need to change the cooling water system as referred to in the programme.

The disposal of decommissioning waste requires a significant expansion of the VLJ repository. The extent of excavations resulting from the continued use of plant units is not sufficiently clear in the EIA programme.

GTK points out that the assessment should consider the need to update the Hästholmen rock model, especially from the point of view of water-leading structures. The moderately high need for expansion of the VLJ repository will probably increase the occurrence of water leaks and the amount of water pumped into the sea. In order to reliably estimate the volume and effects of increasing pumping, the design of the expansion (e.g. positioning and possible injection design) must be based on up-to-date structural geological and hydrogeological data.

In GTK's view, it is important to examine how the options presented affect the need to update environmental impact monitoring programmes. GTK highlights, in particular, the change in rock groundwater conditions due to the expansion of the VLJ repository. In addition, by 2060 or 2080, changes in the baseline may result from global warming, changes in precipitation and a shortening winter season. These may require increased monitoring for both the environment and the operation of the independent plant components.

4.1.3 Eastern-Uusimaa Emergency Services Department

The Eastern-Uusimaa Emergency Services Department states that it will draw up an external emergency plan for the nuclear facility together with the operator. In the case of decommissioning, the Emergency Services Department shall maintain an emergency plan and organise statutory preparedness exercises until the site no longer poses a particular risk under section 48 of the Rescue Act (379/2011).

The Emergency Services Department states that in the project options, the operator must comply with the licence conditions and requirements set by STUK and the Finnish Safety and Chemicals Agency with regard to emergency arrangements. Upon request, the Emergency Services Department issues statements to the responsible authorities in matters in accordance with the steering obligation of the rescue services.

When applying for a decommissioning licence, the licence applicant must submit a plan regarding security and preparedness arrangements to STUK. If necessary, the Emergency Services Department will issue statements on the above plans concerning the implementation of the operating conditions for rescue operations.

4.1.4 Eastern Uusimaa Police Department

The Eastern Uusimaa Police Department says it will mark the project for information and take into account its impact on policing in accordance with their legislation. In its statement, the police department explains its own responsibilities, including regular planning and review of various preparedness and security arrangements and traineeships in cooperation with other security authorities. The police department emphasises the importance of regular and practical cooperation to prevent various threats and incidents between different authorities, operators and power plant personnel.

With regard to threats, the police department highlights e.g. the National Counter-Terrorism Strategy 2018–2021, which addresses the possible attempt by terrorist activities to exploit nuclear weapons or other radioactive substances. In addition, the police department points out that preparing for major accidents requires education, training and advance plans

4.1.5 Porvoo Museum

Porvoo Museum considers that the studies described in the programme are sufficient to assess the impact of the alternatives on the cultural environment and landscape of the area. The museum highlights, among other things, the cultural environment and relic area of the nationally significant Svartholma fortress, as well as the provincially significant western and southern parts of Gäddbergsö and the water area between them.

4.1.6 Radiation and Nuclear Safety Authority

According to STUK, the assessment programme meets the criteria of the EIA safety programme laid down in section 16 of the Nuclear Safety Act. STUK will assess the fulfilment of safety- related requirements in detail in connection with the processing of an application for a licence for use or decommissioning. Anticipating the future licencing process, STUK expects the responsible party to the project to supplement some areas in the assessment report and the studies in accordance with the assessment programme.

According to STUK, the report should address the application of the BAT principle to emission reductions. New solutions and procedures, known or planned, should be addressed, at least under option 1.

STUK states that it is not clear from the assessment programme which substances are included in the study of harmful substances in sediments on the seabed. STUK requires that the amounts of artificial radioactive substances in sediments in a possible dredging area be investigated and the impact of their possible release on the environment be assessed in connection with dredging work. According to STUK, the effects of changes in flow fields on the transport of radioactive substances from the discharge opening should also be investigated in cooling water modelling that takes into account the new embankment structure and in expert assessments based on it.

Nuclear fuel used in option 1 is generated more than has been taken into account in the licence process and decisions of the Posiva final disposal project. In the assessment report, it would be a good idea to assess whether the spent fuel generated in connection with option 1, i.e. further use, has an impact on the decisions of principle and the construction licence granted to Posiva.

The EIA report should also indicate the estimated amount of activity of waste coming from other parts of Finland to the Loviisa power plant, the composition of the nuclides and the physical/chemical state of radioactive substances.

In addition, STUK points out that section 3.1 refers to the activity limits set by the authority for water emissions. However, the authority, STUK, has not set any limits, but has established the limits proposed by the licence holder in accordance with section 7c of the Nuclear Energy Act.

4.1.7 The Centre for Economic Development, Transport and the Environment of Uusimaa (Uusimaa ELY Centre)

Uusimaa ELY Centre states that the assessment programme appears to be properly prepared and that the descriptions of the current state of the project and the environment are comprehensive. The ELY Centre proposes supplements to the following points, among others.

According to the ELY Centre, the studies carried out to assess the impacts must be described with sufficient accuracy, which was not achieved in the case of impacts on surface waters. The study of harmful substances in sediments, the impact of waterworks on flow conditions and the methods used in the assessment e.g. to assess underwater noise should have been described in more detail. The description of cooling water modelling should also be specified, e.g. with regard to starting assumptions and sensitivity analysis. The effects of the different options on the water quality and ecological status of Lake Lappominjärvi must be assessed.

The ELY Centre points out that the assessment report should present a model of soil, bedrock and groundwater conditions based on the latest studies, as well as an assessment of the leakage water accumulated in rock spaces. The information on the studies used should be specified in the report. Information on nearby wells, including heating wells, should be updated regularly.

The statements highlight the negative impact on fisheries of the continued operation of the power plant and the related water construction. The programme should examine the effects of condensing waters on both alien species and existing species more extensively than is presented.

According to the ELY Centre, it is important to describe the climate impacts of the project in the assessment report as a separate item, the effects of construction and decommissioning, as well as the long-term effects. As regards the climate impact assessment, it should be specified whether the effects of the nuclear fuel production chain and spent fuel disposal are included in the review. It would be a good idea to relate the direct climate impacts of project options, not only to national climate objectives but also to regional objectives. The report should set out the impact of continued use on the structure and emissions of domestic electricity production. The risks posed by climate change to the operation of the nuclear power plant should also be described in the statement.

The ELY Centre requests clarifications on the environmental and water permits required for the project. For example, in the case of the cessation of water intake, the removal of structures for water intake requires a permit in accordance with the Water Act, which was not mentioned in the programme.

The opinion states that the impact of transportation and the assessment of noise and vibration effects should also be specified. The ELY Centre makes various comments related to, among other things, participation in pandemic arrangements, the affected area and exposed residents, the entry into force of the Uusimaa phase county plan, the utilisation of quarrying from the expansion of the VLJ repository and the sites of contaminated soil. In addition, the assessment report should clarify the manner in which the environmental impact of increasing the intermediate storage capacity for nuclear fuel will be assessed.

4.1.8 Helsinki Uusimaa Regional Council

The Helsinki Uusimaa Regional Council considers that the assessment programme provides sufficient conditions for the preparation of the assessment report. The council notes that the project options presented in the programme are in accordance with the current regional plans and the Eastern Uusimaa phase county plan 2050 approved by the Regional Council on 25 August 2020. The project area also has a waterfront plan and a change and extension of the town plan for the nuclear power plant area in Hästholmen. The regional plan is not valid in the area of a general or town plan with legal effect, but it is a guide when drawing them up and changing them.

4.1.9 Municipality of Lapinjärvi

The Municipality of Lapinjärvi considers that it is important to take sufficient account of safety and preparedness aspects for the entire area of impact of the project, regardless of the municipal limits.

4.1.10 The City of Loviisa

The City of Loviisa's City Board is in favour of continuing the use of the nuclear power plant, as it does not see any problems with the safety or production capability of the nuclear power plant. The City considers nuclear power to be an invaluable way of producing carbon dioxide free and domestic electricity for growing needs.

The City notes that the infrastructure requires, and has required, significant investments, e.g. to ensure the safety of the electricity transmission. If the use is discontinued and a new nuclear power plant is built elsewhere, such investments will have been wasted. The City refers to the significant local economic impacts of the plant, such as local employment.

According to the City of Loviisa, Hästholmen is well suited for nuclear power plant operations, and the City has no plans or needs to change the planning of the area in such a way as to call the operation into question or become more difficult.

The City of Loviisa's Building and Environment Board considers it important to investigate and evaluate all activities that could reduce the thermal load at sea in the context of continued operations (VE1). Cooling water has a local impact on the surrounding area, such as the eutrophication of shallow sea bays. The programme has pointed out that water construction work may make it possible to reduce the temperature of cooling water discharged into the sea.

The board considers it important to examine the impact of the current water supply and the water level rationing it includes on Lake Lappominjärvi and its surroundings, as well as in Lappomviken. The domestic water is currently processed from raw water pumped from Lake Lappominjärvi. According to the programme, alternative ways of using water (process, fire, washing, rinsing and domestic water) will be considered.

4.1.11 City of Porvoo

The City of Porvoo considers the assessment programme to have been broadly and comprehensively developed and that the key impacts have been identified. In some places, however, the programme was difficult to understand, which should be taken into account during the reporting phase.

According to the City of Porvoo, the programme does not indicate whether the continued use is projected to increase the thermal load on the seawater and how the effects of any increase in the thermal load are to be assessed. The City of Porvoo also points out that the water impact assessment should take into account the combined effects of various load factors, such as the thermal load, water turbidity due to marine construction and nitrogen emissions from the treatment of evaporation concentrations.

The City of Porvoo proposes that the energy market and security of the supply section of the programme should present the plant's share of Finland's electricity production in a more transparent manner, including a long-term assessment of the electricity production and the share of Loviisa Nuclear Power Plant. In this case, it would be easier to compare the continuation of licences with substitute alternatives. In addition, the method of calculating CO_2 emissions should be clarified, at the latest, during the report phase.

4.1.12 Municipality of Pyhtää (Environmental Services of the City of Kotka)

The Municipality of Pyhtää states that the assessment programme is comprehensive and that it has identified the most significant environmental impacts of the project. However, Pyhtää would like to emphasise Pyhtää and the proximity of key settlements (about 20 km from Loviisa). It is therefore important to identify sensitive sites and examine the main impacts to an adequate regional extent. The presenting of

sensitive locations, their distances and impacts by using maps and rings would illustrate the situation and hence also preparedness measures.

4.1.13 Ministry of the Interior, Ministry of Foreign Affairs, Ministry of Finance, Ministry of the Environment, Regional State Administrative Agency for Southern Finland, Finnish Safety and Chemicals Agency Tukes

The above authorities had no statements on the project.

4.2 OTHER STATEMENTS REQUESTED

4.2.1 Greenpeace

Greenpeace stresses the importance of complying with the Espoo and Aarhus agreements and the Environmental Impact Assessment Directive. The organisation notes that the overall economic impact should also be taken into account when examining the various options.

According to the organisation, the assessment procedure should also include a scenario in which the power plant would be shut down early due to a fault in the power plant. Finland's carbon neutrality target by 2035 and the EU's emission reduction target for 2030 should also be included in the review, and the achievement of the targets should be ensured even if the power plants are closed ahead of schedule or the use is not continued after the current licence period.

The organisation proposes that an assessment of the operating reliability of the power plant should be presented in the procedure until the end of any extension to be applied for. The assessment should examine, among other things, the ageing of the reactors and changes in natural conditions and the electricity market. Greenpeace considers the modelling of a serious nuclear accident and the subsequent contingency plan to be a key element of the assessment process.

Further information on the background to the statement was set out in the appendix accompanying the statement.

4.2.2 Fennovoima Oyj

Fennovoima Oyj declares its support for the continuation of the operation of Loviisa Nuclear Power Plant and trusts the authority's ability to assess the safety of the operation of the plant. The company justifies its position by, among other things, reducing greenhouse gases, the security of supply and cost-effectiveness. In addition, the statement mentions the excellent operating history of Loviisa Nuclear Power Plant in terms of safety, usability and reliability.

4.2.3 Natur och Miljö rf

Natur och Miljö rf considers the assessment programme to be, generally, carefully prepared. According to the organisation, the focus of the EIA procedure should be on the safe extension of the life of nuclear power plants, although a review of decommissioning is also essential. For the management of radioactive waste generated in Finland, it is important that option 0+ is also included in the assessment and Finland assumes responsibility for the disposal of these wastes.

Natur och Miljö states that a risk analysis of a nuclear accident is the most important part of the EIA procedure and suggests looking at several different accident scenarios. The organisation also suggests that the citizens' survey mentioned in the programme should cover at least the entire population of southern Finland, as a possible nuclear accident would affect a wider area than just the 20 kilometres proposed in the programme.

According to the organisation, the environmental impacts of fuel management should also be taken into account in the assessment procedure. Section 6.15 (exploitation of natural resources) of the programme should be supplemented by the environmental impact of the production of fuel rods in order to include the effects in the comparison of project options.

If the increase in the capacity of the intermediate storage facility for spent fuel is achieved by placing the fuel more frequently than before, this option shall be presented at the stage of the report with sufficient accuracy to assess the safety. It would also be a good idea to set out in the assessment programme how the thermal load from cooling water will affect the aquatic nature of the area during possible further use. Dredging - presented in the programme - also has side effects that, according to the organisation, can be reduced by choosing the right dredging time.

Natur och Miljö also declares their willingness to participate in stakeholder meetings organised in connection with the project.

4.2.4 Posiva Oy

Posiva Oy states that the various options in the assessment programme have sufficiently prepared for the final disposal of spent nuclear fuel. Posiva Oy has decisions in principle and a construction licence for the final disposal of spent nuclear fuel for a quantity corresponding to 6,500 tonnes of uranium (tU). According to the current service life, the amount of fuel to be finally sourced from the Olkiluoto and Loviisa Nuclear Power Plants is approximately 5,500 tU. If a decision is made to extend the use of the Loviisa 1 and 2 plant units by 20 years, the total amount of spent nuclear fuel would be approximately 6,000 tU. Posiva Oy sees no obstacle to the possible continuation of the use of Loviisa power plant units, as the implementation and safety of their disposal will not be compromised.

4.2.5 STTK ry

STTK ry considers the environmental impact assessment programme to be sufficient. The modifications proposed in the programme are moderately small and do not have a significant impact on the environment of the area. STTK ry welcomes the further use of the power plant based on Finland's high level of nuclear safety and emission reduction targets.

4.2.6 The Central Organisation of Finnish Trade Unions (SAK)

The Central Organisation of Finnish Trade Unions (SAK) says that it strongly supports the continuation of the operation of Loviisa Nuclear Power Plant for 10–20 years, provided that it is safe according to STUK's estimates. SAK justifies its position on the greenhouse gas emissions of nuclear power, the increase in electricity consumption and energy security. In the opinion of the organisation, domestic and affordable electricity supports the competitiveness of Finnish industry.

4.2.7. Finnish Association for Nature Conservation

The Finnish Association for Nature Conservation (FANC) states that the assessment programme has not addressed the impacts of climate change on the operation of the power plant during the planned extension period. Possible impacts include an accelerated sea level rise, increased flooding, rising sea temperatures and mass deposits of new species, as well as increasing sediment runoff due to increasing rainfall, for example. The programme should assess the interactions between climate change and the impacts of the power plant on the water and its organisms (e.g. the presence of invasive alien species).

SLL considers that the environmental impact assessment should be based on the anticipated conditions close to the end of the planned extension period. The programme should assess changes in circumstances and the resulting effects and risks over a period of 20-50 years by using the precautionary principle.

4.2.8 VTT Technical Research Centre of Finland

According to VTT Technical Research Centre of Finland (VTT), the assessment programme is sufficient from the point of view of the EIA Act. VTT considers it a good thing to investigate the continued operation of Loviisa Nuclear Power Plant in terms of national and international climate objectives.

VTT says in its statement that Fortum's EIA programme includes an environmental impact assessment of radioactive waste from VTT, and VTT considers that the waste has been duly taken into account in the programme. VTT states that in March 2020 they signed an agreement with Fortum to dismantle the FiR 1 research reactor, as well as a research reactor and a decommissioned research laboratory (Otakaari 3) for radioactive waste management services.

VTT's radioactive waste is generated by these demolition works. Fortum's EMI programme has also referred to the environmental impact assessment of the decommissioning of the FiR 1 research reactor previously carried out in 2013-2015.

VTT understands that radioactive waste generated elsewhere in Finland (up to 2,000 m³), which may be disposed of at Loviisa Nuclear Power Plant, also includes other radioactive waste that requires disposal from VTT, i.e. at least waste from the operation of VTT Centre for Nuclear Safety. The amount of these radioactive wastes has yet to be specified and has not been the subject of contractual negotiations. VTT considers that the maximum amount proposed by Fortum is sufficient preparedness.

VTT also considers it excellent that the VLJ repository should also be prepared to dispose of radioactive waste from other parts of Finland. According to VTT, this is very positive from the point of view of the national waste management of radioactive waste.

4.2.9 Fingrid Oyj, Teollisuuden Voima Oyj

Fingrid Oyj and Teollisuuden Voima Oyj have not provided statements on the project.

4.3 STATEMENTS OF THE INTERNATIONAL CONSULTATION

4.3.1 Austria

Austria's Ministry of Climate, Environment, Energy, Mobility, Innovation and Technology has announced Austria's participation in the environmental impact assessment procedure. According to the Ministry, the possibility of significant environmental impacts on Austria cannot be excluded in the event of a serious accident in the first place. It is hoped that Finland will later send Austria an assessment report, as well as information on public consultations and participation in the procedure.

The statement was accompanied by a statement commissioned by experts from the Austrian Environment Agency. The statement adopts a position on the content of the environmental report in several sectors. It states that the assessment of project options should take into account scenarios for future electricity needs, energy efficiency, energy saving and other alternatives to electricity generation.

The EIA report should include timetables and options for nuclear waste management arrangements in the event that the capacity necessary to dispose of low- and medium-level waste and spent fuel generated during continued use is not available. The report should also comment on the functionality of the KBS-3 method with regard to copper corrosion.

The statement addresses the aspects of the long-term use and ageing of the VVER 440 reactor type and highlights the studies carried out by several different parties in this regard.

According to the statement, the EIA report shall include a comprehensive description of the current level of science and technology, as well as explanations of all cases in which derogations are made. The report should also include all measures to improve service life and prevent a serious reactor accident. The fragility of the pressure medium should also be treated.

The analysis of an accident situation should be updated to the updated probability-based risk analysis, as the source term presented in the programme is too low in this respect. The source term is also considered to be too low for the analysis of the potential impact on Austria. The EIA statement should explain how the safety issues related to the retention of molten core pressure have been resolved. The opinion states that situations related to earthquakes, floods and extreme weather phenomena (including safety margins, extreme consequences and planned measures to prevent these) should be presented in the EIA report. In addition, the review of accident situations should consider a situation in which a nuclear facility is attacked by a third party.

In its opinion, the Anti Atom Beauftragter des Landes Oberösterreich (state office) puts forward 12 arguments to which it proposes to waive the user life extensions of Loviisa Nuclear Power Plant units. In several of these parts, it notes that the information provided is incomplete and better and more complete information is necessary during the EIA report phase. The number one argument is that extending the use of the nuclear power plant raises the risks of nuclear energy in Europe, as the majority of European nuclear power plants are technically obsolete in terms of nuclear safety. An example of ageing phenomena has been the radiation framing of the reactor pressure container at VVER power plants, which also applies to the pressure containers of Loviisa Nuclear Power Plant. The statement states that the recovery heating of Loviisa 1 occurred in 1996 and that further processing by the PMI requires further information on the management of the life of the reactor pressure containers at the nuclear power plant. More concrete and complete information on decommissioning measures is also required for the decommissioning of the entire plant during the report phase.

4.3.2 Latvia

The Latvian Environmental Authority declares that, though Latvia will not participate in the environmental impact assessment procedure, it hopes to be informed of the results of the assessment procedure.

4.3.3 Lithuania

The Lithuanian Ministry of Environment has announced Lithuania's intention to participate in the environmental impact assessment procedure. The Ministry points out that the procedure should focus, in particular, on the implementation and promotion of the management of the ageing nuclear power plant, and the related safety aspects should be dealt with in accordance with the Espoo Agreement.

4.3.4 Norway

The Norwegian Environmental Authority has no objections to the environmental impact assessment programme, but says that it wants to participate in the later stage of the procedure.

4.3.5 Poland

The Polish Environmental Authority declares that it does not intend to participate in the environmental impact assessment, but hopes to be informed of the results of the procedure and, in particular, accident modelling. The Environmental Authority says that it has taken into account protected species and habitats in the Gulf of Finland, as well as Natura 2000 sites, and has assessed radiation exposure in the event of a disturbance.

4.3.6 Sweden

The Swedish Environmental Protection Agency (Naturvårdsverket) has announced Sweden's will to participate in the environmental impact assessment procedure. The agency sought opinions on the assessment programme from authorities, organisations and citizens. Summaries of statements issued by organisations and citizens can be found in section 4.4. Other statements and opinions.

According to the Swedish Radiation and Nuclear Safety Authority (Strålsäkerhetsmyndigheten), a serious accident at the nuclear power plant is highly unlikely, but would affect the radioactivity of Swedish soil, for example. It is therefore important for Sweden to be involved in the assessment process. According to STUK, the assessment programme is well planned. According to their statement, however, the programme could emphasise the increase in the intermediate storage of spent fuel, as it increases the possibility of the release of long-life nuclides (Cs-137). The best available technology should be used to minimise emissions when extending the service life of a power plant. Moreover, according to the statement, the programme could make it clearer that the expert opinions used in the procedure are also based on various studies and measurements.

The Swedish Board of Agriculture (Jordbruksverket) states that the procedure should examine the effects of radioactive substances released in the event of an accident on Swedish agriculture, animal husbandry, fisheries, reindeer husbandry, farming, rural areas and forest management.

The Swedish Agency for Marine and Water Management (Havs och Vattenmyndigheten) states that the assessment of cross-border environmental impacts highlights accident situations that may have consequences for species and habitats in the Baltic Sea. The statement also states the effects of normal operations on water bodies in relation to the extraction and restoration of cooling water. However, the authority does not consider it necessary to participate in the assessment procedure.

The Swedish Sámi Parliament (Sametinget) highlights the effects of a possible accident on reindeer herding. In the event of an accident, radioactive discharges may accumulate in reindeer which will have to be culled due to excessively high levels of harmful substances, which will then, as a result, cause economic damage. This is what happened as a result of the Chernobyl Nuclear Power Plant accident. The programme should examine the impact of an accident on the reindeer herding area, measures to mitigate any damage and who will be responsible for damages.

The following parties replied to the request for statements, but had no objections to the assessment programme: Totalförsvarets forskningsintitut, Sveriges meteorologiska och hydrologiska institut (SMHI), Myndigheten för samhällsskydd och beredskap, Länsstyrelsen i Uppsala, Länsstyrelsen i Stockholm.

4.3.7 Germany

Germany's statement is given primarily by the state of Mecklenburg-West Pomerania. The state of Mecklenburg-West Pomerania states that it is in favour of decommissioning the power plant on the basis of nuclear accidents. According to the state, the impact assessment of the continuation of the operation of the power plant (VE1) should take into account the fragility of the pressure containers.

A statement was also issued by the state of Rheinland-Pfalz, which states in its opinion that EU countries have the right to choose their own energy sources. Finland has chosen the path towards further construction of nuclear energy. The state prefers energy saving and the use of renewable energy resources. Rhineland-Pfalz adopts a negative view of Loviisa's further use, which means that it sees decommissioning as the best option in the EIA. It emphasises that, due to high-risk technology, an accident in Loviisa could affect a state 1,800 kilometres away within a matter of hours.

4.3.8 Denmark

The Danish Emergency Management Agency has declared its wish to participate in the environmental impact assessment procedure. According to the Emergency Management Agency, a more realistic source term should be used when calculating the health and environmental impact of a major accident as set out in the assessment programme, whilst a mixture of different isotopes should be considered. According to the Agency, the values now used (100 TBq Cs-137-nuklids) are an acceptable way to reduce the computational burden. However, they do not correspond to the real effects of an accident, as different isotopes, for example, affect different tissue types. In addition, the agency expects the responsible party to the project to supplement the chapter on the prevention and mitigation of harmful effects, including with regard to the release of radioactive substances.

4.3.9 Russia

The Ministry of Natural Resources and the Environment of the Russian Federation declares Russia's interest in international consultations on the EIA procedure concerning Loviisa Nuclear Power Plant, even though it is not a party to the Espoo Agreement.

4.3.10 Estonia

The Estonian Ministry of Environment has announced Estonia's participation in the environmental impact assessment procedure. The Ministry of Environment states that it has organised a public consultation on the matter, but there were no comments on the assessment programme.

The statement of the Ministry of Environment was accompanied by the statement of the Environmental Board. The statement concludes that the options set out in the programme do not entail any greater environmental impact or risk than at present. The Environmental Board supports the continued operation of the power plant and states that it is a more useful solution for both Finland and Estonia. The statement deals with well-functioning cooperation with STUK and states the assessment of exceptional and accident situations in accordance with the programme.

4.4 OTHER STATEMENTS AND OPINIONS

4.4.1 Common Earth, Friends of the Earth Austria, Friends of the Earth Bulgaria, Friends of the Earth (FoE) Finland, South Bohemian Mothers, Verein Lebensraum Waldviertel, Wiener Plattform Atomkraftfrei

The abovementioned organisations submitted the same opinion to the Ministry. According to their statements, the environmental report should present an option based on renewable energy and a long-term forecast of Finland's energy needs. According to the organisations, the report needs to specify the risk assessments of serious nuclear accidents, use a larger source term and look at the wider scope. The statements refer to the flexRISK research project. The organisations point out that the report should also address the impact of the risks posed by the ageing of the facility, such as terrorism and climate change. In addition, the associations state that the assessment programme should take a position on the method of disposal of nuclear fuel used for copper corrosion research.

4.4.2 Folkkampanjen mot Kärnkraft & Kärnvapen

The Swedish organisation Folkkampanjen mot Kärnkraft & Kärnvapen supports the decommissioning of the power plant without the possibility of receiving waste from other parts of Finland (VE0). The organisation justifies its position on the safety risks arising from the ageing of the nuclear power plant, the proliferation and affordability of renewable energy sources and the need to protect the Baltic Sea from pollution and radioactive discharges.

4.4.3 Loviisan Seudun Vihreät ry

Loviisan Seudun Vihreät ry suggests that the assessment report should include a table comparing CO2 emissions from different forms of electricity generation sources, taking into account the entire life cycle, including fuel management. The procedure should also consider the option of extending the operating licences of Loviisa Nuclear Power Plant, but not the importing of radioactive waste from other parts of Finland into the plant area. The procedure should assess the impact of the continuation of use on the ecosystem of the Loviisa sea area, such as fisheries, plankton and demersal animals.

4.4.4 Miljöorganisationernas kärnavfallsgranskning

According to the Miljöorganisationernas kärnavfallsgranskning (MKG) organisation, extending the use of the nuclear power plant means a significant risk for Sweden, as the risks of an accident will increase as the plant ages. MKG refers to the flexRISK study, which suggests that the source term and scope used in the accident modelling are too small. The organisation states that the service life of the plant should not be extended if there is no guarantee that the nuclear waste processing will be sustained. MKG refers to the KBS-3 method and copper corrosion research.

4.4.5 Miljövänner för kärnkraft

Miljövänner för kärnkraft considers the assessment programme to be comprehensive and relies on the safety culture of the Finnish nuclear industry. The organisation says that it expects the operating licences of the plants to be extended, citing, among other things, greenhouse gas free use. The opinion highlights the global experience that the lifespans of pressure and light water reactors are longer than initial estimates. The statement states that, according to the organisation, Sweden does not need to participate in the assessment.

4.4.6 Naiset Atomivoimaa Vastaan and Naiset Rauhan Puolesta

According to the Naiset Atomivoimaa Vastaan and Naiset Rauhan Puolesta (Women against Atomic Power and Women for Peace movements), the operating licences for Loviisa Nuclear Power Plant should not be extended. The movements justify their position on the risks posed by the plant's ageing and climate change, among other things. The movements also call into question the safety of the disposal methods.

According to their statement, the assessment programme should present a risk report comparing the measures taken and plans to extend the service life with the safety requirements for new reactors. The movements stress that the risk of a nuclear accident should be dealt with in a transparent manner, and the assessment should also include an examination of the most serious accident possible.

The movements would like to know how the programme takes into account the principle of the best available technology in the EU and on which energy consumption forecasts the need to extend the life of the power plant will be established. The statement also highlights the potential impacts of climate change on activities and the impact on the environmental impacts of fuel production.

4.4.7 Ecomodernist Society of Finland (ESF)

The Ecomodernist Society of Finland advocates for the continuation of the operation of Loviisa Nuclear Power Plant for 10 or 20 years, provided that the operation is safe. According to the organisation, Loviisa Nuclear Power Plant will play an important role both in Finland's energy supply and in reducing greenhouse gas emissions between 2030 and 2050. As additional reasons, the organisation highlights the growing emission-free electricity demand of industry, the electrification of transport and the elimination of other stable and flexible production capacity.

4.4.8 Technology Industries of Finland

According to Technology Industries of Finland, the assessment has been properly prepared and meets the requirements of the act. The organisation declares itself in favour of continuing the operation of the power plant, as Finland will need more carbon dioxide neutral electricity over the next few decades. The organisation states that the operating factors of the Loviisa plant units are high, and the units are in a state of new condition as a result of modernisation work and the renewal of automation systems.

4.4.9 Vesiluonnon puolesta ry

The Vesiluonnon puolesta ry association takes a stand in favour of investigating the environmental impact of radioactive substances and environmental toxins. The procedure should assess the impact of the transportation and production of nuclear fuel with sufficient precision, and the organisation also considers it important, among other things, to protect the life of the region, e.g. in relation to the extraction of cooling water.

4.4.10 Opinions of private individuals

Opinion 1 supports the extension of the operating licences for Loviisa Nuclear Power Plant, as this would contribute to achieving Finland's climate objectives in a cost-effective manner.

Opinion 2 deals with the eutrophication of Lappomviken and Lappomträsket, the fall in water levels and the disappearance of the bird population in the area. According to an individual, Fortum has failed to comply with the obligations under the water permit regarding the Lappomträsket landing stream to Lappomviken and Sundet's outfall. They suggest taking the power plant's domestic water from Valko, Loviisa, and stress the need to improve Lappomviken's condition as soon as possible.

Opinion 3 was signed by two citizens. The statement takes a position on the water observation programme under the responsibility of the ELY Centre, which, in the opinion of the statement- givers, is too limited. The statement states that the condensate of the power plant will also affect the wider areas of Hästholmsfjärden and Kristianslandet. The statement refers to a decision of the Supreme Administrative Court (508/2017) ordering Fortum to pay compensation for the difficulty of recreational use to owners of beach properties in the area.

In an international consultation under the Espoo Agreement, 11 German and Belgian citizens signed a statement with identical content (Opinions 1 to 9). The statement referred to nuclear accidents that have occurred and noted that the risks would increase as the nuclear power plant ages. According to the statement, nuclear waste cannot be stored safely for millions of years. Nuclear power is not climate-friendly, taking into account the entire lifecycle of production. The statement advocates investing in renewable energy sources.

Statement 10 states that Loviisa Nuclear Power Plant should be shut down as soon as possible. The VLJ repository and other storage facilities belonging to the plant complex should be moved off the coast. The statement also questions the safety of the final disposal of spent fuel.

Statement 11 opposes extending the life of the nuclear power plant. The writer refers to the increasing risks of an ageing nuclear power plant, the flexRISK study and uncertainties related to the method of disposal of spent fuel.

4.5 REMARKS MADE AT A PUBLIC EVENT

The Ministry of Economic Affairs and Employment organised a public event on the assessment programme in Loviisa on 3 September 2020. Fortum was responsible for the practical arrangements for the event. Six people attended the public event on site, and about 50 people followed the event online. The event discussed, among other things, possible investment needs, the reception of radioactive waste generated elsewhere in Finland and the fate of the plant building after decommissioning. In addition, the public were concerned about the impact of various further options on the value of nearby properties.

5. Statement of liaison authority

The statement of the Ministry of Economic Affairs and Employment is based on the requirements of the EIA Act and Decree (Law on the environmental impact assessment procedure section 16, section 18, section 3 Government Decree on the environmental impact assessment procedure) and on the statements and opinions obtained from the assessment programme.

The Law on the environmental impact assessment procedure section programme drawn up by Fortum Power and Heat Oy covers content requirements in accordance with section 3 of the Law on the environmental impact assessment procedure section. In the adopted statement, the assessment programme is considered to be largely comprehensive. The Ministry considers that the scope and accuracy of the assessment programme is a sufficient plan to assess the environmental impact of the project, provided that the issues set out in this statement are taken into account as the project progresses and at the later stages of the EIA procedure. In addition, other questions, comments and considerations have been raised in the statements and opinions to which the responsible party to the project should pay attention.

The responsible party to the project shall examine the impacts of the project and its options on the basis of the assessment programme and the statement of the liaison authority. In accordance with Article 4(15) of the EIA regulation, the assessment report shall provide an explanation of how the liaison authority's statement on the assessment programme has been taken into account.

5.1 PROJECT DESCRIPTION AND OPTIONS

In accordance with Article 3 of the EIA regulation, the assessment programme provides descriptions of the project, its purpose, the planning phase, location, size, land use needs and the project's connection to other projects. The programme shall contain information on the party responsible for the project, an assessment of the timetable for the design and implementation of the project and the plans and licences required for the implementation.

According to the EIA regulation, the assessment programme must present reasonable options to the project, which are worthy of the project and its specific characteristics. One option must be to not to carry out the project. The definition and review of options are key elements of the EIA procedure, as the aim is to provide information on the impact of alternative solutions to the project and to reduce the adverse environmental impact of the project.

5.1.1 Continuation of use

In project option 1, the power plant use would be extended for a maximum of approximately 20 years. The assessment programme states that the operation would be similar to the activities carried out so far, and there are no plans to increase the thermal power, for example.

However, further use may require some modernisation and construction work. The intermediate storage of spent fuel would either be expanded or its capacity increased. In connection with the cooling water supply structures, water construction work aimed at reducing the temperature of cooling water would possibly be carried out. Some old buildings, such as a reception facility and a sewage plant, may be replaced by new buildings, in addition to which changes may be made to the power plant's operating and wastewater connections.

Option 1 would also provide for decommissioning, including the extension and operation of the VLJ repository until approximately 2090 before closure, as well as preparatory work and use of the installations to be independent, and finally decommissioned.

5.1.2 Zero options

The assessment programme includes two zero options (VE0, VE0+), both of which would decommission Loviisa Nuclear Power Plant after the current operating licences have ended. The options are otherwise the same, but option 0+ would also make it possible to process, intermediately store and dispose of small amounts of radioactive waste generated elsewhere in Finland.

In the EIA programme, decommissioning refers to the dismantling of radioactive systems and equipment of the power plant and the disposal of waste resulting from the dismantling. During its operation, preparations for decommissioning will be made, e.g. by expanding the VLJ repository so that radioactive waste from decommissioning can be disposed of there. In addition, in connection with decommissioning, certain waste management activities and facilities must be independent, among other things. According to the assessment programme, the decommissioning phase of the power plant units would be set between 2030 and 2040. The VLJ repository would continue to be used until about 2065.

A decommissioning licence must be applied for the decommissioning of the power plant. Decommissioning is regulated by the Nuclear Energy Act and Decree and STUK's decrees and guidelines.

5.1.3 Comparison of options

Comparing the options to the project and their environmental impact is a key part of the EIA procedure. The assessment programme states that during the procedure, comparisons will be made between the environmental impact of the project and its non-implementation and the differences between them. The assessment of the significance of the environmental impacts takes into account both the magnitude of the change and the sensitivity of the impact site. Impacts are classified on the basis of their significance as minor, moderate, large and very large. The impacts can be either positive or negative from an environmental point of view.

5.2 IMPACTS AND THEIR INVESTIGATION

The assessment programme describes the current state and development of the likely scope of the project. The assessment programme shall detail the initial areas of the analysis and impact, the scope of which has been assessed on an impact-by-impact basis.

The assessment programme shall include a proposal on the identified and assessable environmental impacts, including transnational environmental impacts and interactions with other projects, as well as a justification for limiting the impacts to be assessed.

According to the programme, the most significant environmental impact of the project in the case of continued use, estimated on the basis of preliminary planning data, is the thermal load of cooling water in the nearby sea area. Similarly, the most significant environmental impacts of preparing for decommissioning have been provisionally identified as the effects of mining related to the expansion of the VLJ repository. Based on a preliminary assessment, the most significant environmental impacts of decommissioning are due to the dismantling of radioactive plant parts and the treatment, transport and disposal of waste.

The studies on environmental impacts, as well as the methodology used and related assumptions, are described in the programme. In addition to utilising previous studies, specific studies will be carried out as part of the assessment, including a study of sedimental harmful substances on the seabed and an assessment of regional economic impacts.

According to the assessment programme, the uncertainties associated with the assessment and their significance are described in the assessment report, which also provides a description of the prevention and mitigation of adverse effects. In the context of the environmental impact assessment, the existing environmental impact monitoring programme will be reviewed and, if necessary, updated.

Next, the Ministry will present some detailed points that the responsible party of the project should take into account in the further work of the project.

5.2.1 Continued operation and management of the ageing of the plant

In project option 1, the power plant use would be extended for a maximum of approximately 20 years. The assessment programme states that the ageing of systems, structures and equipment will be prepared for by design-phase solutions, in-service monitoring and by maintaining the plant's good condition until decommissioning. The assessment programme also mentions the measures taken in recent years to modernise the plant and states that the power plant is in excellent technical and safety condition, which is what is required for the plant to continue its operation after the licence periods in force.

There was a mixed attitude towards continued use in the statements. A large number of Finnish statement providers said that they were in favour of further use of the power plant. The position was justified e.g. by the plant's good operating history, a high-quality safety culture, previous modernisation work, emission reduction targets and employment impacts.

There were objections to continued use in the opinions of the Austrian and German state statements and from NGOs and citizens. In particular, the growing nuclear safety risks, such as the fragility of the pressure testing system, were highlighted due to the ageing of the plant. In addition, according to Greenpeace, a scenario should be included in the assessment procedure in which the power plant would be shut down early due to a fault in the power plant. In its statement, Lithuania also stressed the importance of managing the ageing plant.

According to STUK and the Swedish Radiation and Nuclear Safety Authority, the BAT principle should be applied in the assessment report to reduce emissions, especially if the plant continues to be used. According to Austria's opinion, the EIA report should include a description of the current level of science and technology and a description of all the cases where these are deviated from. The report should also list all the planned actions to promote service life and safety.

The Ministry of Economic Affairs and Employment considers it important that the risk factors related to the possible continuation and decommissioning of use and the effects of the plant's ageing are investigated and that the means of preventing or mitigating the effects are carefully assessed. STUK will assess the safety of continued use or decommissioning later in connection with the processing of the licence application.

The Ministry believes that the report should describe closely the methods by which ageing is monitored and how the consequences of ageing will be reduced. In particular, the method of preventing potential risks of an accident due to ageing and therefore high emissions, such as the ageing of the pressure vehicle, should be described. The report should also address the application of the BAT principle in reducing or preventing emissions.

5.2.2 Cooling water supply, water construction, impacts on water bodies and their lives

According to the assessment programme, the most significant environmental impact of continued use is the thermal load on the local sea area due to the restoration of cooling water. In connection with option 1, possible hydraulic works in front of the cooling water intake structure and in the near-sea area have been described. The aim is to reduce the temperature of the cooling water to be taken and possibly restored. The programme has identified environmental impacts from dredging, mining and the construction of a new embankment structure related to water construction.

The effects related to the taking of cooling water were highlighted in several opinions. The City of Loviisa's Building and Environment Board considers it particularly important that the procedure assesses all measures to reduce the thermal load on the sea. According to the Geological Survey of Finland, the assessment procedure should take into account the effects of warming seawater caused by climate change on the temperature of the water returned to the sea.

STUK requires that the procedure investigates the amounts of artificial radioactive substances in sediments in the dredging area and assesses their possible release in connection with dredging work. Cooling water modelling that takes into account the new embankment structure should take into account the effects of changes in flow fields on the transport of radioactive substances.

The Uusimaa ELY Centre also proposes that the report should specify information on the harmful substance study of the sediment, the impact of waterworks on flow conditions and cooling water modelling.

The City of Porvoo points out that the combined effects of various factors, such as thermal load, water turbidity and nitrogen emissions, should be taken into account when assessing water impacts. The statements of the Ministry of Agriculture and Forestry and the ELY Centre draw attention to the impact on the lives of water bodies. The statement calls for compliance with the precautionary principle and states that activities in spawning and occurrence areas important to fish stocks, for example, should be avoided.

The domestic water of Loviisa Nuclear Power Plant is currently taken from Lake Lappominjärvi. The City of Loviisa's Building and Environment Board and the Uusimaa ELY Centre consider it to be important to investigate the impact of project exchanges on Lake Lappominjärvi, its surroundings and Lappominlahti bay. The area was also highlighted in one of the statements from the citizens on the eutrophication of Lake Lappominjärvi and Lappominlahti bay, the fall in water levels and the disappearance of some bird species.

The opinions also took a position on reducing the adverse effects of dredging by choosing the right time, the extent of the condensing water monitoring area, the protection of life and the assessment of marine ecosystem impacts.

The Ministry considers that the effects of cooling water are the most significant environmental impacts of a nuclear power plant during normal operation. Therefore, when considering the environmental impacts of the thermal load, the available information must be widely exploited. The modelling shall also take into account the impact of climate change on the plant's environmental load. The calculation of the environmental load due to cooling water should be presented conservatively and the results presented in an illustrative manner. The Ministry also notes that the environmental impact assessment of water bodies should not be limited to cooling waters, but should be assessed for the operation of the entire plant.

5.2.3 Exceptional and accident situations

According to the assessment programme, the EIA report includes the modelling of a serious reactor accident, which assumes that 100 TBq Cs-137-nuclides will be released in an accident. This amount corresponds to the limit value for serious accidents under the Nuclear Energy Regulation. The scope of the accident modelling set out in the assessment programme is 1,000 km from the power plant. In addition, the report also intends to cover other exceptional situations, such as fires or transport-related risk situations, as well as conflicting environmental and safety risks.

Several different statement providers drew attention to the accident modelling presented in the assessment programme. Among other things, the source term used in the modelling of the statements of Austria and several NGOs and citizens, as well as the area of impact examined, were considered too small for an environmental impact assessment In connection with the case, NGOs appealed for flexRISK studies.

The opinion of the Danish Emergency Management Agency also suggested that a more realistic source term should be used to assess the health and environmental impact of an accident situation and to address the mix of different isotopes. However, the Emergency Management Agency says it accepts the use of the chosen source term to reduce the computing burden. Natur och Miljö rf suggests that the assessment procedure should examine several accident scenarios.

The Swedish Agricultural Board states that the procedure should examine the effects of radioactive substances released in the event of an accident on Swedish agriculture, animal husbandry, fisheries, reindeer husbandry, farming, rural areas and forest management. In the event of an accident, the Swedish Sámi Parliament emphasises the impact on reindeer herding.

The Ministry of Economic Affairs and Employment states that in Finland (Section 22b of the Nuclear Energy Decree) a high emission limit value of 100 TBq for caesium-137 has been set, and this value has been used as a source term, which describes the accident in the INES 6 category in Finnish environmental impact assessments. However, a number of statements and opinions have suggested the inclusion of a more realistic source term in the reviews to be made. The Ministry considers that it is appropriate for the responsible party of the project to provide a comparison between the source term used and a more realistic emission estimated for the installation under consideration. At the same time, the responsible party of the project should also examine the safety principles of the installation aimed at preventing high emissions in the event of serious accidents.

In addition, the Ministry of Economic Affairs and Employment states that the impact assessment of exceptional and accident situations should not be limited to the protection zone or the emergency preparedness area. In accordance with the EIA Regulation, the EIA report shall present accident situations causing different emissions and describe, by means of illustrative examples, the extent of the affected areas and the impact of emissions on humans and nature.

5.2.4 External threats

The assessment programme states that the risks posed by climate change, such as floods and sea level rise, will be addressed in the assessment report. The Ministry of Agriculture and Forestry, the Uusimaa ELY Centre and the Finnish Association for Nature Conservation draw attention to the lack of discussion of the effects of climate change in the programme.

The Ministry of Agriculture and Forestry points out that consideration of the risks of climate change should be promoted in projects that, due to the nature or long life of the activity, involve specific climate risks. The Ministry states that the risk of flooding should have also been treated as a separate factor in the programme from climate change.

According to the Finnish Union for Nature Conservation, possible effects of climate change may include accelerated sea level rise, rising sea surface temperatures, increasing sediment runoff due to increasing rains, mass deposits of new species and floods. The Union considers that the environmental impact assessment should be based on anticipated conditions close to the end of the extension period.

The Ministry of Economic Affairs and Employment states that the external threats of the project and the risks arising from climate change must be taken into account when assessing the safety of the project. STUK will assess the safety of the project later in connection with the processing of the licence application. However, the Ministry of Economic Affairs and Employment considers that the analysis should assess the phenomena caused by climate change at the plant site and their preparedness.

5.2.5 Impacts on the climate

The assessment programme states that the climate impacts of the project will be examined through greenhouse gas emissions from the operation. The assessment programme will also compare CO2 emissions from different forms of energy production, based on, among other things, life cycle studies of different fuels.

The Uusimaa ELY Centre states that it would be important to describe the climate impacts of the project under its own heading, broken down by construction and decommissioning and long-term impacts. In the case of climate impact assessments, the ELY Centre should specify whether the impacts of the nuclear fuel production chain and spent fuel disposal are included in the review, and it would also be a good idea to relate the direct climate impacts of project options not only to national climate objectives but also to regional targets.

Natur och Miljö, the Finnish Water Nature Association and several EU citizens pointed out in their statements that the environmental impact of the fuel supply should also be taken into account in the assessment procedure.

Loviisan Seudun Vihreät ry proposes that a table should be included in the assessment report comparing CO2 emissions from different forms of electricity generation, taking into account the entire lifecycle.

According to the City of Porvoo, the method of calculating CO2 emissions from the project should be specified in the assessment report. For its part, the Ministry of Agriculture and Forestry emphasises the importance of taking climate change into account, especially in the case of decommissioning.

The Ministry considers it appropriate for the project manager to examine the climate impacts through greenhouse gas emissions from operations and to compare different forms of energy production, taking into account the life cycle of different fuels.

5.2.6 Energy markets

According to the assessment programme, the impact on the electricity market will be examined, taking into account the different timetables of the options. However, the programme states that, in the case of decommissioning, it is difficult to assess the form and location of the replacement electricity.

The statements commented on Finland's forecasts for electricity production and consumption. According to the views of the Uusimaa ELY Centre and the City of Porvoo, the share of the power plant in Finland's electricity production should be presented in a more transparent manner, including a long-term forecast of the development of the power plant's share and the Finnish electricity market. According to the City, this would make it easier to compare different forms of energy production. According to Austria, the procedure should deal with different scenarios of future electricity needs and different options to electricity generation.

Greenpeace also points out that the overall economic impact of the project should be examined in the procedure.

The Ministry considers that it is appropriate to examine the effects on the electricity market, taking into account the timing of the different options. The results and the starting points of the report must be clearly and transparently expressed. The Ministry also notes that the responsible party for the project is the company producing and selling electricity. It is up to the state to carry out nationwide reviews of energy supply.

In addition, the Ministry notes that the Government, under the leadership of the Ministry of Economic Affairs and Employment, is currently preparing a new national climate and energy strategy with the aim of carbon neutrality in Finland in 2035, in accordance with Prime Minister Sanna Marin's Government Programme.

5.2.7 Impact of continued use on nuclear waste management

The continued operation of the power plant will increase the accumulated total amount of low- and medium-level waste and spent nuclear fuel. The programme estimates that an extension of approximately 20 years would produce approximately 600 m³ of low-activity and 2,400 m³ of additional medium-level waste packed.

However, the methods of nuclear waste management would, as a rule, remain the same, and the existing capacity of the VLJ repository is also estimated to be sufficient for the disposal of nuclear waste resulting from continued use. However, according to the GTK, the extent of the extraction in the case of continued use is unclear and the assessment programme does not sufficiently set out the requirements, in particular the increase in medium-level waste. For excavating additional space in the VLJ repository.

According to the preliminary estimate, the most significant change caused by continued use related to nuclear waste management would be the intermediate storage of spent nuclear fuel at Loviisa Nuclear Power Plant. The annual accumulation of spent fuel is expected to be 24 tonnes of uranium (UO_2). Extending use by approximately 20 years would increase the amount of spent nuclear fuel by just under 500 tonnes of uranium.

According to the programme, the increase in intermediate storage capacity for spent nuclear fuel would be achieved either by expanding the intermediate stockpile or by placing nuclear fuel in intermediate storage tanks more frequently than at present. The cooling need for spent nuclear fuel in the intermediate storage facility is not expected to increase significantly, despite the increasing amount of fuel, as the fuel thermal output is constantly decreasing during the intermediate storage. However, it is possible to increase the cooling capacity if necessary.

The Uusimaa ELY Centre states that it is important to describe in the assessment report which option will be used to assess the environmental impact of the increase in intermediate storage capacity of spent nuclear fuel. According to the Swedish Radiation Authority, the EIA procedure should emphasise the increase in the intermediate storage of spent fuel, as this increases the possibility of releasing long-life nuclides. Natur och Miljö rf suggests that if the intermediate storage of spent fuel is carried out by placing fuel in storage basins more frequently, the alternative must be described in the assessment report with sufficient accuracy to ensure safety.

At the end of the intermediate storage, the spent nuclear fuel is to be finally deposited at Posiva Oy's disposal facility in Olkiluoto, Eurajoki. STUK's statement points out that more fuel used in connection with the possible continuation of use would be generated than previously taken into account in the licence procedures for the Posiva disposal project. However, Posiva Oy states in its own statement that the decision-in-principle and construction licence granted for the disposal project enable the final disposal of fuel, taking into account the aforementioned fuel increase.

The safety of the final disposal of spent nuclear fuel was called into question in the Austrian statement and in a number of statements by organisations and citizens. In particular, studies on the KBS-3 method on the premature corrosion of copper capsules were highlighted, which Austria said should be commented on in the assessment report. Greenpeace also argued that nuclear waste management should generally be dealt with more comprehensively in the procedure, in particular as regards disposal.

The Ministry of Economic Affairs and Employment states that despite the increase in the amount of nuclear waste caused by continued use, the methods of nuclear waste management will, as a rule, remain the same and it will be possible to increase the necessary capacity. The Ministry periodically assesses the effects of the increase in low- and medium-level nuclear waste and spent fuel as part of the Loviisa nuclear waste management package. If necessary, the increase in the amount of spent nuclear fuel and its impact on Posiva Oy's operations must be taken into account.

STUK assesses the safety of nuclear waste management in connection with the processing of possible operating licence applications for Loviisa Nuclear Power Plant. In addition, STUK assesses the safety of the final disposal of spent nuclear fuel in connection with the processing of Posiva's operating licence application. In the Ministry's view, it is sufficient at this stage for Fortum to ensure that the investigation related to corrosion of the copper capsule is carried out, e.g. by Posiva Oy as part of the preparations for the operating licence phase of the encapsulation and disposal. In addition, the report shall specify on the basis of which option the environmental impact of the increase in intermediate storage capacity of spent nuclear fuel is assessed.

5.2.8 Decommissioning and independence of spent fuel intermediate storage facility, liquid waste storage facility, solidification plant and VLJ repository

After the operation phase of Loviisa Nuclear Power Plant, the decommissioning of nuclear power plant units will be carried out. The decommissioning strategy of the nuclear power plant has been selected as an immediate dismantling. However, the dismantling will be preceded by a preparatory phase lasting a few years. The assessment programme provides two alternative times for decommissioning. In option 1, the decommissioning would take place between 2050 and 2060. In options 0 and 0+ decommissioning would take place after an already valid operating licence in 2030–2040.

Loviisa Nuclear Power Plant has a decommissioning plan in accordance with the decommissioning strategy. The decommissioning plan is currently based on the nuclear power plant's 50-year service life and decommissioning after the current operating licence in 2030-2040. The decommissioning plan sets out all phases of decommissioning and their up-to-date plans. The decommissioning plan will be evaluated at regular intervals, and the plan will develop based on the operating experience of the nuclear power plant, regulatory feedback and the monitoring of international projects towards the final plan before the decommissioning is carried out.

Decommissioning is carried out in two phases in time. In the first phase, the intermediate storage of spent nuclear fuel from nuclear power plant units, the intermediate storage of liquid waste, the solidification plant and the VLJ repository will be independent, and the nuclear power plant units will be dismantled. At the end of the intermediate storage of nuclear fuel used in the second phase, i.e. in the 2060s at the earliest, the remaining plants will be dismantled and the VLJ repository will be closed.

The decommissioning and dismantling of Loviisa Nuclear Power Plant produces significant amounts of low- and intermediate-level waste, but the accumulation of spent fuel will end at the end of the operating phase. Decommissioning involves a significant amount of waste characterisation, sorting, packaging, transport and disposal. According to the programme, the amount of decommissioning waste to be disposed of is approximately 25,000 m³.

The assessment programme has provisionally identified, as the most significant environmental impacts possible, radiation exposure of personnel in the dismantling of radioactive plant parts, waste treatment, transport and disposal. In addition, impacts may also arise from process waters that are treated and discharged cleaned into the sea. Other environmental impacts related to the end of operations have also been provisionally identified.

In the Ministry's view, the decommissioning part of the programme is sufficient. The Ministry shall periodically evaluate the updated decommissioning plan for Loviisa Nuclear Power Plant. The decommissioning plan shall also discuss the radiation protection planning of personnel. In its previous assessment, the Ministry has drawn attention to the coverage of the plan with regard to the use of independent plants and, initially, their decommissioning. The final decommissioning plan for Loviisa Nuclear Power Plant will be approved by STUK during the decommissioning licence phase.

5.2.9 Expanding, operating and closing the VLJ repository

According to the programme, the VLJ repository will be expanded already during the operation of Loviisa Nuclear Power Plant for the disposal of decommissioning waste. If Loviisa Nuclear Power Plant enters the decommissioning phase after the expiry of the operating licence in force (VE0 and VE0+), it will be expanded as early as the late 2020s and otherwise (VE1) in the late 2040s.

Disposal facilities for decommissioning waste are designed in connection with existing waste disposal facilities during operation, so that the facilities form a coherent and functional whole. The disposal facilities are located underground at a depth of about 110 metres from sea level.

The excavation and temporary storage of the quarry related to the expansion of the VLJ repository have been identified in the programme as the most significant environmental impact of preparing for decommissioning. According to the programme, the expansion requirement arising from the disposal of decommissioning waste is approximately 57,000 m³.

In its opinion, the Geological Survey of Finland (GTK) states that the need to expand the VLJ repository is significant. GTK also notes that the assessment should examine the need to update the Hästholmen rock model, especially from the point of view of water-conducting structures. The design of the extension must be based on up-to-date structural and hydrogeological data. The need to update environmental impact monitoring programmes must also be specified in terms of the impact of the various options. Global warming, changes in precipitation and the shortening winter season impact, among other things, the monitoring of rock groundwater.

The Uusimaa ELY Centre also considers it important that the report presents a model of soil, bedrock and groundwater conditions based on the latest research results, as well as an assessment of the leakage water accumulated in the rock spaces. The ELY Centre also proposes that the assessment report should specify the utilisation of the quarry resulting from the expansion of the VLJ repository.

According to the programme, the use of the repository shall continue until either the 2060s (VE0, VE0+) or about 2090 (VE1). At the end of the operation, the repository will be closed by filling in the spaces containing the barriers and the driving tunnel, after which the area will remain under the supervision of the authorities.

According to the programme, long-term safety after the closure of the VLJ repository will be assessed as part of the environmental impact assessment. In 2018, the responsible party of the project prepared a safety basis for the disposal of radioactive waste generated during the operation and decommissioning of Loviisa Nuclear Power Plant. The safety criterion demonstrates compliance with the long-term safety requirements for disposal. According to the programme, the assessment report will present the key results of the safety reasoning approved by STUK in 2019 and assess separately, among other things, the impact of extending the life of the power plant on long-term safety.

The Ministry of Economic Affairs and Employment considers it important that the project manager assesses the timeliness of models describing soil, bedrock and groundwater conditions, the amount of leakage water accumulated in rock spaces and the need to update the monitoring programme. The utilisation of the quarry resulting from the expansion of the VLJ repository should also be specified in the report. The expansion of the VLJ repository is significant compared to the existing scope. The lifespan of the VLJ repository will be extended beyond the current operating licence in the options presented. A longer service life requires applying for a new operating licence for the repository. The valid operating licence for the VLJ repository extends until 2055.

In the Ministry's view, it is a good idea to make clear in the report the future licence procedure for the VLJ repository, taking into account the need to expand the repository and the total amount of radioactive waste to be disposed of with a licence. If possible, the closure of the repository must also be taken into account in the length of the operating licence, as, according to the current Nuclear Energy Act, disposal facilities will be closed under the operating licence. In connection with the operating licence procedure, STUK shall assess the long-term safety of the VLJ repository.

5.3 NUCLEAR WASTE MANAGEMENT COOPERATION

Options 1 and 0+ include the possibility to receive, process, intermediately store and dispose of small amounts of radioactive waste generated elsewhere in Finland. Waste generated elsewhere typically comes from industry, universities, research institutes and hospitals. The programme has estimated that the amount of waste generated elsewhere in Finland at Loviisa Nuclear Power Plant will not exceed 2,000 m³, which is a fraction of the total amount of nuclear waste to be disposed of. VTT considers the amount of waste from other parts of Finland presented in the assessment programme to be sufficiently prepared for.

Waste from the operation and decommissioning of VTT's FiR 1 research reactor and Otakaari 3 research laboratory will also be located at the Loviisa power plant. Fortum and VTT have signed an agreement on the dismantling of the research reactor and the waste management services of the research reactor and the decommissioning research laboratory. In addition, one option for decommissioning the research reactor is to store spent and unused fuel at the Loviisa power plant. The import of VTT's waste to the Loviisa power plant area requires a licence in accordance with the Nuclear Energy Act.

The statements are largely positive about receiving waste generated elsewhere in Finland at Loviisa Nuclear Power Plant. VTT and Natur och Miljö rf state that the reception of such waste in Loviisa is important for Finland's national management of radioactive waste. VTT and Natur och Miljö rf state that the reception of such waste in Loviisa is important for Finland's national management of radioactive waste. Loviisan Seudun Vihreät argued that an alternative should be included in the procedure, in which the power plant would continue to be used, but that waste generated elsewhere in Finland would not be imported into the plant area.

According to STUK, the estimated amount of activity of waste from other parts of Finland, the composition of nuclides and the physical and chemical state of radioactive substances should also be reported in the assessment report.

In the view of the Ministry of Economic Affairs and Employment, there must be a treatment and disposal route for all radioactive waste that has been born in Finland. The treatment and disposal of waste generated elsewhere in Finland in the Loviisa Nuclear Power Plant area would significantly complement the national waste management of radioactive materials. The Ministry sees that it is possible for the responsible party for the project to refine the information on the properties of waste highlighted by STUK in the assessment report only in a fairly general way. STUK assesses the safety of the management of radioactive waste generated elsewhere in Finland as part of Loviisa Nuclear Power Plant's waste management package in connection with the licence procedures for Loviisa Nuclear Power Plant and the VLJ repository.

5.4 COMPETENCE OF THE RESPONSIBLE PARTY OF THE PROJECT AND THE LIAISON AUTHORITY

The assessment shall contain information on the competence of the authors of the assessment programme. The Ministry considers that the responsible party for the project has sufficient expertise at its disposal to draw up an environmental impact assessment programme.

The Ministry of Economic Affairs and Employment, which acts as the liaison authority, has ensured that its own personnel involved in examining the environmental impact assessment programme and drafting the liaison authority's opinion has sufficient expertise necessary for the quality and scope of the project under assessment and the complexity of the task.

5.5 PLAN FOR ORGANISING THE ASSESSMENT PROCEDURE AND RELATED PARTICIPATION

The assessment programme shall include a plan for the organisation of the assessment procedure and related participation and interaction. The programme describes public events organised in connection with the EIA programme and later in connection with the EIA report. A monitoring group of different stakeholders will be set up for the assessment procedure. In addition, a survey will be organised for nearby residents as well as small group events for different target groups during the reporting phase.

The Uusimaa ELY Centre and Greenpeace consider it important that the current pandemic situation be taken into account in the participation arrangements. Natur och Miljö rf proposes that the citizens' survey mentioned in the programme should cover the entire population of Finland, or at least southern Finland, as a possible nuclear accident would affect a wider distance than the 20 kilometres proposed in the programme.

The Ministry of Employment and the Economy states that upon completion of the EIA report, the Ministry will announce it and make it available for inspection, as well as request the opinions of the authorities and any other parties. A public event will be organised on the EIA report, in connection with which sufficient opportunities will be arranged for everyone to participate in the event, taking into account the circumstances. Ministry of Economic Affairs and Employment The reasoned conclusion of the EIA report as a liaison authority shall be communicated to the municipalities and authorities concerned.

5.6 TIMETABLE FOR THE EIA PROCEDURE

The assessment programme includes the project and the preliminary timetable for the EIA procedure. According to the assessment presented in the programme, the party responsible for the project will submit the assessment report to the liaison authority in August 2021. The period of viewing of the assessment report will be in September and October 2021.

The reasoned conclusion of the liaison authority would then be adopted in December 2021.

6. Communication of the liaison authority's statement

The liaison authority shall forward its statement and other statements and opinions to the project manager. At the same time, the statement of the liaison authority shall be communicated to the authorities concerned and published on the liaison authority's website.

Minister of Economic Affairs
Mika Lintilä

Senior Specialist
Jaakko Louvanto

Distribution Fortum Power and Heat Oy
Information Ministry of Economic
Affairs and Employment
Relevant authorities
Other statement providers

APPENDIX 3

Consideration of the coordinating authority's statement when drawing up the assessment report

The Ministry of Economic Affairs and Employment, acting as the coordinating (liaison) authority, gave its statement on the project's EIA Programme on 26 November 2020. According to the statement, the EIA Programme drawn up by Fortum Power and Heat Oy covers the content requirements pursuant to section 3 of the EIA Decree. The coordinating authority considered that the scope and accuracy of the assessment programme constituted a sufficient plan for assessing the environmental impact of the project, provided that the issues set out in the coordinating authority's statement were taken into account as the project progressed and at the later stages of the EIA procedure. In addition, other questions, comments and considerations were raised in the statements and opinions to which the project owner should pay attention. In accordance with section 4, subsection 15 of the EIA Decree, the assessment report must provide an explanation of how the coordinating authority's statement on the assessment programme has been taken into account.

The following table summarises the matters to which attention should be paid, according to the coordinating authority's statement, during the impact assessment work, or which should be supplemented when drawing up the assessment report. The information provided in the column on the right describes how the statements have been accounted for in the EIA Report.

Main points given in the statement by the coordinating authority	Consideration in the EIA Report
5.1 Project description and options	
According to the EIA Decree, the assessment programme must present reasonable options to the project, which are credible in terms of the project and its specific characteristics. One option must be not to carry out the project. The definition and review of options are key elements of the EIA procedure, as the aim is to provide information on the impact of alternative solutions to the project and to reduce its adverse environmental impact.	Nothing to consider in terms of what is presented in the programme.
5.1.1 Continuation of use	
In its statement, the coordinating authority describes the project option of extended operation (VE1), in which use would be extended for a maximum of 20 years. The extended use may require some modernisation and construction work. The intermediate storage for spent fuel would either be expanded, or its capacity increased. In connection with the cooling water supply structures, water construction work aimed at reducing the temperature of cooling water might be carried out. Some old buildings such as a reception facility and a wastewater treatment plant may be replaced by new buildings, in addition to which changes may be made to the power plant's operating and wastewater connections. Option VE1 would also provide for decommissioning,	Based on the techno-economic investigations, the water engineering projects are nevertheless no longer being planned, which is why they are not reviewed in the EIA Report.
5.1.2 Zero options	
The coordinating authority describes two zero options (VE0, VE0+) in its statement. A decommissioning licence must be applied for in terms of the decommissioning of the power plant. Decommissioning is regulated by the Nuclear Energy Act and Nuclear Energy Decree and STUK's regulations and guidelines. The coordinating authority's statement did not mention matters that would require separate consideration in the environmental impact assessment.	Nothing to consider in terms of what is presented in the programme.
5.1.3 Comparison of options	
The coordinating authority's statement did not mention matters that would require separate consideration in the environmental impact assessment.	Nothing to consider in terms of what is presented in the programme.

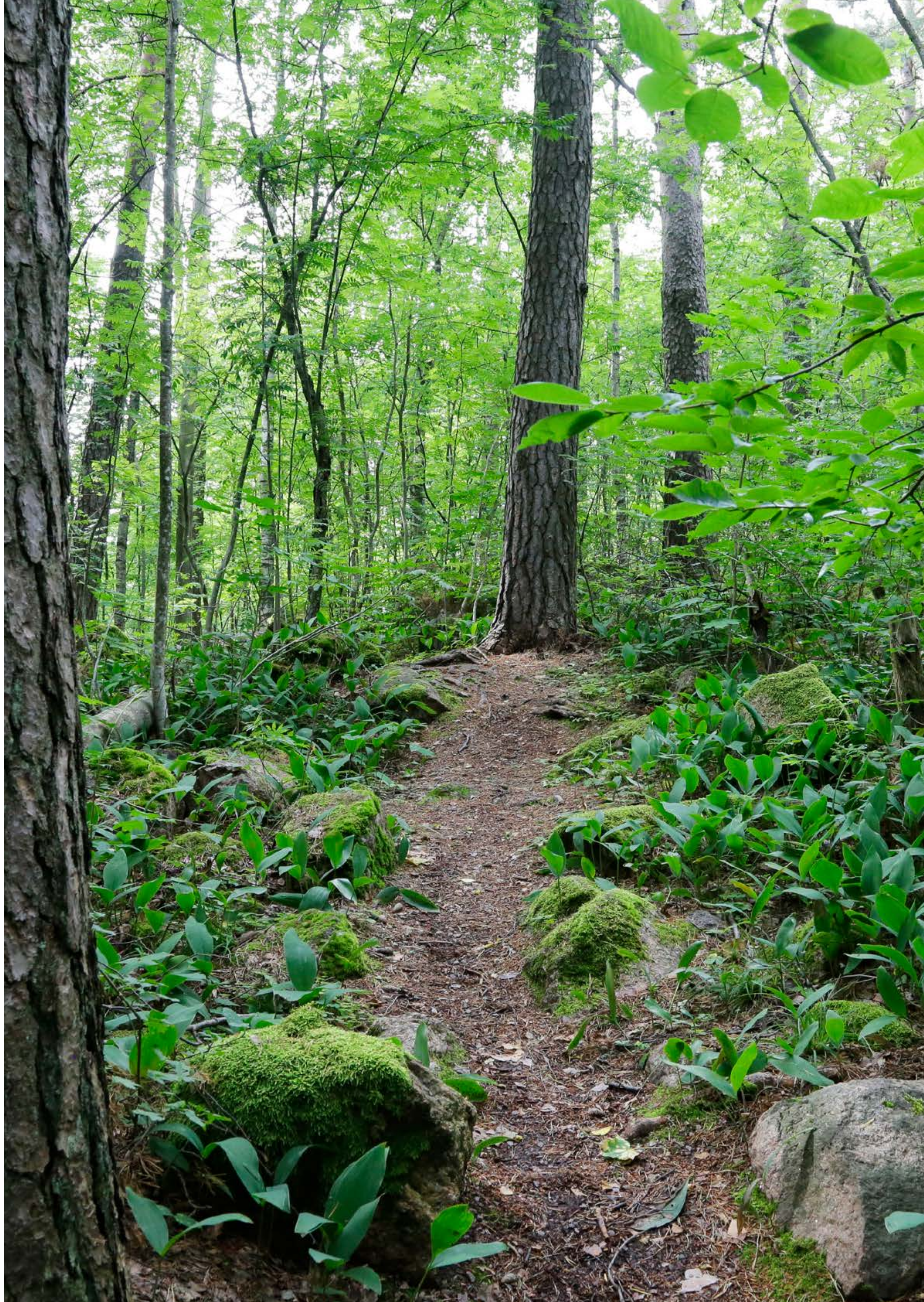
Main points given in the statement by the coordinating authority	Consideration in the EIA Report
5.2 Impacts and their investigation	
5.2.1 Continued operation and management of the ageing of the plant	
In its statement, the Ministry of Economic Affairs and Employment considers it important that the risk factors related to the possible continuation of use and decommissioning, and the effects of the plant's ageing, are investigated, and that the means of preventing or mitigating the effects are carefully assessed. STUK will assess the safety of continued use or decommissioning later in connection with the processing of the licence application. The Ministry believes that the report should - closely describe the methods by which ageing is monitored and how the consequences of ageing will be reduced. - In particular, the methods for preventing potential risks of an accident due to ageing and therefore major emissions, such as the ageing of the pressure vehicle, should be described. - The report should also address the application of the BAT principle in reducing or preventing emissions.	Radiation safety, including the assessment and improvement of nuclear safety and accident risks, are discussed in Chapter 7. Ageing management and maintenance, as well as the related aspects to be investigated, developed and improved, are discussed in Chapter 4.1. The measures and methods are also discussed in Chapter 7.8 (Assessing and improving safety and security) and Chapter 9.10.4 (Environmental impact of extended operation). Ensuring the implementation of the BAT principle is discussed in Chapter 4.12.3.
5.2.2 Cooling water supply, water construction, impacts on water bodies and their lives	
According to the assessment programme, the most significant environmental impact of continued use is the thermal load on the local sea area due to the restoration of cooling water. In connection with Option VE1, possible hydraulic works in front of the cooling water intake structure and in the near-sea area have been described. The aim is to reduce the temperature of the cooling water to be taken and possibly restored. The programme has identified environmental impacts from dredging, mining and the construction of a new embankment structure related to water construction.	The water engineering projects were removed from the assessment procedure on the grounds of techno-economic investigations; the matter will continue to be reviewed in Fortum's internal project (Chapter 9.16.8).
The effects related to the taking of cooling water were highlighted in several opinions. It would be particularly important that the procedure assesses all measures to reduce the thermal load on the sea. The assessment procedure should also take into account the effects of warming seawater caused by climate change on the temperature of the water returned to the sea.	The baseline data and assessment methods used in the cooling water modelling are described in Chapter 9.16.2 and Appendix 4. The means by which to mitigate adverse impacts are described in Chapter 9.16.8.
The statements suggested that the amounts of artificial radioactive substances in sediments in the dredging area should be investigated, and that their possible release in connection with dredging work should be assessed. The report should likewise specify information on the harmful substance study of the sediment, the impact of waterworks (such as a new embankment structure) on flow conditions and the cooling water modelling as well as the impact that changes in the flow fields would have on the migration of radioactive substances.	The impacts of dredging and water engineering works have not been assessed because the operations were not included in the environmental impact assessment (see above). The sediments are monitored as part of Fortum's radiation control programme (see Chapter 9.8.3.4).
The statements pointed out that the combined effects of various factors such as thermal load, water turbidity and nitrogen emissions should be taken into account when assessing water impacts. The impact on the lives of water bodies should also be accounted for. The precautionary principle should be complied with, and activities in spawning and occurrence areas important to fish stocks, for example, should be avoided.	The impacts on the sea area are assessed in Chapter 9.16. The assessment considers the combined effects and the impact on the aquatic organisms.

Main points given in the statement by the coordinating authority	Consideration in the EIA Report
The domestic water of Loviisa nuclear power plant is currently taken from Lappomträsket lake. It is important to investigate the impact that the different project options would have on Lappomträsket lake, its surroundings and Lappominlahti bay.	The impacts on Lappomträsket lake are assessed in Chapters 9.16.4.7 and 9.16.5.7.
The Ministry of Economic Affairs and Employment considers that the effects of cooling water are the most significant environmental impacts of the nuclear power plant during normal operation. When considering the environmental impacts of the thermal load, the available information must therefore be widely exploited. - The modelling must also take into account the impact of climate change on the plant's environmental load. - The calculation of the environmental load due to cooling water should be presented conservatively, and the results in an illustrative manner. - The Ministry also notes that the environmental impact assessment concerning water bodies should not be limited to cooling waters, but should be assessed for the operations of the entire plant.	The modelling results are presented in Appendix 4 and Chapter 9.16 (impact assessment concerning waterways) of the EIA Report. The modelling accounted for the impact of climate change and the results were presented conservatively and illustrated with figures. The impact on waterways in terms of the entire plant's operations are assessed in Chapter 9.16.
5.2.3 Exceptional and accident situations	
The Ministry of Economic Affairs and Employment received several statements which drew attention to the accident modelling concerning a severe reactor accident presented in the assessment programme. The Ministry of Economic Affairs and Employment states that in Finland (section 22b of the Nuclear Energy Decree), a high emission limit value of 100 TBq for caesium-137 has been set, and this value has been used as a source term, which describes the accident in the INES 6 category in Finnish environmental impact assessments. However, a number of statements and opinions suggested the inclusion of a more realistic source term in the reviews to be made. The Ministry considers that it is appropriate for the project owner to provide a comparison between the source term used and a more realistic emission estimated for the installation under consideration. At the same time, the party responsible for the project should also examine the safety principles of the installation aimed at preventing high emissions in the event of serious accidents.	The modelling of a severe reactor accident was conducted according to plan. The emission would consist of a total of 200 nuclides or states. The emission would release 100 TBq of the Cs-137 nuclide and other radionuclides in equal proportion to what would be expected to be released in proportion to caesium-137 in the accident. As a more realistic emission, the assessment included a review of an accident in which a major leak from the primary system to the secondary system occurred. The classification of incidents and accidents, and the requirements concerning them, are discussed in Chapter 7.4. Safety principles are presented in Chapter 7.5. The modelling of a severe reactor accident is discussed in Chapter 9.21, and transboundary impacts in Chapter 9.24. Other incidents and accidents are discussed in Chapter 9.22, and their combined effects with other projects in Chapter 9.23.
In addition, the Ministry of Economic Affairs and Employment states that the impact assessment of exceptional and accident situations should not be limited to the protection zone or the emergency preparedness area. In accordance with the EIA Decree, the EIA report must present accident situations causing different emissions and describe, by means of illustrative examples, the extent of the affected areas and the impact of emissions on humans and nature.	The impacts of a severe reactor accident were assessed up to a distance of 1,000 km (Chapters 9.21 and 9.24). The impacts of a more realistic accident (a major leak from the primary system to a secondary system) were assessed up to a distance of 100 km (Chapter 9.22).

Main points given in the statement by the coordinating authority	Consideration in the EIA Report
5.2.4 External threats	
The Ministry of Economic Affairs and Employment states that the project's external threats and the risks arising from climate change must be taken into account when assessing the safety of the project. STUK will assess the safety of the project later in connection with the processing of the licence application. However, the Ministry of Economic Affairs and Employment considers that the analysis should assess the phenomena caused by climate change at the plant site and the preparedness for them.	The impacts of climate change are discussed in Chapter 9.12 and in the impact assessments concerning surface waters and aviofauna (Chapters 9.16–9.17). Preparedness for external threats and climate change is addressed in Chapter 7.5.6.
5.2.5 Impacts on the climate	
It would be important to describe the climate impacts of the project under a separate heading in the assessment report, broken down by construction and decommissioning and long-term impacts. In the case of climate impact assessments, it should be specified whether the impacts of the nuclear fuel production chain and spent fuel disposal are included in the review, and it would also be a good idea to relate the direct climate impacts of project options not only to national climate objectives but also to regional targets.	Climate impacts in terms of extended use and decommissioning are described in Chapters 9.12.4 and 9.12.5. Chapter 9.12.4 discusses the greenhouse gas emissions of various forms of energy production over their lifecycles. Climate impacts were also reviewed in relation to the climate targets.
The statements drew attention to the fact that the assessment procedure should also account for the environmental impact of fuel supply. The carbon dioxide emissions of different forms of energy production should also be compared – with consideration for entire lifecycles – in a table, for example.	The environmental impact of the procurement of nuclear fuel is discussed in Chapter 9.9.4. Chapter 9.12.4 discusses the greenhouse gas emissions of various forms of energy production over their lifecycles.
The statements pointed out that the method for calculating the project's carbon dioxide emissions should be specified in the assessment report. In addition, accounting for climate change is important, especially in the case of decommissioning.	The calculation method is described in Chapter 9.12.2.
The Ministry of Economic Affairs and Employment considers it appropriate for the project owner to examine the climate impacts through the greenhouse gas emissions of operations and to compare different forms of energy production, taking into account the lifecycle of different fuels.	Greenhouse gas emissions and climate change are discussed in Chapter 9.12.
5.2.6 Energy markets	
The statements on the EIA programme drew attention to the forecasts concerning Finland's electricity production and consumption. The power plant's share of Finland's electricity production should be presented more transparently, including a long-term forecast on the development of the power plant's share and the Finnish electricity market. The procedure should also deal with different scenarios of future electricity needs and the project's overall economic impact. The Ministry of Economic Affairs and Employment notes the following in terms of the submitted statements: the examination of the effects on the electricity market, taking into account the timing of the different options, is appropriate. The results and the starting points of the report must be clearly and transparently expressed. The Ministry also notes that the party responsible for the project is a company producing and selling electricity. It is for the state to carry out nationwide reviews of energy supply. In addition, the Ministry notes that the Government, under the leadership of the Ministry of Economic Affairs and Employment, is currently preparing a new national climate and energy strategy with the aim of carbon neutrality in Finland by 2035, in accordance with Prime Minister Sanna Marin's Government Programme.	The impacts on the energy markets and security of supply are reviewed in Chapter 9.11. The impacts on the regional economy are assessed in Chapter 9.13

Main points given in the statement by the coordinating authority	Consideration in the EIA Report
5.2.7 Impact of continued use on nuclear waste management	
The continued operation of the power plant will increase the accumulated total amount of low- and medium-level waste and spent nuclear fuel. However, as a rule, the methods of nuclear waste management would remain the same, and the existing capacity of the L/ILW repository is also estimated to be sufficient for the disposal of nuclear waste resulting from continued use. However, according to the GTK, the extent of the excavation in the case of continued use is unclear, and the assessment programme does not sufficiently explain the requirements that the increase in intermediate-level waste in particular sets for excavating additional space in the L/ILW repository.	The excavation volume of the required additional space is discussed in Chapters 5.2.1 and 9.10.5.2, among others. The volume of intermediate-level waste to be generated during the extended operation is discussed in Chapter 4.7.
The Uusimaa ELY Centre states that it is important to describe in the assessment report which option will be used to assess the environmental impact of the increase in the interim storage capacity for spent nuclear fuel. According to the Swedish Radiation Authority, the EIA procedure should emphasise the increase in the interim storage for spent fuel, as this increases the possibility of releasing long-life nuclides. Natur och Miljö rf suggests that if the interim storage of spent fuel is carried out by placing fuel in the storage pools more frequently, the alternative must be described in the assessment report with sufficient accuracy to ensure safety.	Both options for interim storage are described in Chapter 4.6.
Following the interim storage, the intention is to deposit the spent nuclear fuel for final disposal in Posiva Oy's final disposal facility in Olkiluoto, Eurajoki. STUK's statement points out that more spent fuel would be generated in connection with the possible continuation of use than previously taken into account in the licence procedures for the Posiva disposal project. However, Posiva Oy notes in its own statement that the decision-in-principle and construction licence granted for the disposal project enable the final disposal of fuel, taking into account the aforementioned fuel increase.	The volume of spent nuclear fuel is discussed in Chapter 5.9, and the impacts of the increased volume in Chapter 10.2.2.
The safety of the final disposal of spent nuclear fuel was called into question in the Austrian statement, and in a number of statements by organisations and citizens. In particular, studies on the KBS-3 method on the premature corrosion of copper capsules were highlighted, and Austria noted that this should be commented on in the assessment report. Greenpeace also argued that nuclear waste management should generally be dealt with more comprehensively in the procedure, in particular in respect of final disposal.	The environmental impacts of the final disposal of spent nuclear fuel are assessed in the separate EIA drawn up by Posiva Oy, and these impacts are referred to briefly in Chapter 9.10.5.1 of this EIA Report.
The Ministry of Economic Affairs and Employment states that despite the increase in the amount of nuclear waste caused by continued use, the methods of nuclear waste management will remain the same as a rule, and it will be possible to increase the necessary capacity. The Ministry periodically assesses the effects of the increase in low- and intermediate-level nuclear waste and spent fuel as part of the Loviisa nuclear waste management package. If necessary, the increase in the amount of spent nuclear fuel and its impact on Posiva Oy's operations must be taken into account. STUK will assess the safety of nuclear waste management in connection with the processing of the possible operating licence applications for Loviisa nuclear power plant. In addition, STUK will assess the safety of the final disposal of spent nuclear fuel in connection with the processing of Posiva's operating licence application. In the Ministry's view, it is sufficient at this stage for Fortum to ensure that the investigation related to corrosion of the copper capsule is carried out, e.g. by Posiva Oy as part of the preparations for the operating licence phase of the encapsulation and final disposal. In addition, the report must specify the option based on which the environmental impact of the increase in intermediate storage capacity for spent nuclear fuel is assessed.	The increase in the volume of spent nuclear fuel is addressed in Chapters 5.9 and 10.2.2. Posiva will present the long-term safety case for the final disposal of spent nuclear fuel in connection with its application for an operating licence (Chapter 9.10.5.1). Both options for interim storage are described in Chapter 4.6. The comparison is made in Chapter 10.2.2. The differences between the options are minor (Chapter 9.10.4.1).
5.2.8 Decommissioning and independence of spent fuel intermediate storage facility, liquid waste storage facility, solidification plant and L/ILW repository	
In the Ministry's view, the decommissioning part of the programme is sufficient. The Ministry evaluates the updated decommissioning plan for Loviisa nuclear power plant periodically. The decommissioning plan also discusses the radiation protection planning for personnel. In its previous assessment, the Ministry drew attention to the coverage of the plan with regard to the use of independent plants and preliminarily, their decommissioning. The final decommissioning plan for Loviisa nuclear power plant will be approved by STUK during the decommissioning licence phase.	Decommissioning is discussed in Chapter 5, the operation and decommissioning of the plant parts to be made independent in Chapter 5.4, and the environmental aspects of decommissioning in Chapter 5.8.

Main points given in the statement by the coordinating authority	Consideration in the EIA Report
5.2.9 Expanding, operating and closing the L/ILW repository	
Among other things, the statements on the EIA Programme note that that the assessment should examine the need to update the Hästholmen rock model, especially from the perspective of water-conducting structures, and that the design of the extension must be based on up-to-date structural and hydrogeological data. The volume of the leakage water accumulated in the rock spaces must also be assessed, and the utilisation of the quarry material resulting from the expansion of the L/ILW repository must be specified. The need to update environmental impact monitoring programmes must also be specified in terms of the impact of the various options. Based on the statements given, the Ministry of Economic Affairs and Employment considers it important that the project owner assess the timeliness of models describing the soil, bedrock and groundwater conditions, the amount of leakage water accumulated in rock spaces and the need to update the monitoring programme. The utilisation of the quarry resulting from the expansion of the L/ILW repository should also be specified in the report. The expansion of the L/ILW repository is significant compared to the existing scope. The service life of the L/ILW repository will be extended beyond the current operating licence in the options presented. A longer service life requires that a new operating licence for the repository be applied for. The current operating licence for the L/ILW repository is valid until 2055. It is the view of the Ministry of Economic Affairs and Employment that it is advisable to make the future licence procedure for the L/ILW repository clear in the report, taking into account the need to expand the repository and the total amount of radioactive waste to be disposed of with a licence. If possible, the closure of the repository must also be taken into account in the length of the operating licence, as, according to the current Nuclear Energy Act, disposal facilities will be closed under the operating licence. STUK will assess the long-term safety of the L/ILW repository in connection with the operating licence procedure.	The expansion of the L/ILW repository and the interim storage of the quarry material are discussed in Chapter 5.2, and the environmental aspects of the expansion are identified separately in the sub-chapters of Chapter 5.8. The environmental impacts are assessed in Chapter 9. The rock model used for the calculation of groundwater flows was updated for the 2018 safety case, and took the latest information into account (Chapters 9.14 and 9.15). The safety case also reviews the expanded spaces (Chapter 9.10.5.2). The monitoring programmes are discussed in Chapter 11, and the bedrock and groundwater conditions in Chapters 9.14 and 9.15. Seepage waters are reviewed in Chapter 9.15, and the reuse of the quarry material in Chapter 9.9 The licensing procedure for the L/ILW repository is addressed in Chapter 12.1. The tentative schedules of the project options account for the closure of the L/ILW repository (Chapter 3).
5.3 Nuclear waste management cooperation	
Options VE1 and VE0+ include the possibility of receiving, handling, placing in interim storage and depositing for final disposal small amounts of radioactive waste generated elsewhere in Finland. In the view of the Ministry of Economic Affairs and Employment, there must be a treatment and disposal route for all radioactive waste generated in Finland. The treatment and disposal of waste generated elsewhere in Finland in the Loviisa nuclear power plant area would significantly complement the national waste management of radioactive materials. The Ministry is of the opinion that the project owner can specify the information on the properties of waste highlighted by STUK in the assessment report only in a fairly general way. STUK will assess the safety of the management of radioactive waste generated elsewhere in Finland as part of Loviisa nuclear power plant's waste management package in connection with the licence procedures for Loviisa nuclear power plant and the L/ILW repository.	Other radioactive waste is described in Chapter 6.2 at the currently possible general level. The environmental impacts of the reception of radioactive waste generated elsewhere in Finland are assessed in Chapter 9.
5.4 Competence of the project owner and the coordinating authority **5.5 Plan for organising the assessment procedure and related participation** **5.6 Schedule of the EIA procedure**	
The coordinating authority's statement did not mention matters that would require separate consideration in the environmental impact assessment.	Nothing to consider in terms of what is presented in the programme.



APPENDIX 4

Impact of Loviisa power plant's intake and discharge of cooling water on sea area

1. Introduction

This report concerns the impact that an extension of Loviisa power plant's operation in its current form would have on the temperature of the surrounding sea area. Dispersion model calculations provide the best way to assess the impact of the discharge of cooling water. The review is carried out using three-dimensional hydraulic modelling, which involves the calculation of the water's temperature and salinity stratification when the power plant is in operation, and when the power plant is not in operation. The thermal effect that the power plant's operation has on the surrounding sea areas is arrived at by comparing the modelling results. The model's initial values, boundary conditions and environmental constraints at the time of the calculation have been obtained from environmental measurements. The modelling results are also compared to earlier cooling water modelling and observations. The review also examines whether the modelling indicates any thermal effect on the Natura area in the vicinity of the power plant which would be attributable to the warm cooling water.

The seawater used for cooling by Loviisa power plant is taken from Hudöfjärden, west of the island of Hästholmen, and the warmed cooling water is discharged into Hästholmsfjärden, east of the island of Hästholmen and connected to the outer archipelago through narrow straits (Figures 2-1 and 2-2). While the general eutrophication trends of coastal areas in the Gulf of Finland (HELCOM 2018) have been visible during the summer monitoring of the aquatic flora in the power plant's surroundings, so has the warming effect of the cooling waters. In the winter, the warmed cooling water weakens the ice cover on the discharge side.

The modelling has been carried out separately for both ice-free and ice seasons. With regard to the ice-free season, the modelling examines the impact that the power plant's operation had on the temperature of the surrounding sea area in the conditions of 2011, because more extensive temperature measurements of the seawater were conducted in nearby areas at the time. The more extensive temperature data allow for the model's more precise calibration, while providing a good point of comparison for the modelling results. The 2011 summer was also warmer than usual, with temperature conditions nearly equal to the 2050 temperature conditions projected in climate change scenarios. By employing the 2011 environmental conditions as a basis for the modelling of the ice-free season, we can simultaneously assess the water temperature of the nearby sea areas in conditions that are likely to become more common as climate change progresses.

With regard to the ice season, the modelling is based on the environmental conditions in March 2018. The ice winter of 2017–2018 was normal, and the Baltic Sea's ice extent was at its maximum in early March 2018 (Appendix 1). The effect that the warm cooling water has on the nearby area's ice conditions is assessed by examining the ice season separately. As climate change progresses, the average extent of the ice cover and the duration of the ice season are likely to reduce (Climate Guide 2021a). Yet a significant variation in the extent of sea ice will also occur from one year to the next in the future. This means that ice winters considered normal now will probably continue to occur, although less frequently. It therefore makes sense to review the situation in terms of the ice season in the conditions of a normal ice winter, to allow the warm cooling water's effect on the ice cover to be assessed.

2. Observed area as well as intake and discharge of cooling water

Loviisa power plant is located on the island of Hästholmen, on the northern shore of the Gulf of Finland (Figure 2-1). Cooling water for the power plant is taken from the shore at Hudöfjärden, and it is discharged, warmed, in Hästholmsfjärden, on the other side of the island of Hästholmen. Figure 2-2 shows the depth of the power plant's nearby sea areas as well as the locations of the intake and discharge points. As can be detected from the figure, the local deeps and straits confine flows from one area of the sea to another.

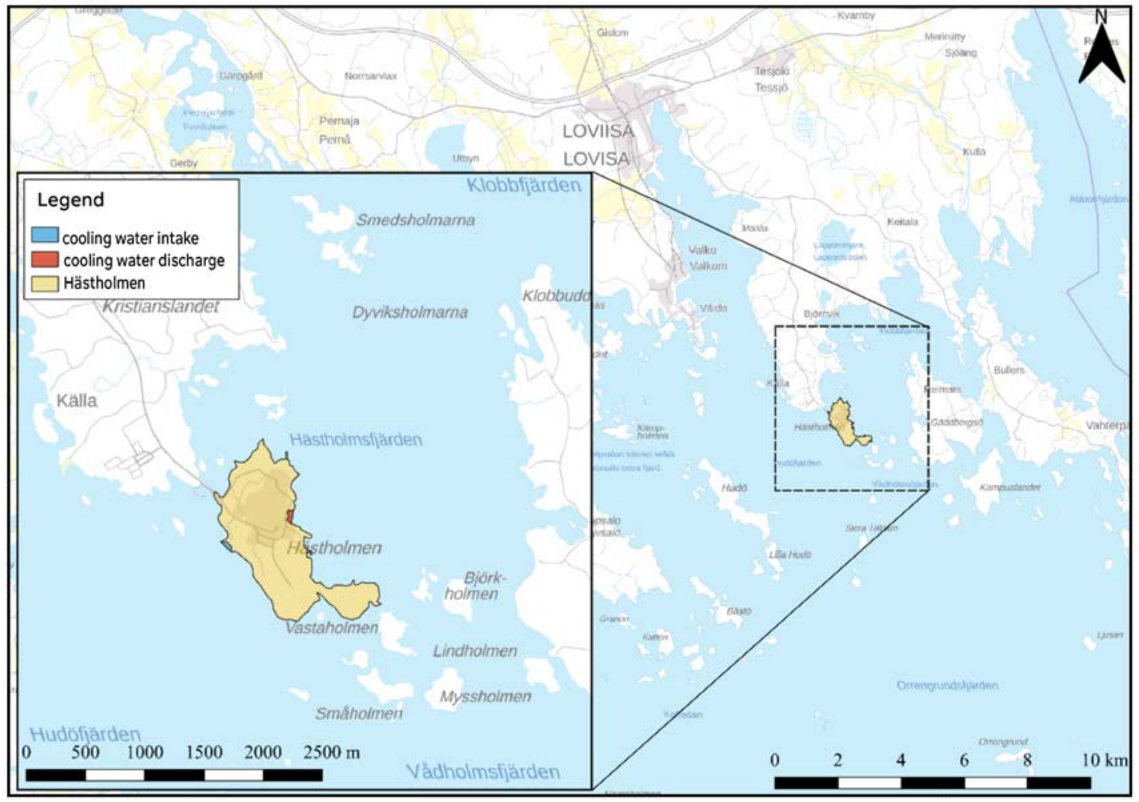


Figure 2-1. The location of Hästholmen. (Background maps: National Land Survey of Finland's 01/2021 material; scales 1:40,000 and 1:80,000)

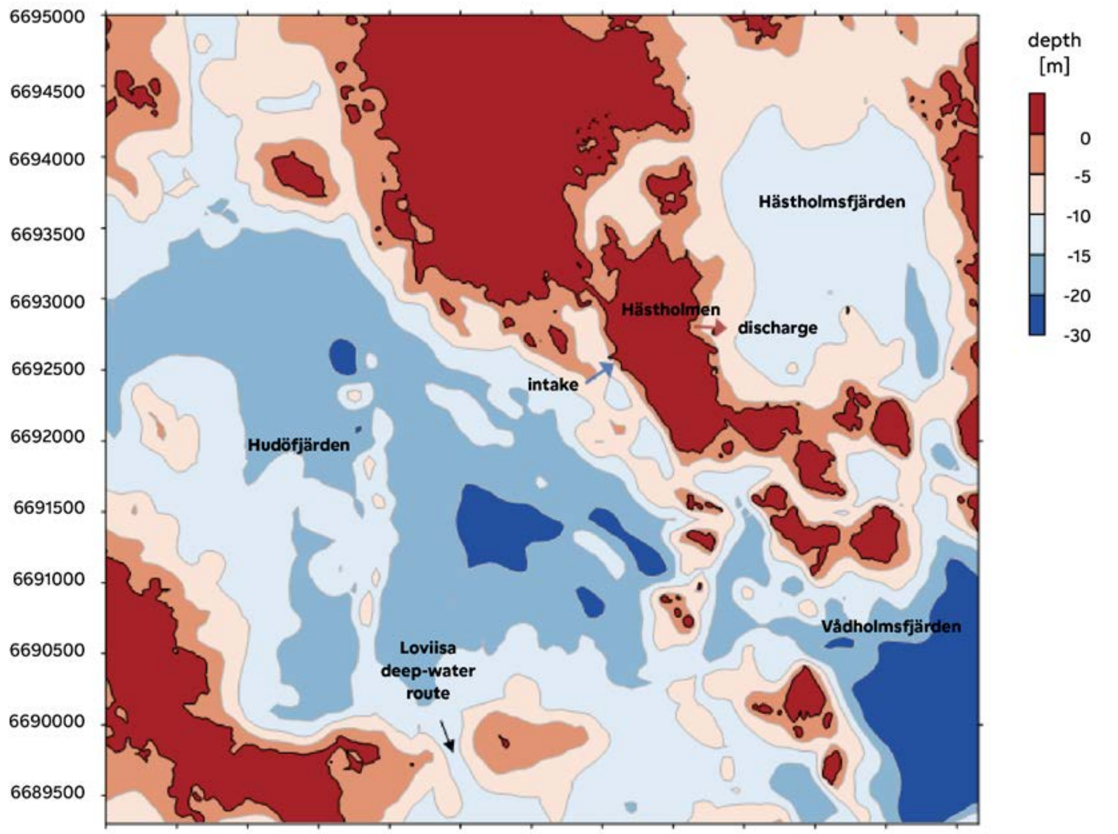


Figure 2-2. Rough depth model of Hästholmen's vicinity. The intake of cooling water is indicated with a blue arrow, and its discharge with a red arrow. The depth model has been adjusted. Coordinate system ETRS-TM35FIN.

3. Data on conditions

3.1 DYNAMICS OF TEMPERATURE VARIATION IN THE BALTIC SEA

On a longer time scale, seawater temperature in the Baltic Sea is influenced by the changing seasons – or the change in the warming effect of the sun's radiation over the course of a year. Solar radiation is at its minimum during the winter, when the seawater is also at its coldest. In winter, the sea is usually covered by an ice sheet, at least close to the shore. This slows down the exchange of water and heat between the sea and the atmosphere. 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 body.

In spring, once the ice has melted, the sun can warm the sea's surface layer, which rapidly achieves the temperature of maximum density as it warms. When this happens, the denser water sinks to the bottom, while the lower and less dense water beneath rises to the surface – a phenomenon referred to as the water body's "spring overturn". Following the spring overturn, the surface water which continues to grow warmer becomes lighter than the cold water underneath, forming a thermocline between the thin and warm surface layer and the layer of colder water deeper down.

Over the summer, the warm surface layer of the sea grows thicker due to mechanical mixing caused by wind, and the thermocline typically achieves a depth of 5–10 m. The thermocline becomes strong during the summer, at which point the temperature can drop by 10 °C over a distance of a few metres. The existence of the thermocline also contributes to the freshwater carried by rivers staying in the surface layer,

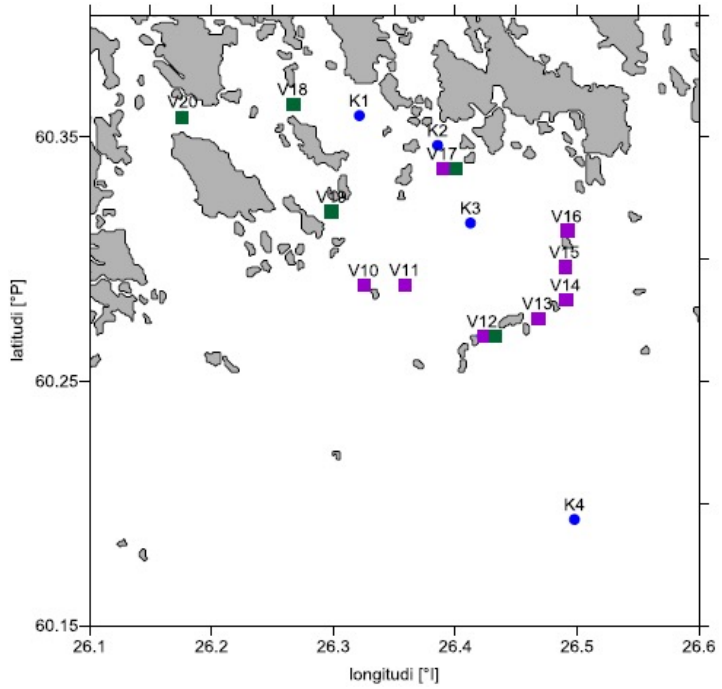


Figure 3-1. The location of the observation points (Luode Consulting Oy 2012) for water temperature at Hudöfjärden (K1), Vådholmsfjärden (K2), Orrengrundsfjärden (K3) and the open sea (K4).

given that any vertical mixing of water through the thermocline is weak.

By the second half of August, the surface layer begins to cool down, becoming heavier than the cold water underneath and sinking as a result. Consequentially, the thickness of the homogeneous surface layer (there is very little vertical change in temperature) begins to grow, while the thermocline starts to weaken. The process continues throughout the autumn, when heat from the surface sinks deeper. Because of this, the water does not usually reach its maximum temperature at a depth of, say, 30 m until October, whereas in terms of surface water, it usually reaches it at the turn of July – August. During the autumn, an overturn of the water body occurs, at which point the temperature is the same throughout the body of water.

Very rapid changes in the temperature of seawater – in terms of both depth and time – may also sometimes take place during the summer. Rather than being directly related to seasonal temperature trends, these changes are the result of short-term weather conditions. What often lies behind rapid temperature changes in seawater occurring in the vicinity of coasts is the upwelling phenomenon, which involves a drop in the temperature of seawater on the coast, or downwelling, which involves a rise in the temperature of seawater on the coast. Upwelling and downwelling refer to the vertical movement of water caused by the dynamics of the sea, which is driven by the movement of the seawater's surface layer towards or away from the coast as a result of wind.

In an upwelling situation, the surface layer moves away from the coast, causing the removed surface water to be replaced by cool water rising to the surface. It is the reverse of a downwelling situation, in which surface water moves towards the coast and begins to accumulate in front of it, sinking more deeply. It is characteristic of upwelling for the water's temperature to change throughout the thickness of the water body during the upwelling. The temperature within a thick layer of water can also change in a downwelling situation, even throughout the thickness of the water body, if the situation is long-lasting. Water colder than the water in the rest of the sea area often accumulates in the deeps during the winter and as a result of upwelling. At the bottom, the water temperature can be as low as five degrees, whereas the surface temperature can rise to 20 °C or even higher.

In 2011, continuous observations of water temperatures were conducted at four different points and at different depths (Luode Consulting Oy 2012). The locations of the measurement points are shown in Figure 3-1. Figure 3-2 shows the measurement results of the observation points at Hudöfjärden (K1), Vådholmsfjärden (K2), Orrengrundsfjärden (K3) and the open sea (K4). The dark blue broken line in the graphs in Figure 3-2 indicates the clearest upwelling situation in the time series in question. However, other upwelling situations did occur during the period reviewed, and these are visible as situations in which the temperature of the water drops throughout, including the surface layer. The graphs show that, based on the temperature measurements, the upwelling situation is clearly distinguishable near the coast, but becomes vaguer the further from the coast we move.

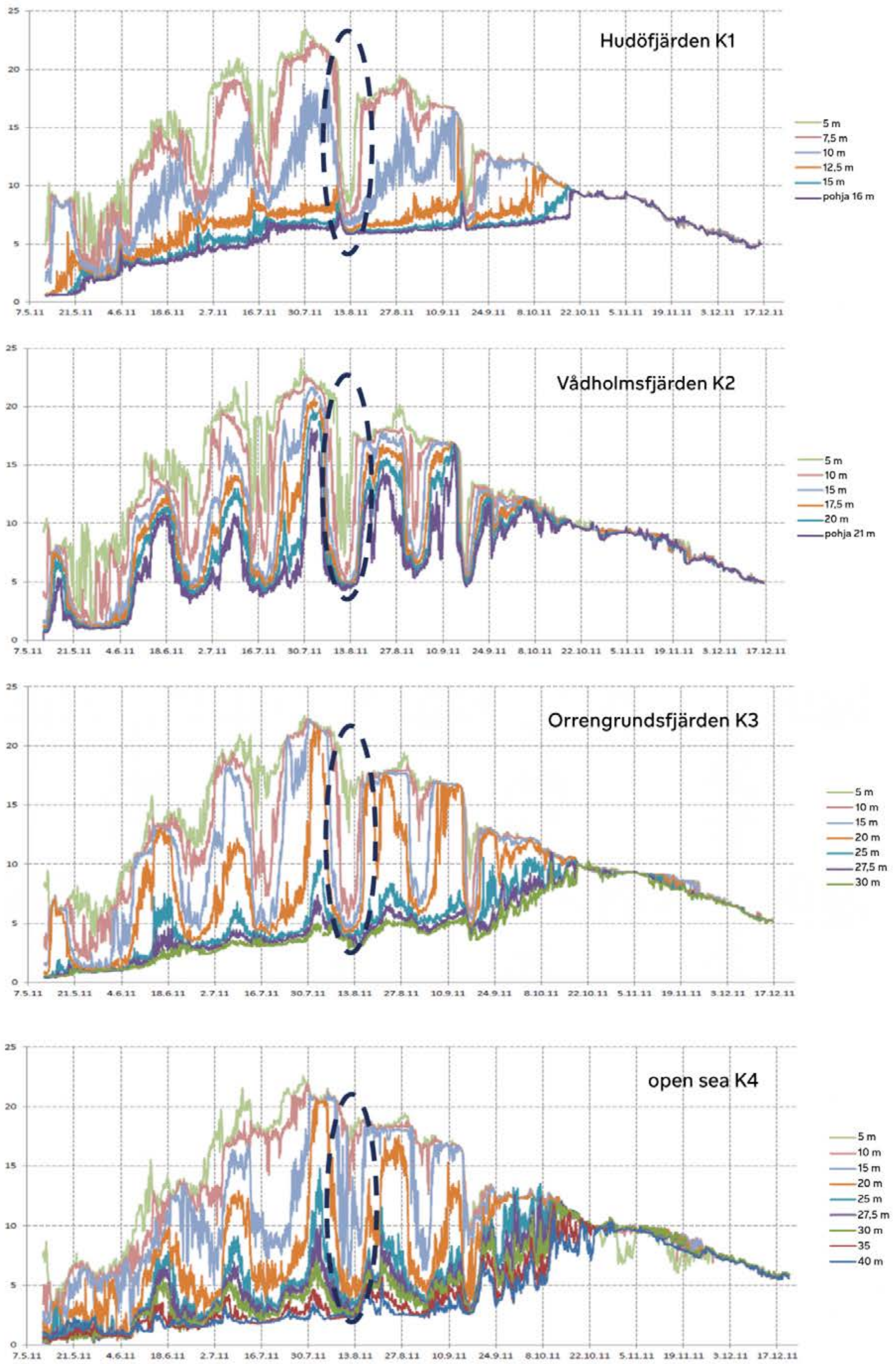


Figure 3-2. Water temperature at Hudöfjärden K1, Vådholmsfjärden K2, Orrengrundsfjärden K3 and the open sea K4, (top-down) in 2011 (Luode Consulting Oy 2012).

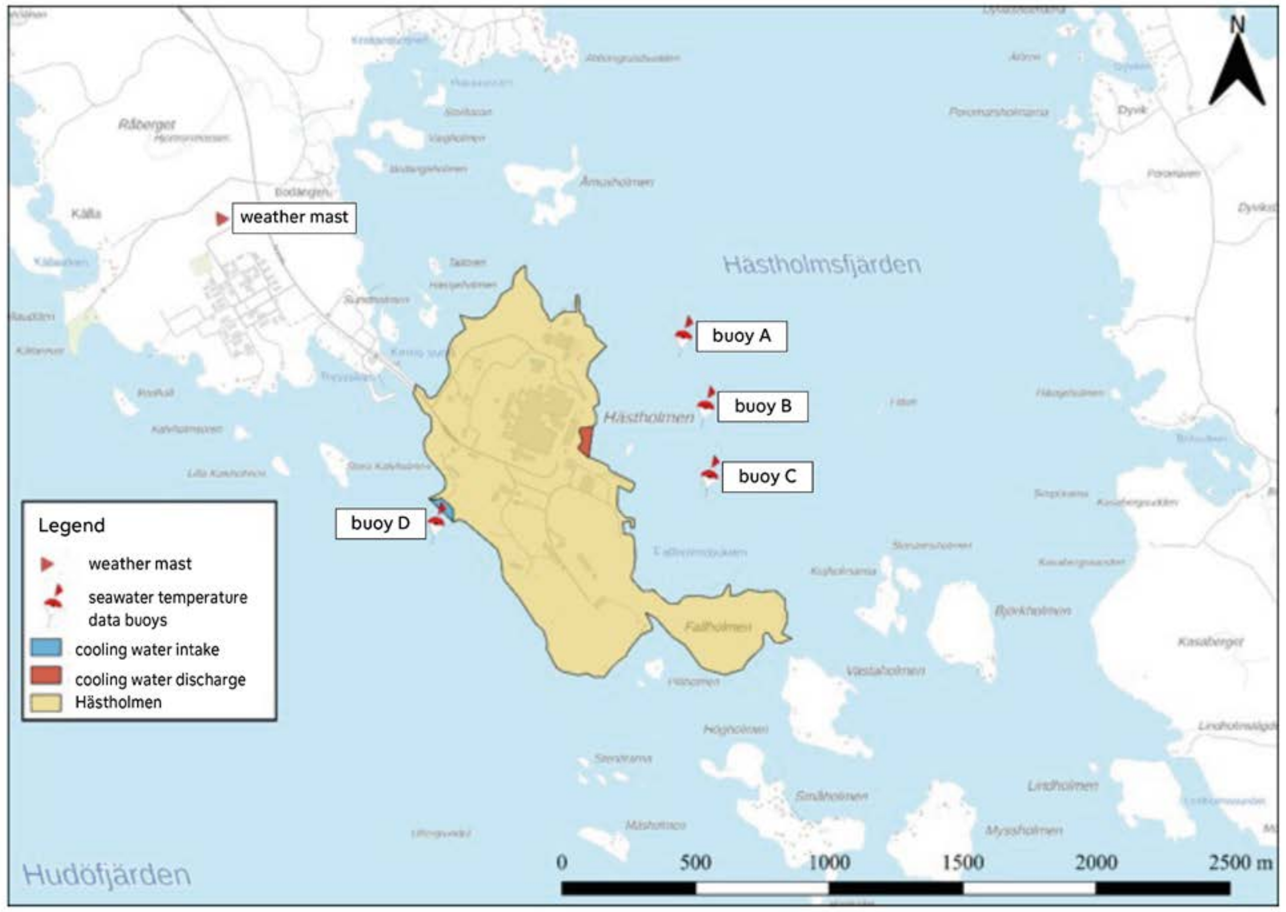


Figure 3-3. The locations of Loviisa power plant's buoys for seawater temperature measurements in front of the cooling water intake at Hudöfjärden (in red) and on the discharge side at Hästholmsfjärden (in orange). (Background map: National Land Survey of Finland's 01/2021 material; scale 1:10,000)

3.2 SEAWATER TEMPERATURE BASED ON CONTINUOUS BUOY MEASUREMENTS

Seawater temperature is measured with continuous buoy measurements in front of the cooling water intake at Hudöfjärden and in front of the discharge location for cooling water at Hästholmsfjärden. The weather mast operated by Loviisa power plant is around a kilometre northwest of Hästholmen (Figure 3-3).

The temperature observations made by the buoy roughly 80 metres from the shore perpendicular to the intake location (D) are shown in Figure 3-4. The proximity of the intake location mostly affects the temperature readings at 6 and 9 metres and to a lesser extent, measurements taken close to the surface, compared to other parts of Hudöfjärden. The warmed water is discharged into Hästholmsfjärden. Figure 3-5 shows temperature observations from 2002 taken at the temperature measurement buoys A and C in Hästholmsfjärden. The 2002 data were selected as an example because the time series of the temperature measurements of that year were the most complete. In terms of the temperature conditions, 2002 was a normal year. As can be seen from Figures 3-4 and 3-5, the seawater begins to warm in mid-March and reaches its maximum temperature at the turn of July–August. The cooling begins in late August and continues until the beginning of December.

Figure 3-6 shows the average temperature given by satellite measurements carried out in 2009. As can be seen from the figure, the southernmost part of Hästholmsfjärden, close to the power plant, is around 2–3 °C warmer than nearby areas.

3.3 SELECTION OF CALCULATION PERIOD – ICE-FREE SEASON

The temperature of seawater along the coast of the Gulf of Finland fluctuates strongly during the summer depending on time and place, as a result of upwelling and downwelling.

Due to the dynamics of the upwelling and downwelling phenomena, a description of the conditions in front of Loviisa power plant by modelling requires continuous temperature observations from several different locations and depths. Fortum has had seawater temperature measurements carried out in the environs of the power plant during several different years. The most extensive of these thus far was

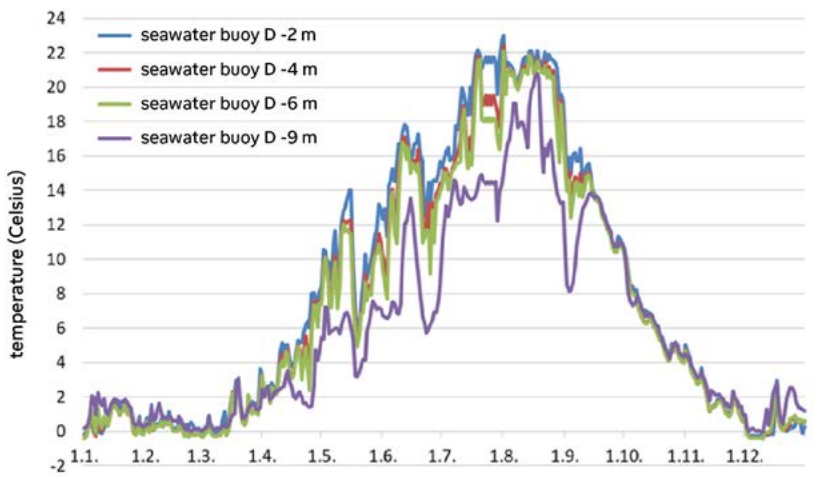


Figure 3-4. Water temperature at temperature measurement buoy D in Hudöfjärden, 80 metres from the intake location, in 2002.

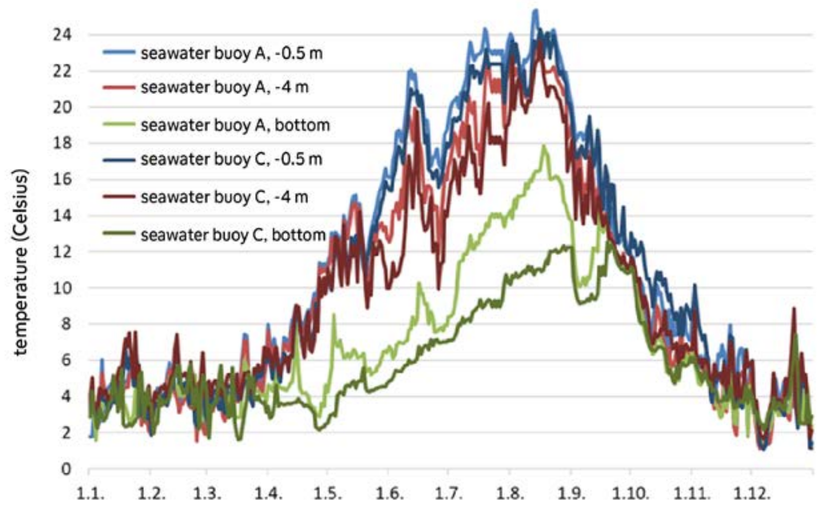


Figure 3-5. Water temperature at temperature measurement buoys A and C on the discharge side in Hästholmsfjärden in 2002.

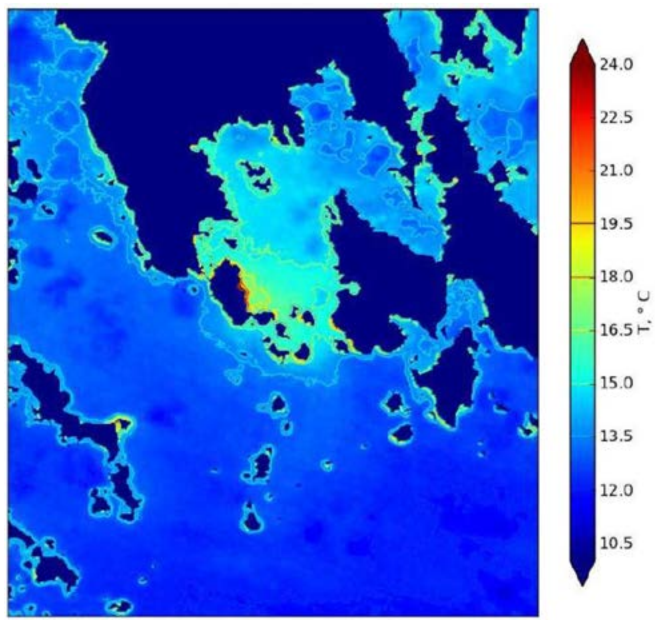


Figure 3-6. Water temperature in Hästholmsfjärden; average calculated from satellite measurements (Marjamäki 2012). The average is calculated from 11 satellite measurements conducted between 16 May 2009 and 29 September 2009.

conducted in the summer of 2011. Due to regionally extensive data on the measurement of seawater temperatures, the reviews concerning ice-free seasons employ data from the 2011 summer season, covering the period 1 June – 30 September.

The year 2011 was also unusually warm (Figure 3-7). The temperature on the southern coast was 1.5–2 °C warmer than average (1981–2000; Finnish Meteorological Institute 2020a). In Helsinki, June was 2 °C, July 3 °C and August 1.3 °C warmer than average. HELCOM reports (2007 & 2013 and BACC Author Team 2008) have projected a 2–4 (5–95% fractiles 1–6) °C increase in air temperatures for summers in the Gulf of Finland in 1961–1990…2071–2099 (Figure 3-8). According to the Intergovernmental Panel on Climate Change (IPCC 2019), the global air temperature will increase by approximately 1.0 °C (probable range 0.4…1.6 °C) by 2050 in the context of emission scenario RCP2.6 or in the context of emission scenario RCP8.5, by 1.8 °C (probable range 1.2…2.3 °C) compared to the global mean air temperature in 1986–2005 (Figure 3-9). Therefore, 2011 also depicts climate conditions which are still relatively rare in our current climate, but which will become significantly more common by the middle of this century (Climate Guide 2021b).

In 2011, the annual outages at Loviisa's power plant units were short-term refuelling outages. The annual outage of Loviisa 1 was carried out in 21 August – 7 September 2011, and that of Loviisa 2 in 10 September – 30 September 2011. The maximum temperatures of seawater in 2011 occurred in July, at which point both power plant units were in power operation (meaning that they were producing electricity for the power grid normally) when the seawater was at its warmest. Figure 3-10 shows the flow of the cooling water used by the power plant in June – August 2011 and indicates that the flow

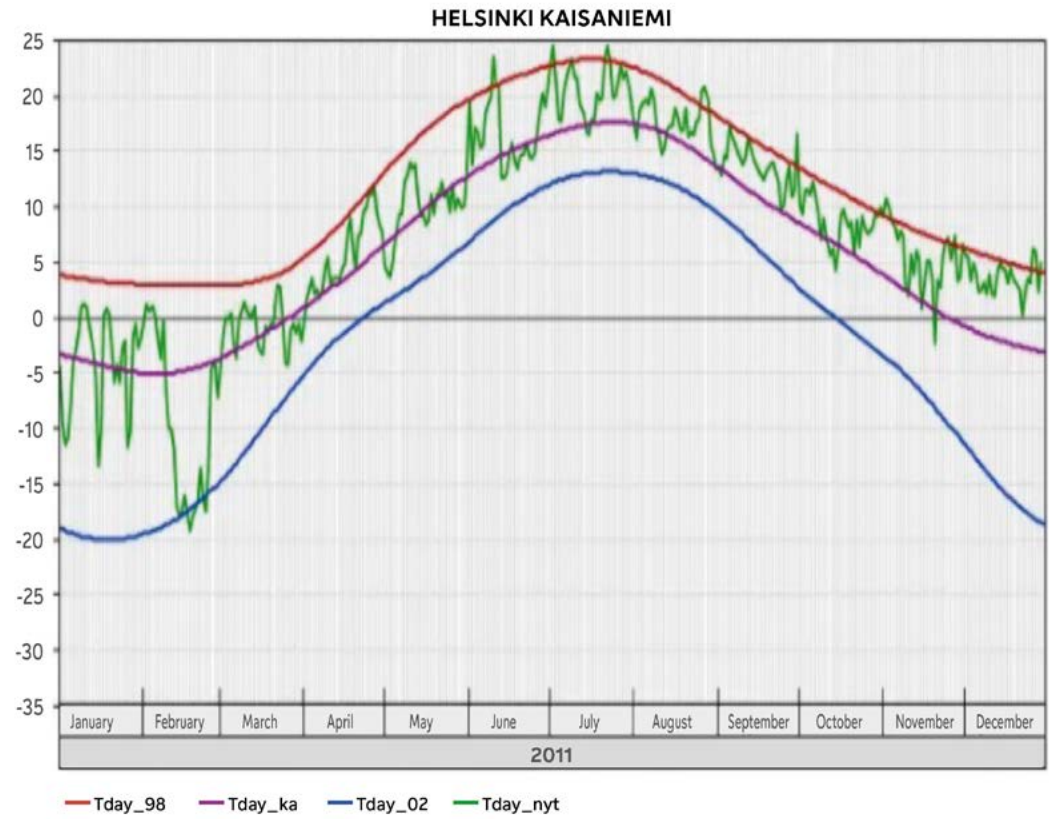


Figure 3-7. The mean daily temperature in Kaisaniemi, Helsinki, in 2011 (green) compared to the reference period (1981–2000) (Finnish Meterological Institute 2020a). Average of the reference period's mean daily temperature (purple) and 2% and 98% fractiles (blue and red).

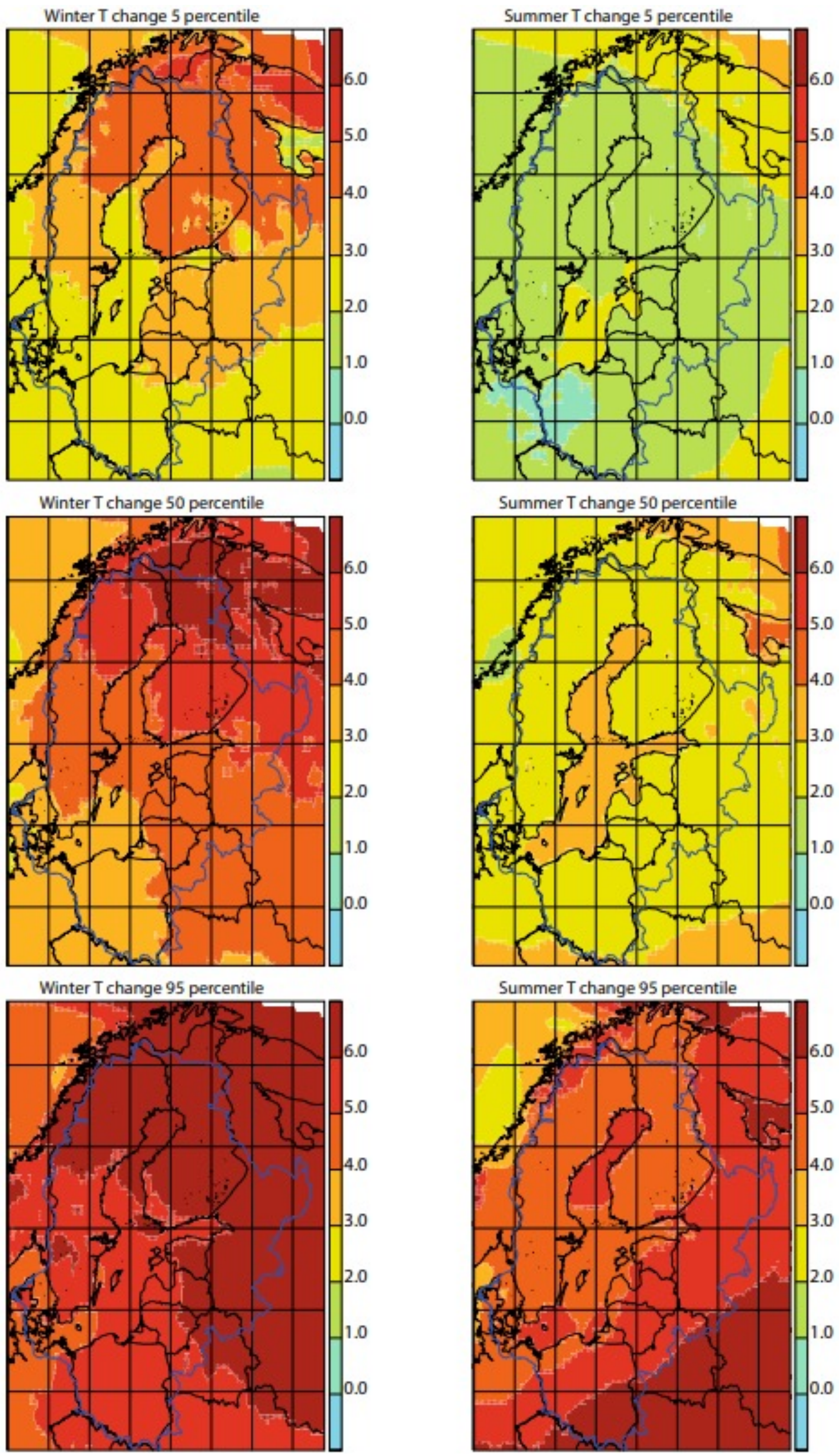


Figure 3-8. Projected change in winter and summer temperatures in 1961–1990...2071–2099 (HELCOM 2013). The left-hand column displays winter; the right-hand column summer; the fractiles from the top are 5, 50 and 95%.

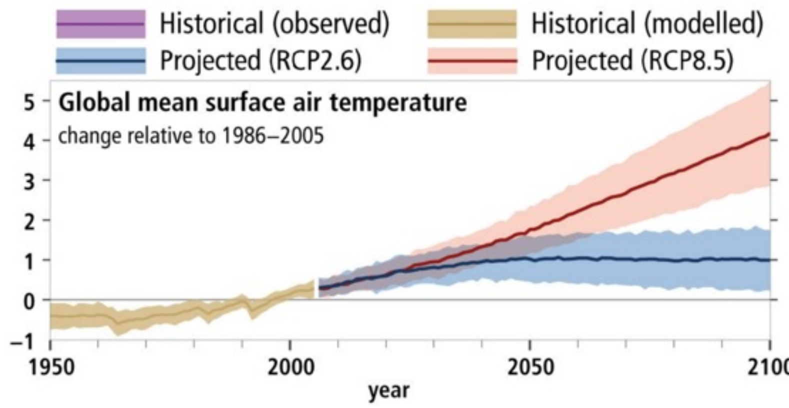


Figure 3-9. Projected change in global air temperature relative to 1986–2005. The figure has been edited from figure SPM.1 of the reference (IPCC 2019).

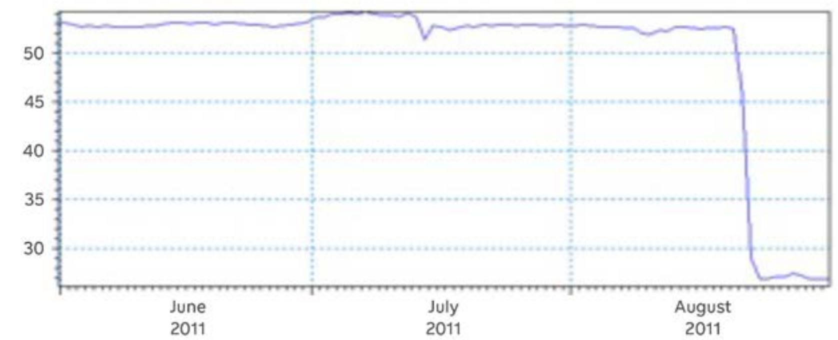


Figure 3-10. Intake flow (m^3/s) of cooling water in June–August 2011.

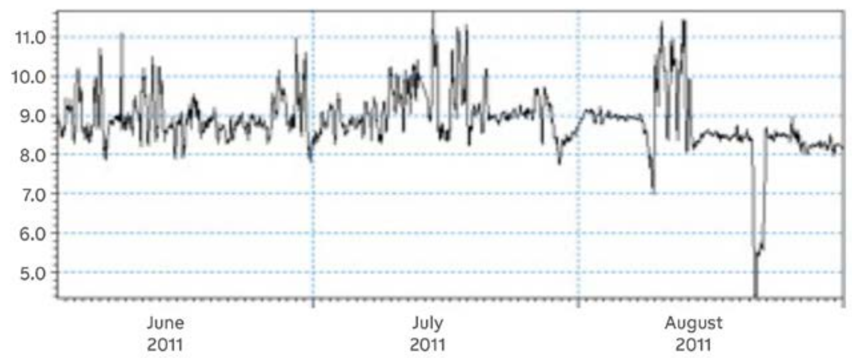


Figure 3-11. Increase in the temperature (°C) of cooling water as it passes through the power plant in June–August 2011.

during both units' power operation was approximately 52–54 m^3/s. The figure also shows that the flow is nearly halved in late August when Loviisa 1 is shut down for the annual outage. Based on Figure 3-11, it can be noted that the cooling water typically warms by around 8–10 °C in the summer as it passes through the power plant.

3.4 SELECTION OF CALCULATION PERIOD – ICE SEASON

Conditions during the ice season differ from the 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. The ice also prevents any mixing of the water by the wind, which can slow down the rate at which the warmed cooling water mixes with the surrounding water column. Ice cover observations which are extensive in terms of both time and place therefore constitute important baseline data for assessing the impact in the winter.

Fortum has monitored the ice cover in the surroundings of Loviisa power plant on an annual basis. The satellite photos from March 2018 (Figure 3-13) are the most applicable data for the modelling. March 2018 was relatively cold (Finnish Meteorological Institute 2020b; Figure 3-12). Although current tools do not allow for the dynamic modelling of ice cover,

Figure 3-12. Mean monthly temperatures at Kaisaniemi, Helsinki, in 2018 (columns) and the temperatures of the reference period. (Finnish Meteorological Institute 2020b)

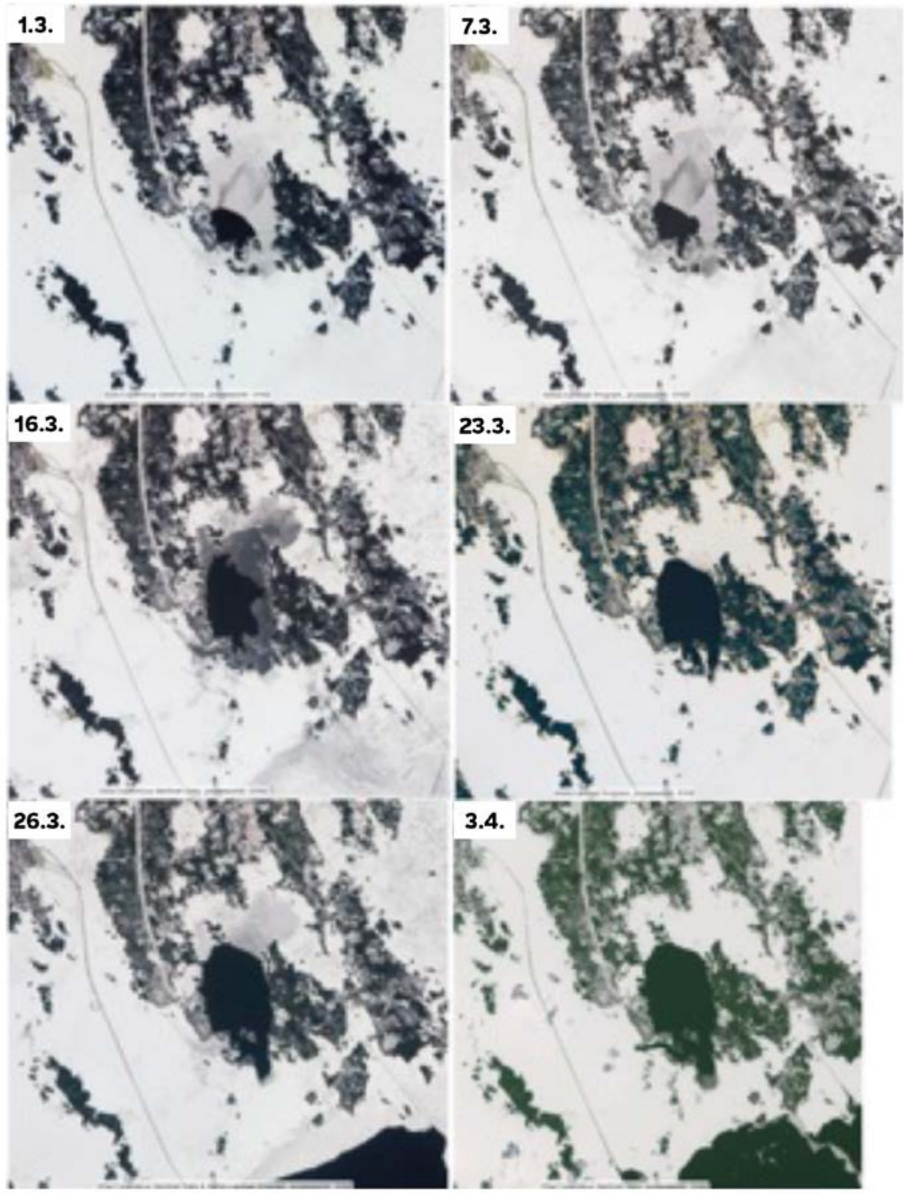


Figure 3-13. Ice cover in the surroundings of Hästholmen in the winter of 2018. The dates on which the photographs were taken are shown in the upper left-hand corner of each photograph.

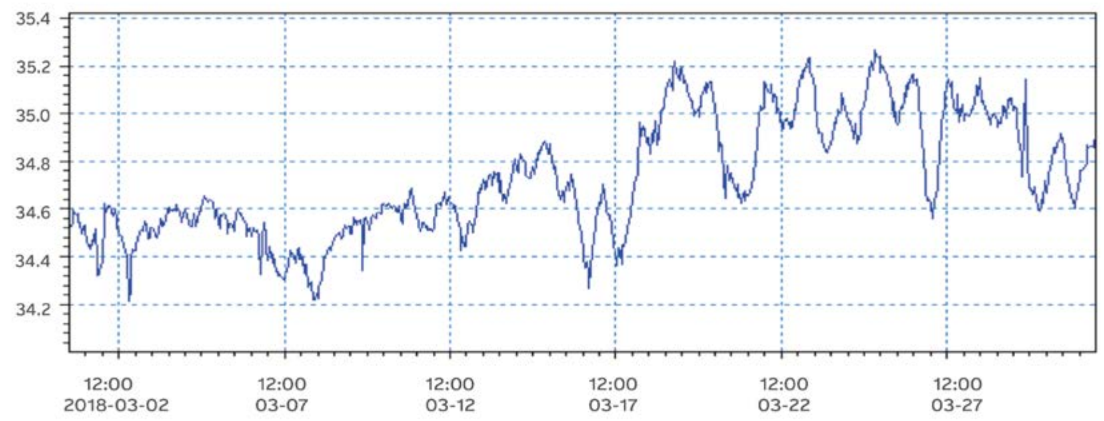


Figure 3-14. Intake flow (m³/s) of cooling water in March 2018.

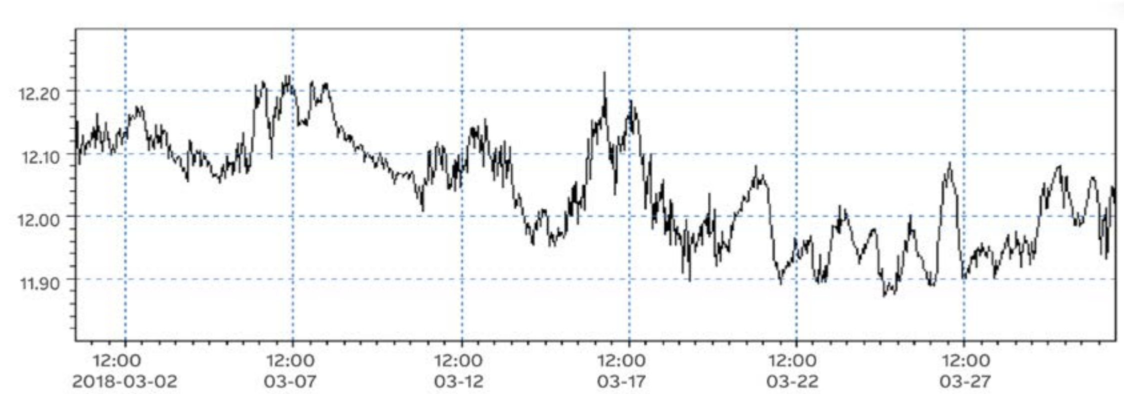


Figure 3-15. Increase in the temperature (°C) of cooling water in March 2018.

modelling with an ice cover pursuant to the observation data provides a useful conservative estimate of the dispersion of the thermal effect. The intake flow (approximately 35 m³/s) and increase in the temperature (approximately 12 °C) of the cooling water in March were normal (Figures 3-14 and 3-15).

3.5 ENVIRONMENTAL CONDITIONS

Figure 3-16 shows the monthly wind speed and air temperature averages based on the measurements of Loviisa power plant, as well as the monthly averages of cloudiness and solar radiation based on the measurements of the Finnish Meteorological Institute (Finnish Meteorological Institute 2021), employed in this report within the framework of a licence (Creative Commons 2021). The cloudiness is indicated in eighths so that 0/8 indicates a cloudless sky, and 8/8 complete cloud cover. The change in the measurement height of wind speed from 30 m to a height of 44 m (Graph 3-16 a) is the result of the modernisation of Loviisa power plant's weather observation system. The break visible in the time series of the air temperature (Graph 3-16 b) is the result of the failure of a temperature sensor. The time of the ice-free season examined in the modelling is marked on all graphs in Figure 3-16 with an orange background, and time of the ice season is marked with a blue background.

Based on Figure 3-16, one can see that the wind speeds during the times employed in the review have been fairly close to normal wind conditions. In respect of air temperature, the maximum temperatures and mean monthly temperatures of the ice-free season reviewed were the highest among the reference years. However, in respect of the ice season, the air temperatures of the review period were among the lowest within the reference years.

Figure 3-17 shows the wind rose and the wind velocity profile based on the hourly averages in 2010–2020. As Figure 3-17 a) shows, the most common wind direction in the vicinity of Loviisa power plant over a long period of time is from the southwest or east-southwest (in 28% of cases). In all directions, wind speeds are typically 0–8 m/s. The most common wind speed is 3–4 m/s (Figure 3-17 b).

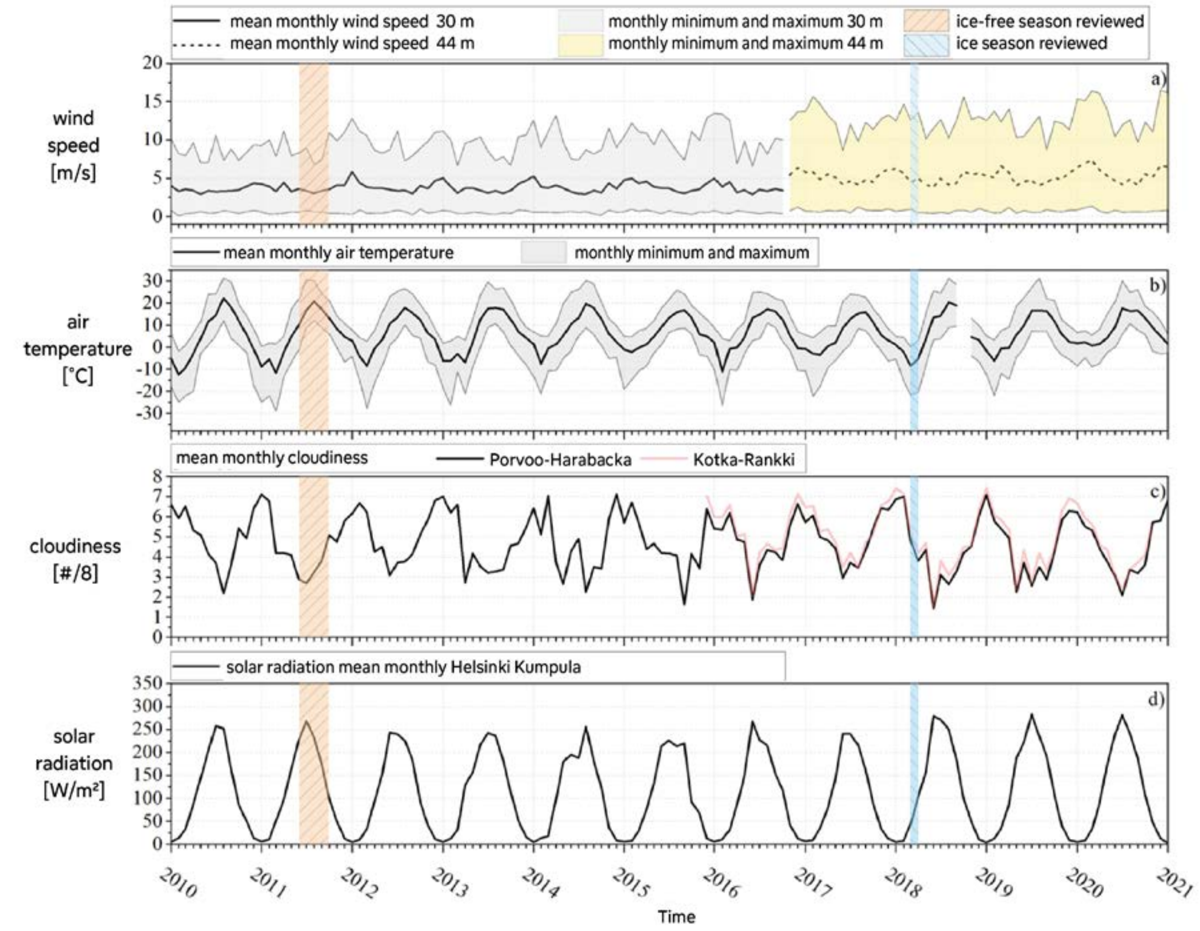


Figure 3-16. The mean monthly a) wind speed, b) air temperature, c) cloudiness and d) global solar radiation in 2010–2020. Also shown are the monthly maximum and minimum hourly averages in terms of wind speed and temperature.

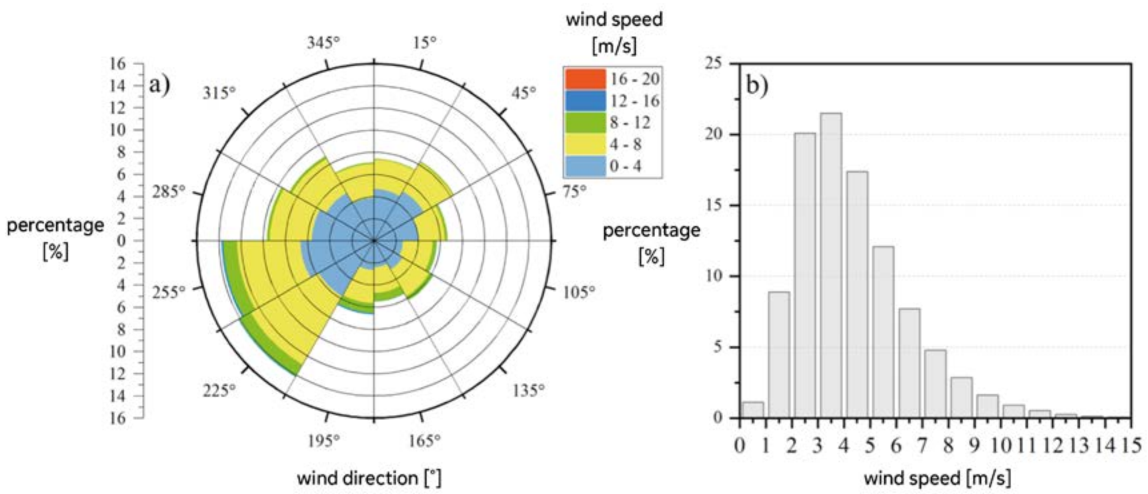


Figure 3-17. A wind rose (a) and wind speed frequency histogram (b), based on the wind measurements conducted at heights of 30 m and 44 m by Loviisa power plant's weather observation system. The measurements were carried out between 2010 and 2020.

Table 3-1 shows the annual averages of wind speed, air temperature, cloudiness and solar radiation. The higher values observed in wind speeds since 2017 are attributable to a change in the height of the measurements from 30 m to 44 m. The data in the table show that while the air temperature is 0.5 °C higher than average in terms of 2011, the annual means of other weather variables are fairly close to the average conditions in 2010–2020. In terms of 2018, the average wind speed was 0.3 m/s lower than the long-term average, and the air temperature was 1 °C lower. Despite the low mean annual temperature, the summer of 2018 was one of the warmest summers in the period between 2010 and 2020. This is also an indication that the winter at the time was colder than average, given that the mean annual temperature was low, despite the warm summer. Cloudiness was slightly below average in 2018, which partly also explains the higher-than-average values of solar radiation during the lightest time of the year and the cold conditions in the winter.

Figure 3-18 shows the wind rose and the wind velocity profile for the ice-free season reviewed in the report. The figure was prepared on the basis of the hourly averages of the wind data. Figure 3-18 a) shows that the most common wind direction is the same (southwest and east-southwest) as when observed over a longer period of time (Figure 3-17 a). In addition, the wind has blown quite often from a sector delimited by the northeast and east-southeast during the period in question. Wind speeds during the period in question were 2–4 m/s for 50% of the time (Figure 3-18 b).

Table 3-2 shows statistics calculated from the weather phenomena during the ice-free season in 2011. Based on the table, the conditions during the period in question can be seen to have been clear and characterised by light wind, due to which solar radiation has warmed the surface effectively. As a result, the air temperature during the period was relatively high.

Figure 3-19 shows the wind rose and the wind velocity profile for the ice season reviewed in the report. The figure was prepared on the basis of the hourly averages of the wind data. As can be seen from Figure 3-19 a, the wind rose for the period significantly departs from the wind conditions observed over a longer period of time (Figure 3-17 a). The most common wind directions in March 2018 were north-northwest and east-northeast, which partly explains the period's lower air temperatures. Besides the wind direction, the wind

Table 3-1. The mean annual wind speed, air temperature, cloudiness and global solar radiation in 2010–2020.

Year	Wind speed [i] [m/s]	Air temperature [i] [°C]	Cloudiness Porvoo /Kotka[ii] [#/8]	Solar radiation[iii] [W/m²]
2010	3.5	4.6	5.0	110.3
2011	3.8	6.8	4.5	116.3
2012	3.9	5.4	5.1	111.1
2013	3.8	6.5	4.5	116.7
2014	3.7	6.7	4.6	109.2
2015	4.0	7.2	4.6	108.6
2016	3.5	5.9	4.7 / 5.2	110.4
2017	5.2	5.9	5.0 / 5.3	105.8
2018	4.9	5.3	4.3 / 4.7	122.3
2019	5.1	6.7	4.5 / 4.9	118.2
2020	5.6	8.1	4.4 / 4.3	119.3
Average	3.7 (30 m) 5.2 (44 m)	6.3	4.7 (Porvoo) 4.9 (Kotka)	113.5

i) The wind speed and air temperature values are based on Loviisa power plant's weather measurements. In terms of wind speed, the results for 2010–2016 are based on wind measurements made at a height of 30 m, and the results for 2017–2020 on measurements made at a height of 44 m.

ii) The values of cloudiness are based on the cloud cover measurements of the Finnish Meteorological Institute (Finnish Meteorological Institute 2021, Creative Commons 2021). The measurements were conducted in Harabacka, Porvoo, and Rankki, Kotka. Measurements from Kotka are available as from November 2015, but in this context, only full-year results are shown.

iii) The results on solar radiation are based on the sun's global radiation measurements conducted by the Finnish Meteorological Institute at Kumpula, Helsinki (Finnish Meteorological Institute 2021, Creative Commons 2021).

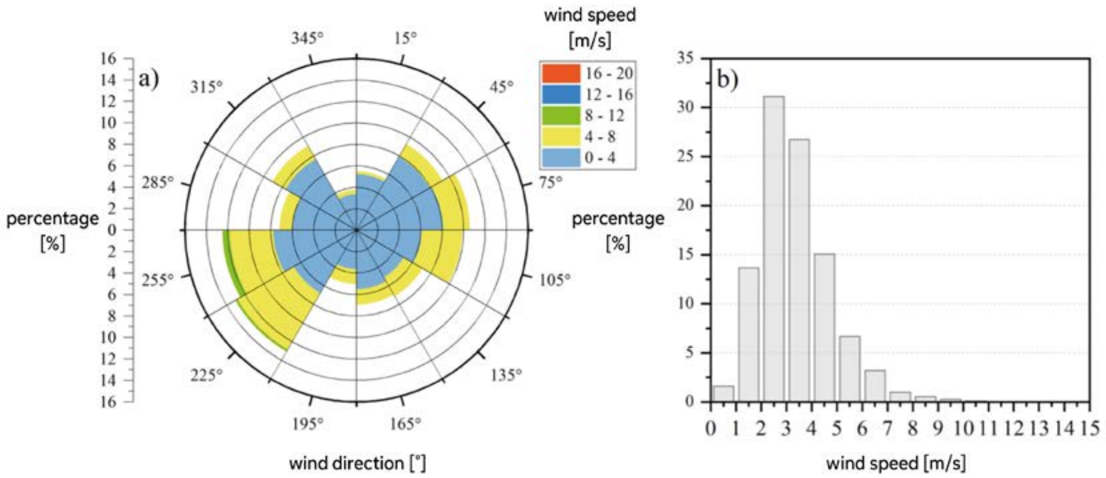


Figure 3-18. A wind rose (a) and wind speed frequency histogram (b) based on the wind measurements conducted at a height of 30 m by Loviisa power plant's weather observation system. The measurements were carried out between 1 June and 30 September 2011.

Table 3-2. Statistics on wind speed, air temperature, cloudiness and total solar radiation from the ice-free season in 1 June – 30 September 2011. The baseline data consist of the variables' hourly averages.

Statistical variable	Wind speed [m/s]	Air temperature [°C]	Cloudiness Porvoo [#/8]	Solar radiation [W/m²]
Minimum	0.4	6.0	0	-4
Maximum	10.9	30.7	8	997
Average	3.3	17.1	3.7	193.5
Median	3.1	16.8	3.7	69
Standard deviation	1.4	4.3	3.2	248.2

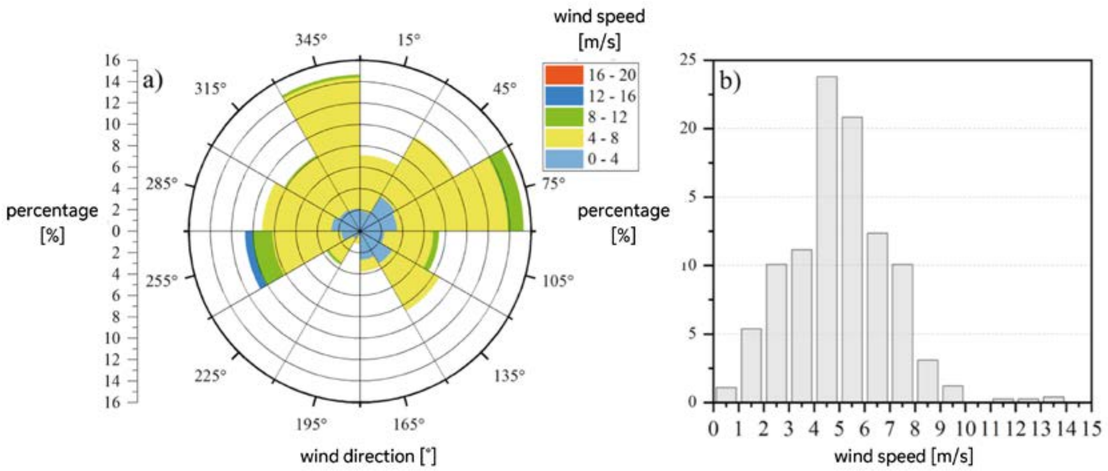


Figure 3-19. A wind rose (a) and wind speed frequency histogram (b) based on the wind measurements conducted at a height of 44 m by Loviisa power plant's weather observation system. The measurements were carried out between 1 March and 31 March 2018.

speeds also deviate from the typical long-term speeds, being somewhat higher than them. The wind speeds during the period were 4–6 m/s for 45% of the time.

Table 3-3 shows statistics calculated from the weather phenomena during the reviewed 2018 ice season. Based on the table, it can be seen that the conditions during the period in question were significantly windier than during the ice-free season. This difference is partly due to the fact that the observations carried out during the ice season employ wind measurements conducted at a height of 44 m, whereas the observations carried out during the ice-free season employ wind measurements conducted at a height of 30 m. However, March is typically a windier time of year than the summer (Figure 3-20). In terms of air temperature, the ice season was fairly cold and reasonably clear with regard to cloud cover conditions. The heightened effect of the diffuse solar radiation caused by the snow cover is visible in the readings of the sun's global radiation.

Figure 3-21 shows the interpolated sea level for Loviisa from the sea level measurements conducted at Helsinki and Hamina by the Finnish Meteorological Institute. The level is indicated relative to the theoretical mean water level. The data on Helsinki and Hamina are part of the Finnish Meteorological Institute's Open Data (Finnish Meteorological Institute 2021), used in this report within the framework of a licence (Creative Commons 2021). Although Loviisa power plant also has a sea level indicator of its own, the level assessed through interpolation from the measurements of the Finnish Meteorological Institute is better at describing the sea level conditions of the open sea, used as a boundary condition for the modelling. As can be seen from the figure, the sea level is at a quite typical level during the ice-free season,

Table 3-3. Statistics on wind speed, air temperature, cloudiness and total solar radiation from the ice season in 1 March – 31 March 2018. The baseline data consist of the variables' hourly averages.

Statistical variable	Wind speed [m/s]	Air temperature [°C]	Cloudiness Porvoo [#/8]	Solar radiation [W/m2]
Minimum	0.5	-20.5	0	-3.1
Maximum	13.7	3.0	8	669
Average	5.0	-5.2	3.8	103.8
Median	4.9	-4.6	4	0.6
Standard deviation	2.0	5.2	3.5	163.8

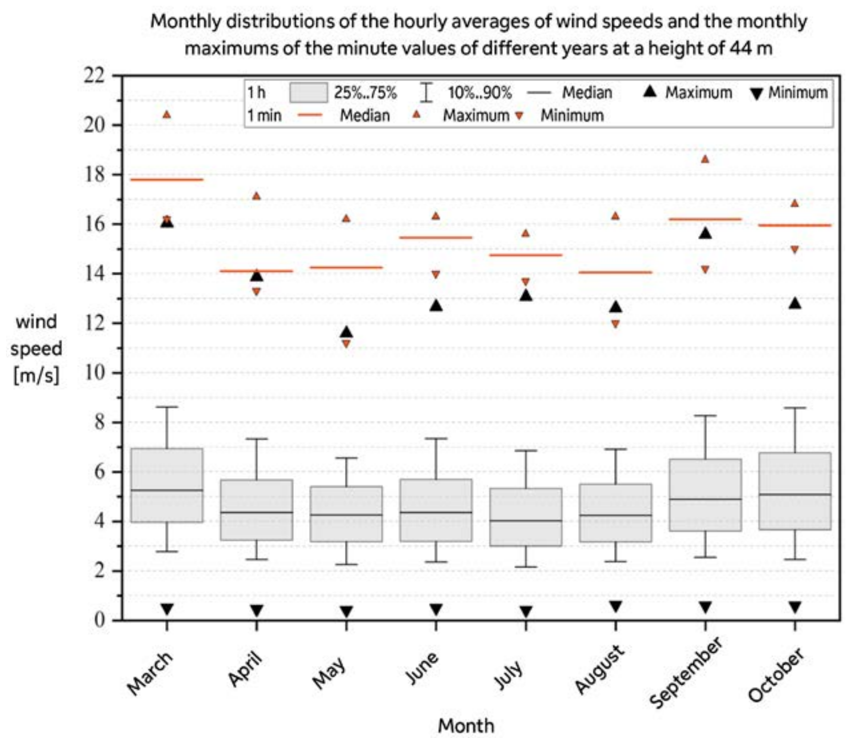


Figure 3-20. The wind velocity profile formed from the 44 m wind speed measurements of Loviisa power plant's weather observation system per month in 2017–2020. The statistics calculated from the hourly averages are marked in grey and black. The statistics calculated from the monthly maximums of a month's average wind speeds per minute are marked in red.

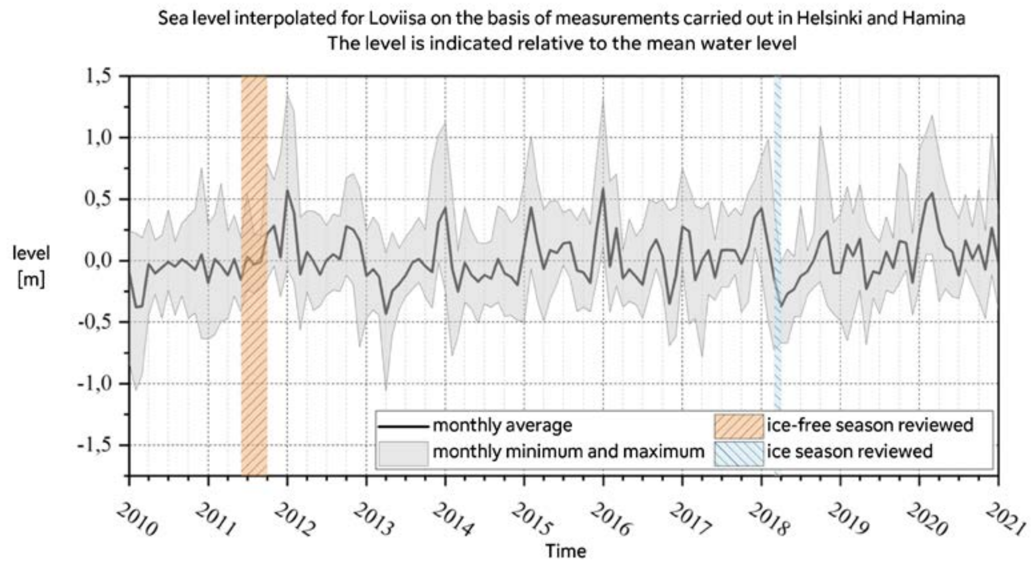


Figure 3-21. The monthly average of the sea level, as well as the minimum and maximum values for an individual hour within a month at Loviisa, relative to the theoretical mean water level.

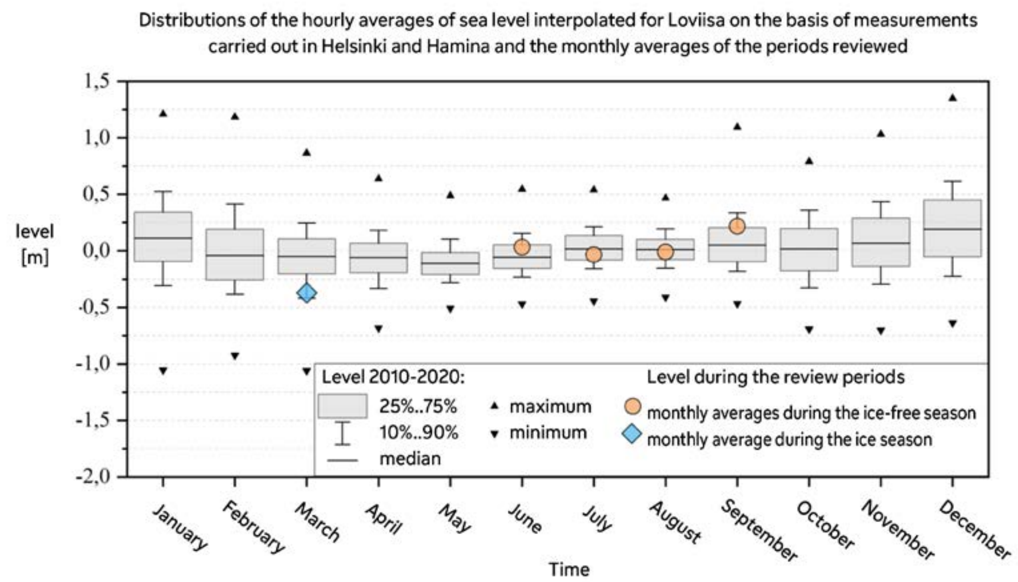


Figure 3-22. The monthly distributions of the average hourly sea levels and the monthly averages of the review periods. The sea levels are indicated relative to the theoretical mean water level.

and even the variation of the minimum and maximum levels during the period is minor. During the ice season, the sea level is at a slightly lower-than-average level, but in this case too, variation within the period is minor.

Figure 3-22 shows the monthly distributions of the average hourly sea levels and the monthly averages of the review periods for Loviisa interpolated from the sea level measurements conducted at Helsinki and Hamina by the Finnish Meteorological Institute. This figure shows more clearly than Figure 3-21 that the sea levels during the review period concerning the ice-free season are at a fairly normal level and in terms of the ice season, at a slightly lower-than-normal level. The figure also shows that in March, variation in the extreme sea level values is typically greater than during the ice-free season. However, in September, the variation in the extreme sea level values is typically greater than in June, July and August.

4. Description of modelling

4.1 CALCULATION EMPLOYED IN THE REVIEW

The review is based on hydraulic modelling, carried out with DHI's Mike 3 FM non-hydrostatic flow model with an adjustable computational mesh, which calculates with complete three-dimensional equations (DHI 2017); it was released in 2019. The tool allows both the hydraulics of smaller areas and the phenomena of more extensive areas to be described simultaneously. In addition to flows, the model calculates the seawater's temperature and salinity. Among other things, the baseline data consist of wind conditions, the sea level (including variations), air temperature, ice cover, and components of the net radiation of the sea and atmosphere. The modelling area extends from the coast up to Orrengrund. The model for the smaller area previously prepared for the front of the intake location was used in validating the intake location's hydraulics in terms of the more extensive model now prepared. 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, and the continuous observations of seawater temperature, salinity and flows, for example. The model was calibrated by comparing the calculated values to the observations made during the 2011 ice-free season. Printouts of the model's three-dimensional flowrate, temperature and salinity values were made every three hours, and the same was applied to selected points at the reviewed depths at 30-minute intervals.

4.2 MODEL'S CALCULATION GRID AND THE EQUATIONS USED IN THE MODELLING

The model's computational mesh and depth ratios are shown in Figure 4-1. The model has 1,832 horizontal elements and 1,900 nodes. The element density is at its greatest at Hästholmsfjärden and Hudöfjärden, near the power plant. The summer model has 44 element layers, of which the surface's four top ones are adjustable (Table 4-1). The winter model is identical in all respects other than there being three adjustable element layers, with the upper surface of the fixed layers at a level of -1 metres. The minimum water depth set for the model in both the summer and winter models was 1 metre. The elements of varying heights are located in the depth zone, starting immediately downwards from the varying water surface and extending to the upper surface of the fixed element layers, unless the area is shallower, in which case they extend all the way down to the seabed. The thickness of the layers was set to be distributed evenly.

Due to the requirements of the calculation, the model employed a minimum depth of one metre, given that the water level, at its lowest, dropped to a value of -0.59 m during the calculation. The intake has been carried out according to a natural width (32.8 m) and height (from a level of 8.5 m to 11.1 m), and an even flowrate in line with the flow and surface area was set for the entire area. The discharge of warm cooling water in the summer model is executed with a gate function so that the water discharges at a depth range of 0…1 m. This allows for a nearly horizontal bottom for the elements, which enables the modelling of the natural horizontal flow. In the winter model, the discharge to the surface is executed so that the water discharges from the discharge location to the surface element in an area with a depth range of 0…1 m without a gate. The difference in the execution is due to the fact that in the summer model, a geometry similar to the winter model produced an unnatural flow from the discharge into the waterway and had to be changed.

The calculation was performed by using complete Reynolds-averaged three-dimensional Navier-Stokes equations and artificial compressibility (DHI 2017). The calculation of the eddy viscosity employed Smagorinsky's Large Eddy Simulation method in the horizontal direction and the k-epsilon method in the vertical direction. The model relies on the advanced Richardson damping to describe the density layer's impact on vertical mixing. The method or its coefficients cannot be changed in the model, although stronger dampening of the kind also suggested in the literature (Elliott & Venayagamoorthy 2010) could indeed have been tried for the Gulf of Finland. The most precise possible approximations of several orders were used in the calculations of time and place, turbulence, and the transport of temperature and salinity, because although this lengthens the calculation time, it simultaneously increases accuracy. The time step could be selected from a range of 0.01–30 seconds, depending on the convergence of the iterations. The Coriolis force was accounted for in the calculations. The standard 0.5 m was used as the bed's roughness height.

4.3 MODEL'S BOUNDARY CONDITIONS AND INITIAL VALUES

In the model, the boundaries, excluding the open sea, are set as land areas, where the perpendicular flowrate has been set at zero. The boundary condition used at the open-sea boundary is the water level; the water level has been interpolated linearly from the hourly averages of the tide gauges at Kaivopuisto, Helsinki, and Hamina, using distance. The temperature and salinity boundary conditions used in the open sea were two-dimensional time series prepared on the basis of Luode Consulting Oy's automated observations and the manual observations in the environmental administration's Hertta database (Vedenlaatu/Uudenmaan ELY, Creative Commons). The river flows (Taasianjoki, Loviisanjoki, Ahvenkoski (Kymijoki), Koskenkylänjoki) are fed to the surface elements (depth approximately 0…0.5 m), with temperatures according to the Hertta service and assuming that the water salinity is zero. The values are complemented with the values of reference waterways.

The start time of the modelling calculation occurs slightly before the start of the actual review period so that the cooling water flow has time to settle into a natural state by the beginning of the review period. In terms of the ice-free sea-

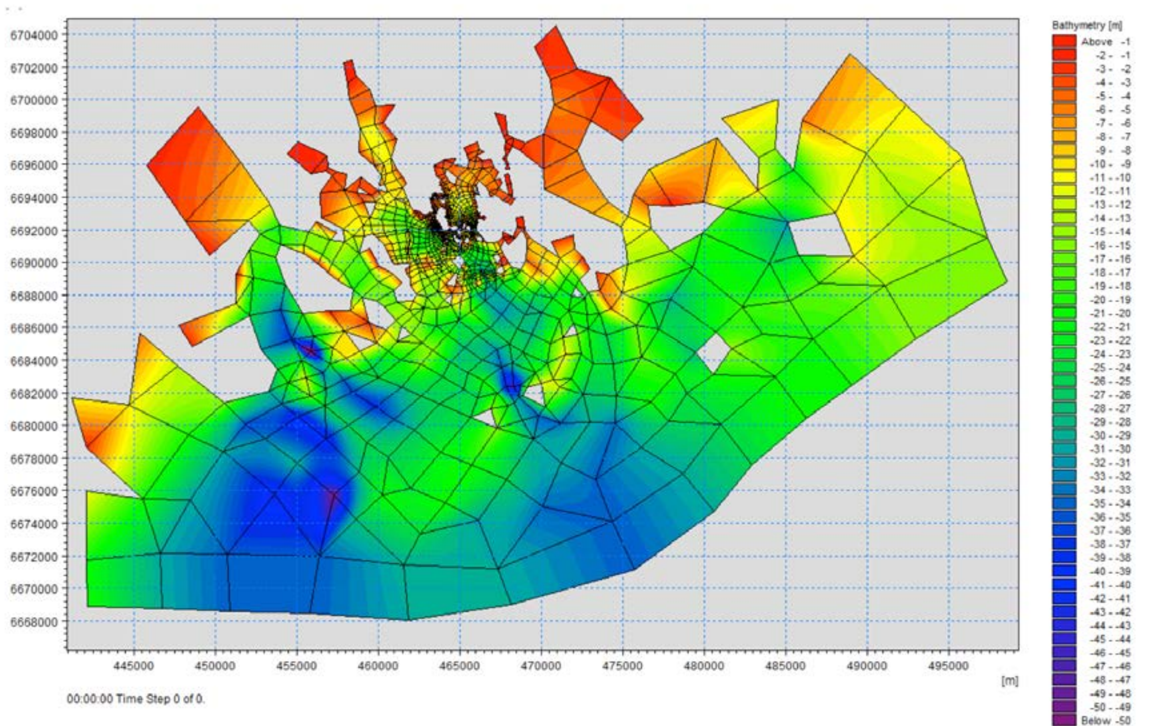


Figure 4-1. Model's computational mesh and the seabed's elevation. Coordinate system ETRS-TM35FIN.

Table 4-1. The vertical structure of the model's computational grid.

Depth (m)	Element type	Cell height
surface...2 m	adjustable 4 cells with even distribution	roughly 0.5 m
2 m...8,5 m	standard levels	0.5 m
8.5 m...11,1 m	standard levels (level of intake location)	0.65 m
11.1 m...12 m	standard levels	0.9 m
12 m...20 m	standard levels	1 m
20 m...30 m	standard levels	2 m
20 m...36 m	standard levels	3 m
36 m...40 m	standard levels	4 m
40 m...65 m	standard levels	5 m

son, the start time of the modelling calculation was 12 noon on 23 May 2011, whereas the review period actually employed in this work began on 1 June 2011. In terms of the ice season, the modelling calculation's start time was 12 noon on 18 February 2018, and the actual review period began on 1 March 2018. The initial condition employed in the model consists of the three-dimensional models of water temperature and salinity prepared on the basis of Luode Consulting Oy's (Luode Consulting Oy 2012) and the Hertta database's manual observations as well as, in terms of surface level, of the standard value for the entire area interpolated linearly from the Helsinki and Hamina tide gauges.

The longwave and shortwave radiation is described with minute averages observed in Kumpula, Helsinki. The model does not allow for the use of emergent longwave radiation calculated on the basis of water temperature. Rather, the longwave radiation emerging from the surface of the water is approximated with the help of solar radiation measurements conducted in Kumpula. During the review period concerning the ice season, the heat exchange between the water and the atmosphere in the modelling is set at zero for ice-covered areas.

The model calculation applied to the ice-free season employs the values 0.9 (Beta) and 1.4 (reduction factor) as the coefficients for the penetration depth of sunlight. These numerical values are high and typical for dystrophic and algae-rich dark waters, such as the Gulf of Finland, which is called "optically black". The model calculation applied to the ice season employs the coefficients 0.6 and 1.4, for clearer water.

The wind values for the vicinity of the power plant and the open sea were provided by Loviisa power plant's weather mast and the Finnish Meteorological Institute's Orregrund weather observation station, respectively. For the purposes of cooling water modelling, they have been converted to an elevation level of 10 m, employing a logarithmic profile conventionally used in wind conversions with a roughness class of 0.5 (Danish Wind Energy Association 2021). The atmospheric pressure, air temperature and relative humidity were provided by the Finnish Meteorological Institute's Orregrund weather observation station.

The numerical values of the wind's drag coefficient for the review periods were estimated in connection with the model's calibration. The values applied for the ice-free season are 0.315...1.12 x 10-3 linearly with a wind speed range of 0...25 m/s. These drag coefficient values are lower than the values for oceans, because the coast of the Gulf of Finland experiences waves emanating from its centre and tall waves caused by shallowness, both of which reduce the coefficients. The numerical diffusion in the model's deeper layers, which is significant compared to the extremely small natural diffusion in the sheltered coastal area, may have a coefficient-reducing impact on the results of the calibration. The use of larger coefficients would lead to an excessive vertical mixing of the temperature. Based on the calibration, the values attained for the review period concerning the ice season were 0.62...2.28 x 10-3. They are greater than the values applied to the ice-free season, because there is hardly any wave formation, and because the waves from the open sea cannot access the area either due to the ice cover.

The evaporation and condensation coefficients were also estimated in connection with the model's calibration. Dalton's coefficient 1 and Dalton's wind coefficient 1.8, as well as 5 and 0.5 x 10-3 as the coefficients for the heat convection in cooling and warming, are applied to the ice-free season. The values are typical for Arctic regions, given that the temperature differences are fairly large, and the topography varying and small-featured (Esbensen & Reynolds 1980). The coefficients may also be influenced by the fact that the model cannot apply the water's surface temperature in the transfer of the longwave infrared radiation. Large numerical values – 3, 5.4 and 10, and 0.5 x 10-3 – in accordance with the reference (Esbensen & Reynolds 1980) were arrived at as the coefficients for the ice season in connection with the calibration. This is a result of the sole ice-free area being immediately next to the discharge location, where the temperature difference of the air and water is also unusually large, and the coefficient correspondingly large. The effect of rain was not modelled, and the same applies to the transfer of heat between the bed and the water column. Nor are these components usually modelled.

Table 4-2. The scaling factor for the added vertical mixing outside the scale of the model's mechanisms and elements at different depths.

Depth (m)	Scaling factor of diffusion
0...0.15 m	0,5
1 m	0,27
2 m	0,15
3 m	0,07
4 m	0,025
4.5 m	0

The diffusion outside the model's mechanisms and scale is described with the eddy diffusion calculated by the model for each cell and moment in time. Due to the amount of natural diffusion below the thermocline, which is small compared to the amount of the model's numerical diffusion, the scaling factor calibrated for it in the vertical direction of the surface and intermediate layers is the usual 0. In the layer above the thermocline, wind increases the mixing up to a point which is significantly larger than the sum of the numerical diffusion and the diffusion described by the model, and an "advanced diffusion coefficient" was arrived at in the calibration by adjusting a logarithm-type profile deeper from the surface in accordance with Table 4-2.

In the winter calculation, the values in Table 4-2 were halved with regard to Hästholmsfjärden; this accounted for the impact of the nearby sea area's ice cover, which weakens the mixing of the water. For the open sea, outside Orrengrundsfjärden, the value was set at 0 in an attempt to reduce mixing there. At the depth level of 0...10 m, the standard value 1.1 was used as the coefficient for horizontal diffusion, excluding the open sea. The turnover of deeper water is small, because the area has many isthmuses at a depth of approximately 10 m, slowing down the water's movements. The value calibrated for the diffusion coefficient in these areas is therefore 0.

A very high value is used for the horizontal diffusion of temperature and salinity in the open sea, outside Orrengrundsfjärden, to bring the boundary condition for temperature and salinity closer. The upswelling and downswelling phenomena, which have an even decisive impact on the boundary condition at the Gulf of Finland, are transverse phenomena, which are rapidly and most clearly visible immediately next to the coast, i.e. the shoreside part of Vådholmsfjärden. However, for the precise description of the dynamics of upswelling and downswelling, the boundary condition cannot be set there, because the effect of the power plant's cooling water extends to part of Orrengrundsfjärden. The boundary condition for temperature and salinity could therefore be brought artificially, with the help of a large horizontal diffusion coefficient, only outside Orrengrunds-fjärden. However, for the description of the fluctuation in the water's surface level and the wind's effect, the model's actual boundary is located further away in the open sea. This procedure allows part of the upswelling and downswelling dynamics to be described, but the description of the cooling waters' impact area and layers is precise.

4.4 MODEL CALCULATION'S VERIFICATION AND VALIDATION

4.4.1 Comparison with manual observations

Manual measurements were carried out at points 8, 9, 11 and 12 in Hästholmsfjärden (Figure 4-2) during the 1 June – 1 September 2011 modelling period. As can be observed, the

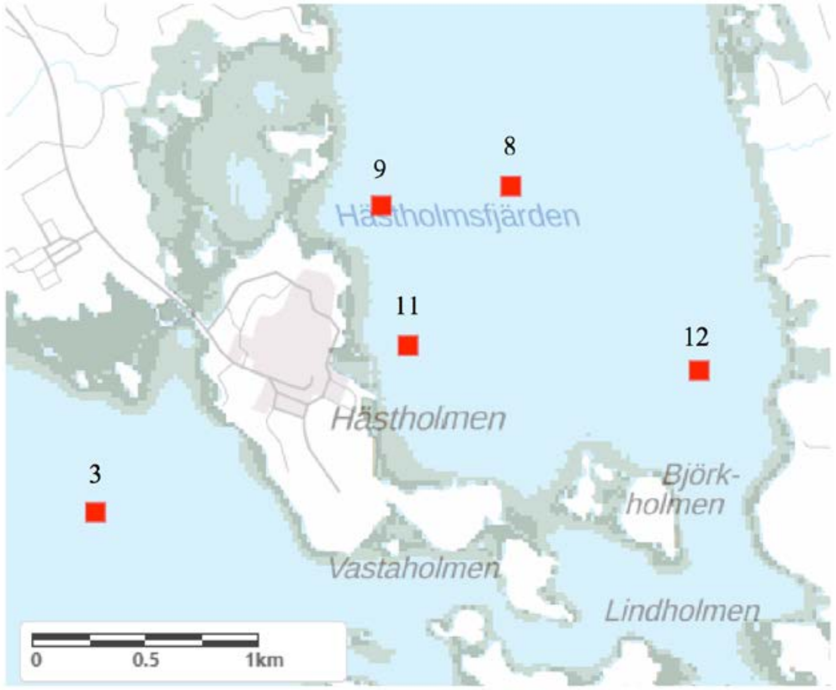


Figure 4-2. Points for the manual observation of water temperature in 2011.

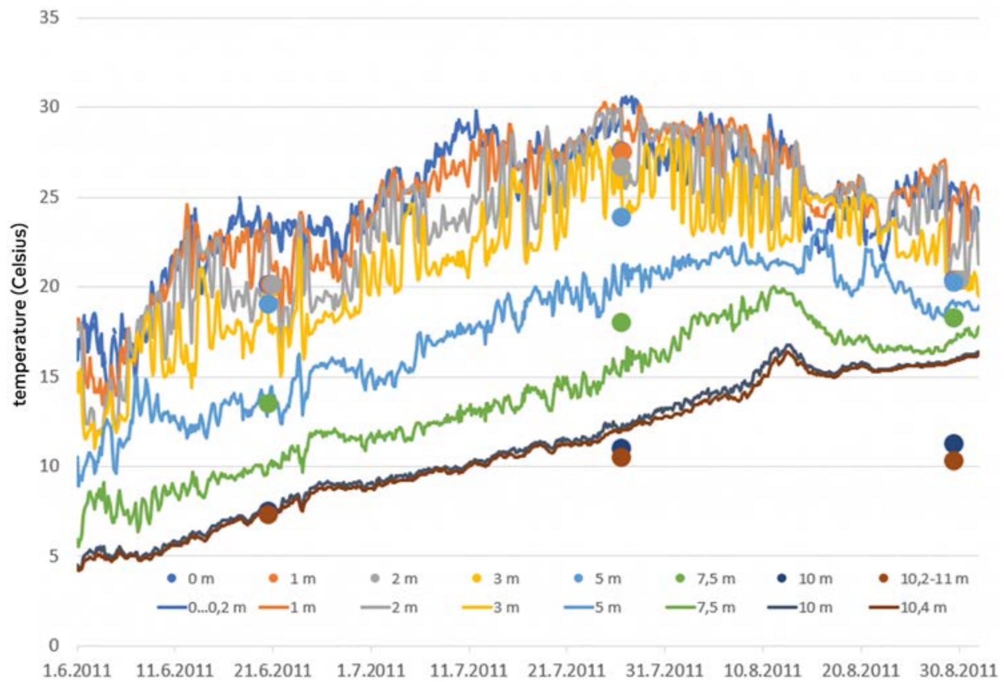


Figure 4-3. Manually observed (circles) and modelled (graphs) water temperatures at point 8 in Hästholmsfjärden.

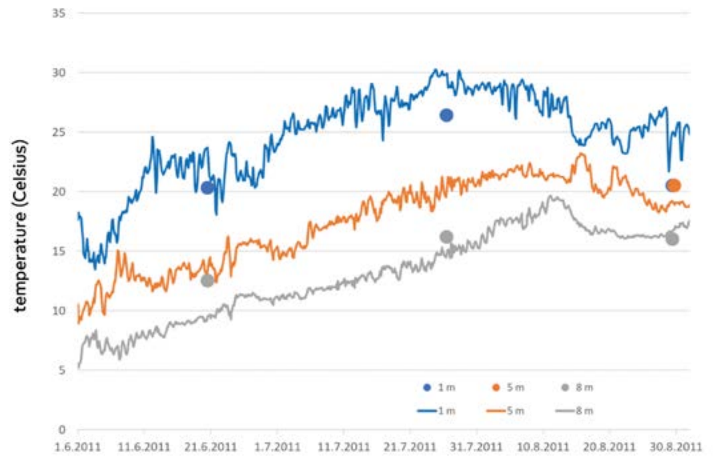


Figure 4-4. Manually observed (circles) and modelled (graphs) water temperatures at point 9 in Hästholmsfjärden.

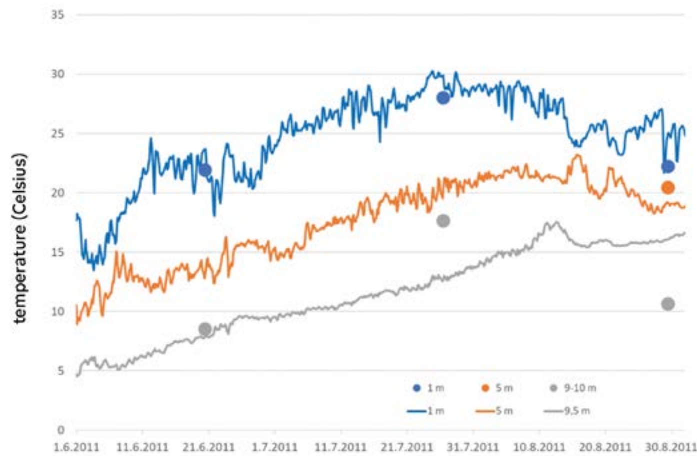


Figure 4-5. Manually observed (circles) and modelled (graphs) water temperatures at point 11 in Hästholmsfjärden.

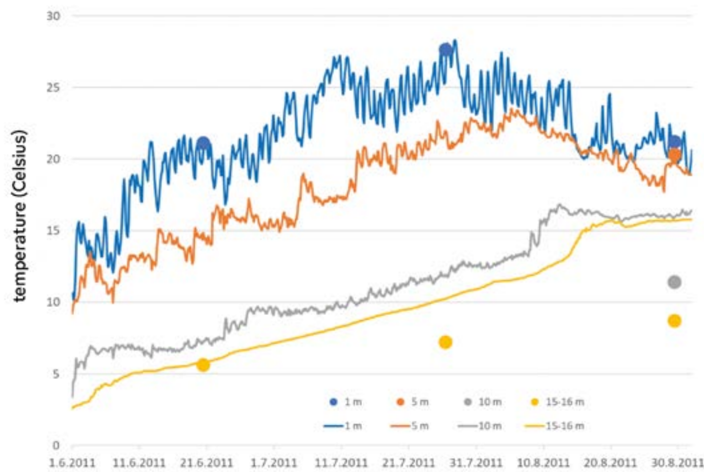


Figure 4-6. Manually observed (circles) and modelled (graphs) water temperatures at point 12 in Hästholmsfjärden.

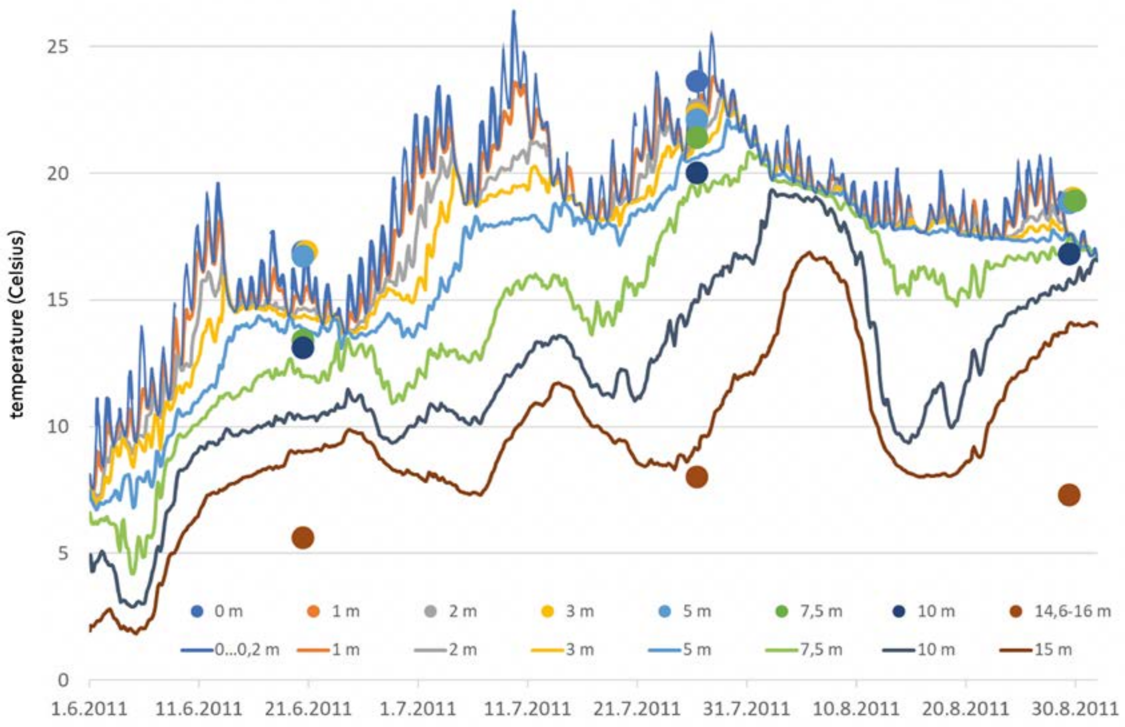


Figure 4-7. Manually observed (circles) and modelled (graphs) water temperatures at point 3 in Hudöfjärden.

modelled seawater temperatures follow the observed temperatures quite closely at points 9, 11 and 12 on the side of Hästholmsfjärden all the way down to a depth of 7.5 metres throughout the summer (Figures 4-3...4-6). The temperature modelled for deeper areas also corresponds with the observed temperature in June and July, but by the end of August, the water in the model has warmed more than the observations indicate. The temperature modelled at point 8 is higher at the surface and lower in the intermediate layer. The temperature modelled at the seabed matches the observations made in June and July, but warms more towards the end of August.

The modelled seawater temperatures therefore correspond with the observed temperatures fairly well, with the exception of the observations made at the deepest points in late August. What is key in terms of this review is that modelled temperatures close to the surface correspond with the observations. The equivalence is very adequate for reviewing the effects of the cooling water.

The seawater temperatures modelled at Hudöfjärden (Figure 4-2, point 3) correspond with the observations quite well down to a depth of 7.5 m (Figure 4-7). The temperatures modelled at a depth of 10 m and a depth of 15 m are slightly colder and warmer respectively than the observed temperatures (Figure 4-7).

4.4.2 Comparison with automated observations

The modelled seawater temperatures were also compared with the results of automatically registered measurements. The readings of the automated observations at point K1–K2 (Figure 3-1) are usually slightly lower than manually observed readings. In terms of the conditions in the summer of 2011, the seawater temperatures calculated with the model were compared with the observed seawater temperatures on the cooling water's discharge side at Hästholmsfjärden (buoys B and C), intake side at Hudöfjärden (K1) and towards the open sea at Vådholmsfjärden (K2). The comparison is shown in Figures 4-8...4-10. As can be seen from the figures, the water

Figure 4-8. Hästholmsfjärden, buoys B and C, the observed (above) and modelled (below) water temperature at various depths in June – August 2011. The fluctuation in the observations at the beginning of August is due to the maintenance of the measuring transducer.

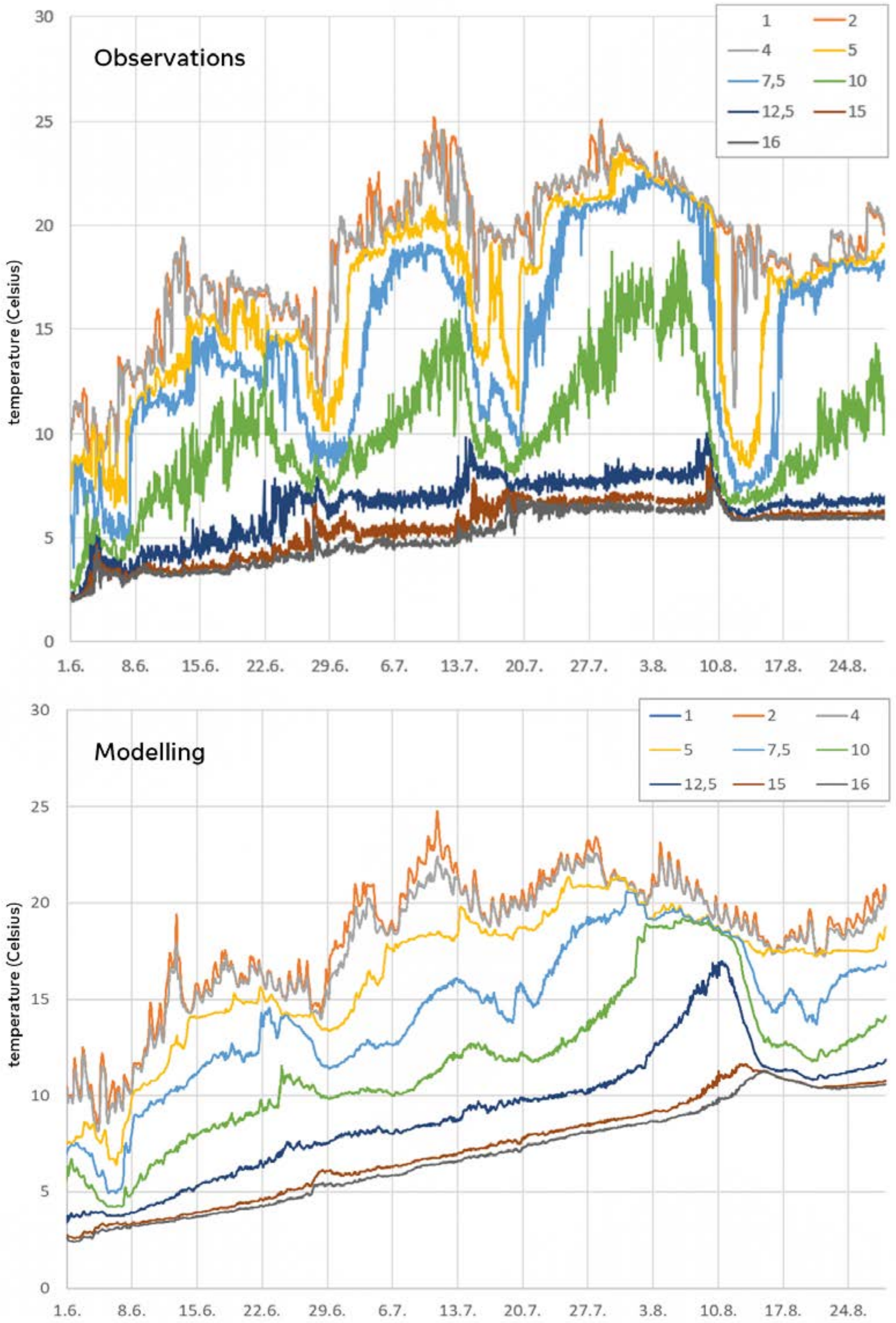


Figure 4-9. Hudöfjärden, buoy D (depths 2–4 m), point K1 (depths 5–16 m), the observed (above) and modelled (below) water temperature at various depths in June – August 2011.

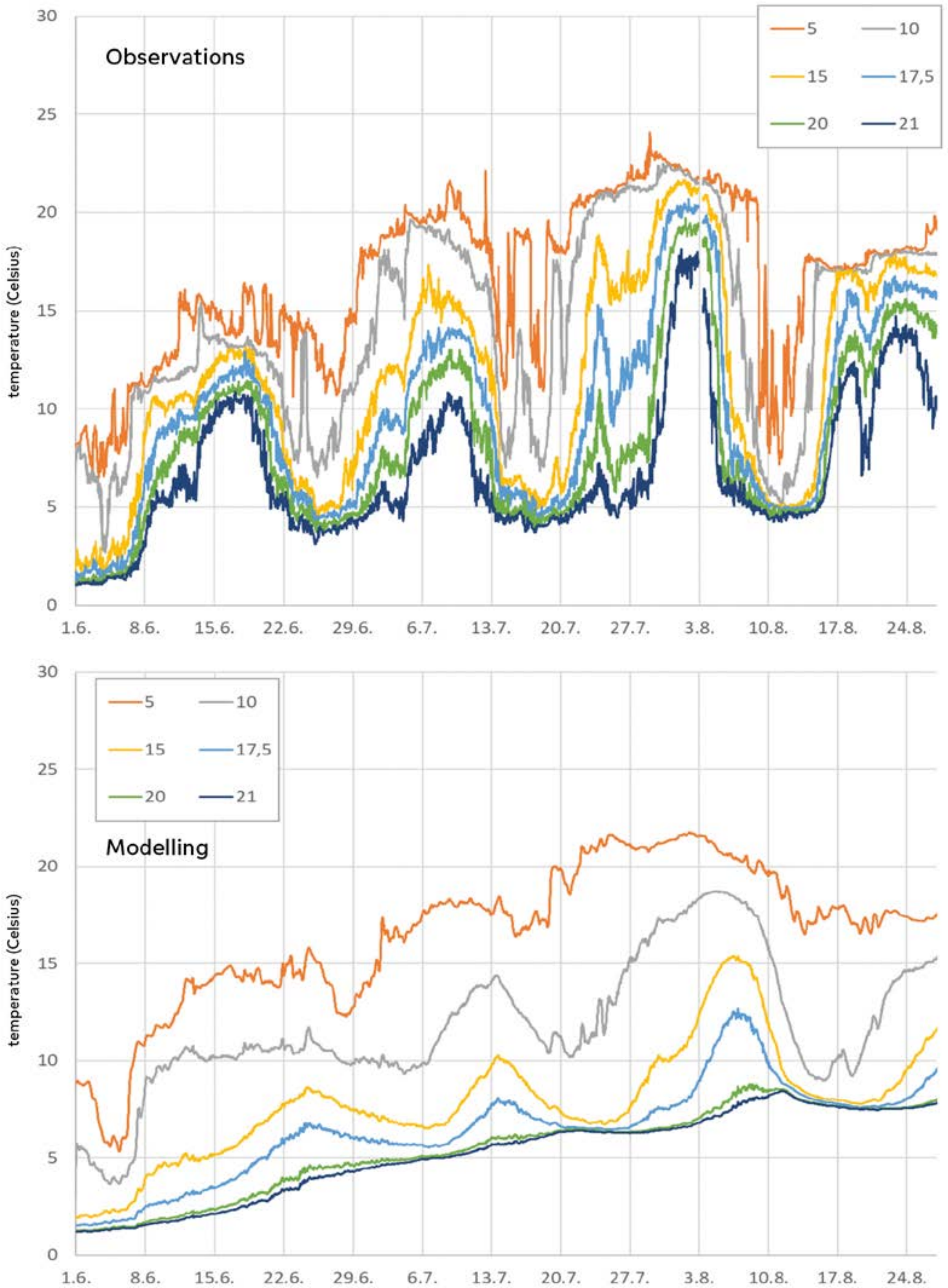


Figure 4-10. Vådholmsfjärden, point K2, the observed (above) and modelled (below) water temperature at various depths in June – August 2011.

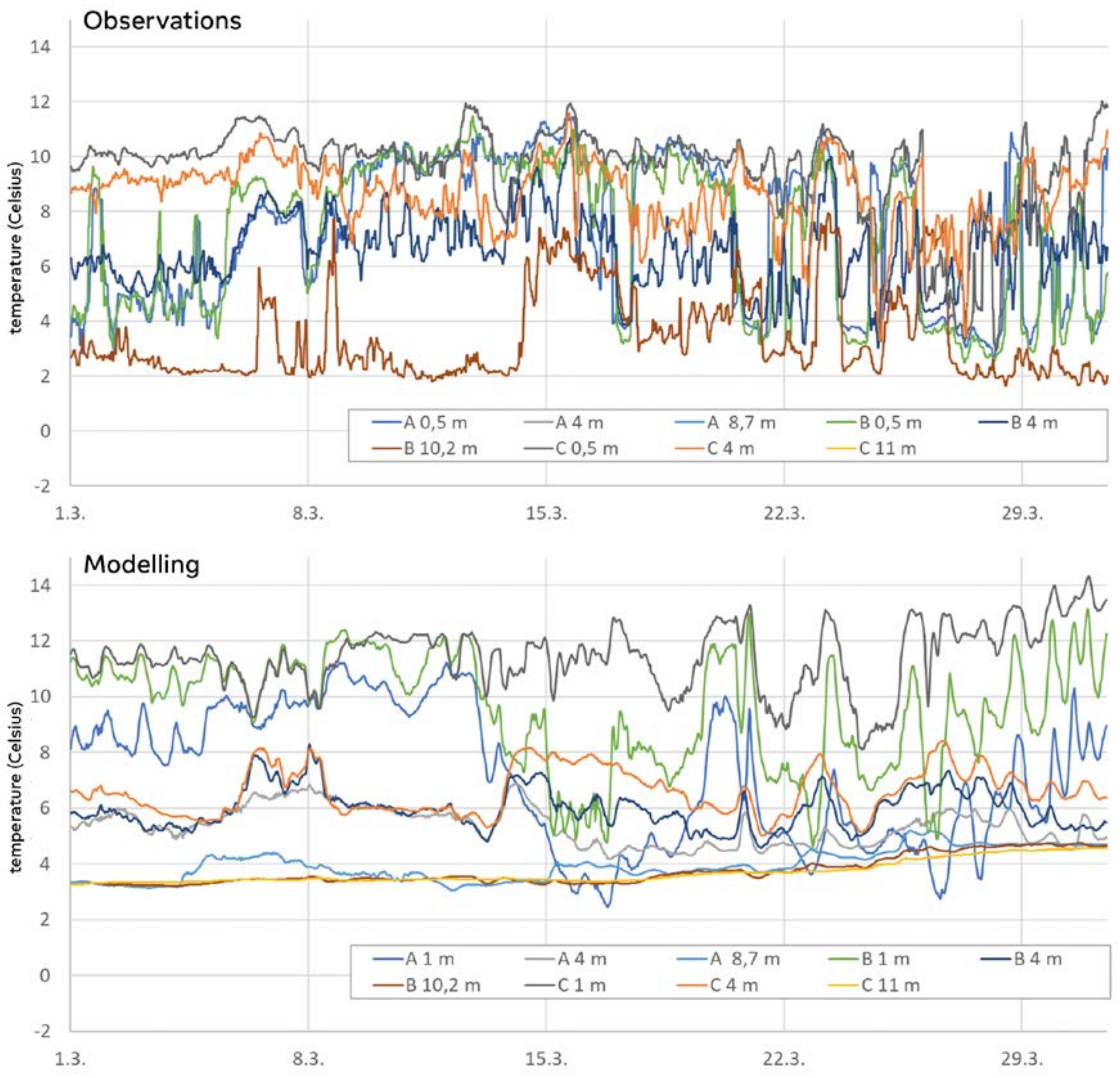


Figure 4-11. The observed and modelled water temperature at various depths and buoys A, B and C of the discharge side in Hästholmsfjärden (Figure 3-3) in March 2018.

temperatures modelled in Hästholmfjärden – important in terms of the effects of the warm cooling water – follow the observed temperatures fairly well. The winter comparison is shown in Figure 4-11.

Further from Hästholmen, in Hudöfjärden and Vådholmsfjärden, the model describes the upwelling and downwelling events as smoother than the events observed. Based on the observations, the strong upwelling situation which began in early August occurs slightly later in the modelling and remains significantly lower in strength than the observed upwelling. In the modelling results of Hästholmsfjärden and Hudöfjärden, the temperatures of the deeper water increase more towards the end of August than in the observations.

In respect of Vådholmsfjärden, the modelled temperatures of the deeper water are lower than those observed. The temperature of the seawater modelled close to the surface nevertheless follows the observed temperature fairly closely. Particularly with regard to Hästholmsfjärden, the modelled surface temperatures correspond with the observations quite well.

4.5 UNCERTAINTIES RELATED TO MODELLING

All modelling involves uncertainties and is never a perfect representation of reality. The errors in the outcomes of the modelling stem from the uncertainties of the baseline data and boundary conditions as well as from the model's parametrisations and numerical calculations. The open sea's sea level used as baseline data, for example, was assessed with the help of the sea levels of Helsinki and Hamina, meaning that the assessment is not fully accurate. On the other hand, the assessment is nevertheless sufficiently good from the perspective of the cooling water modelling and as a source of error, is not that significant. In respect of sources of error, it is indeed essential to identify the most important of them and seek to improve the situation in terms of them insofar as is possible and necessary.

The most relevant sources of error in the modelling carried out in this work are the model's heat transfer from the surface water into the atmosphere, which was calculated, in terms of the longwave radiation, by employing infrared radiation values observed in Kumpula, Helsinki, rather than the surface water temperature. In principle, this feature slows down the transfer of heat from water into air, increasing the water temperature more than it increases in reality. However, this challenge was dealt with satisfactorily by calibrating the model on the basis of the measurements so that the surface temperatures assessed by it corresponded well with the measurements. The realistic description of surface temperatures is the key objective in terms of the results of this work.

Another source of error with a potentially significant effect on the results is the model's success in describing the water's vertical mixing. This is influenced particularly by the selections of the numerical values for the parameters that determine the mixing and the structure of the model's calculation grid. The realism of the vertical mixing was a particular focus in connection with the model's calibration.

The water in the Baltic Sea is brackish water, meaning that its salinity ranges from 0.5%–24.7‰. The salinity in the coastal waters of the Gulf of Finland is typically less than 5‰, but there is some variation in the salinity. The physical properties of brackish water make it a difficult substance from the perspective of the modelling, thereby further increasing the significance of the calibration of the model based on the measurements. The characteristics of the Gulf of Finland also include upwelling and downwelling situations which have a significant impact on the seawater's temperature and salinity conditions, and the description of which by modelling is a challenging task.

5. Modelling results

5.1 ICE-FREE SEASON

Figures 5-1...5-4 show the differences in seawater temperatures between situations in which the power plant is in operation or is not in operation, modelled under ice-free conditions. The time series of the modelling results of seawater temperature at different receiver points and in different situations (power plant in operation or not in operation) are presented in Appendix 2. The reviews are presented at the points of the buoys on the discharge side, K1, K2 and K3 (Figures 3-1 and 3-3). Figures 5-5...5-7 show maps on the average, minimum and maximum temperature.

At the locations of buoys A, B and C, close to the cooling water's discharge location in Hästholmsfjärden, the surface temperature of seawater during the power plant's operation is 1–11 °C warmer than in situations when the power plant is not in operation (Figure 5-1). The temperature differences between the different situations were greatest at the locations of buoys B and C, whereas there is significantly less variation at buoy A. The differences between the locations are explained by the fact that during the power plant's operation, buoys B and C are more distinctly within the cooling water's impact area, while buoy A is slightly further away from it. The relatively large range of variation in seawater surface temperatures at an individual location (such as buoy B and a review depth of 0.5 m) is largely explained by changes in wind conditions, given that changes in wind direction change the route of warm cooling water, sometimes past the observation point and at other times towards it. The increase in the deep's temperature at the locations of buoys A, B and C grows over the summer and is around 2–3 °C in August.

Based on maps drawn up on the basis of the modelling results (Figures 5-5...5-7), the greatest increase in the seawater's surface temperature caused by the power plant occurs right next to the discharge location in Hästholmsfjärden. However, the surface temperature rapidly drops when moving further, given that the surface water is mixed in with the rest of the water column horizontally and vertically, and heat is also transferred efficiently into the atmosphere. The average surface temperature increases by roughly 2 °C in southern Hästholmsfjärden. In western and northern Hästholmsfjärden, the estimated impact no longer exceeds parts of a degree due to the slow flow of water into these areas. Based on the modelling results, surface water temperature can nevertheless occasionally rise in some of these areas due to the thermal effect of the cooling water, with the maximum increase being 2 °C.

Based on the cross-sectional views (Figures 5-5...5-7), one can estimate that the effect that the power plant's operation has on the temperature of seawater during the ice-free season is primarily confined to the top 5 m layer in the southern part of Hästholmsfjärden. Calculated for the Klobbfjärden body of water (Hästholmsfjärden + Klobbfjärden), the estimated average increase in surface temperature is around 1.12 °C. The surface area of the shallow areas further away from the power plant is slightly smaller in the model than in reality, which must be accounted for in the interpretation of the results.

Based on the modelling, the average seawater temperature close to the surface on the discharge side at point K1 in Hudöfjärden is approximately 0.1–0.9 °C higher during the power plant's operation than without the power plant (Figure 5-2). The thermal effect on the Hudöfjärden side is minor and usually detectable only in the far northeast corner near Hästholmen

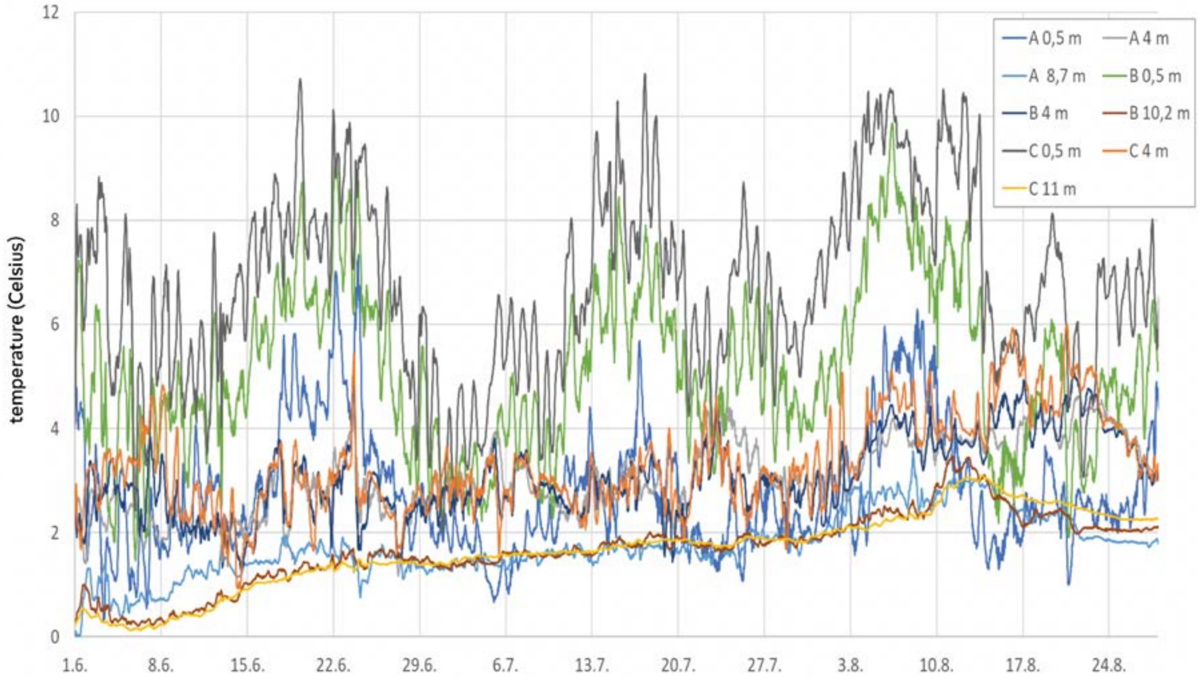


Figure 5-1. The difference in water temperature modelled at different depths (power plant in operation – power plant not in operation) in Hästholmsfjärden on the discharge side's buoys A, B and C during the 2011 ice-free season.

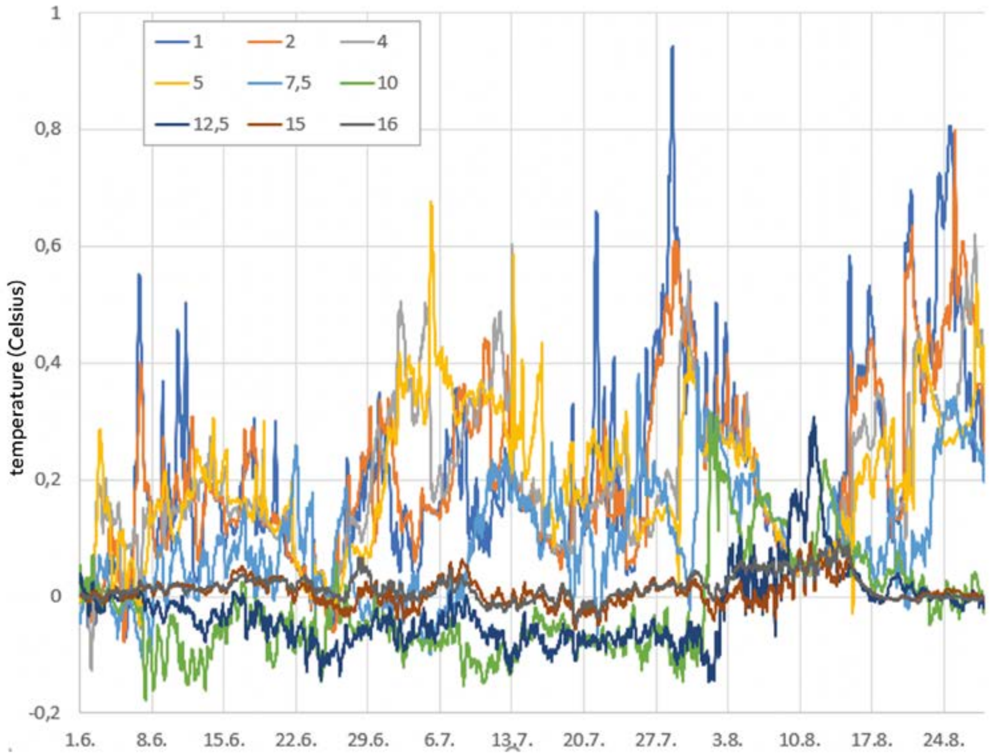


Figure 5-2. The difference in water temperature modelled at different depths (power plant in operation – power plant not in operation) in Hudöfjärden at point K1 during the 2011 ice-free season.

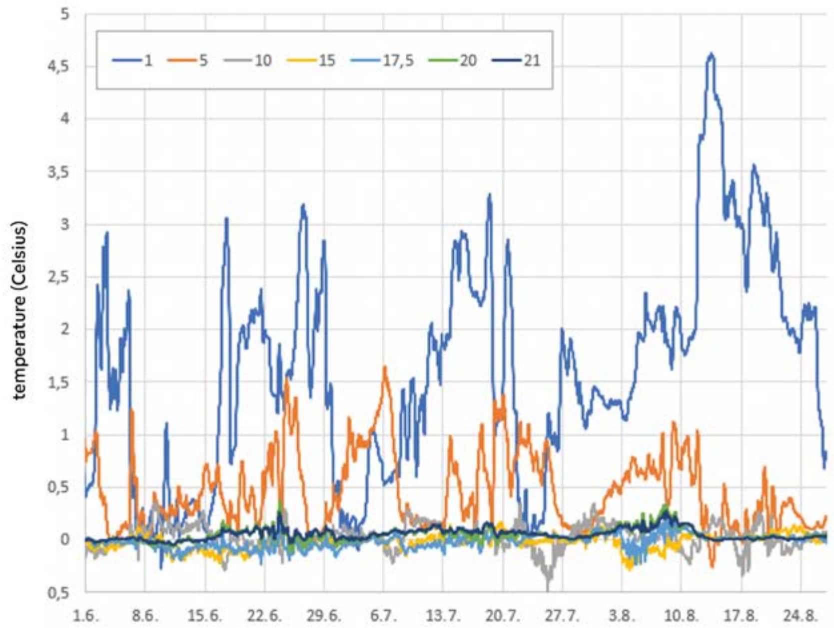


Figure 5-3. The difference in water temperature modelled at different depths (power plant in operation – power plant not in operation) in Vådholmsfjärden at point K2 during the 2011 ice-free season.

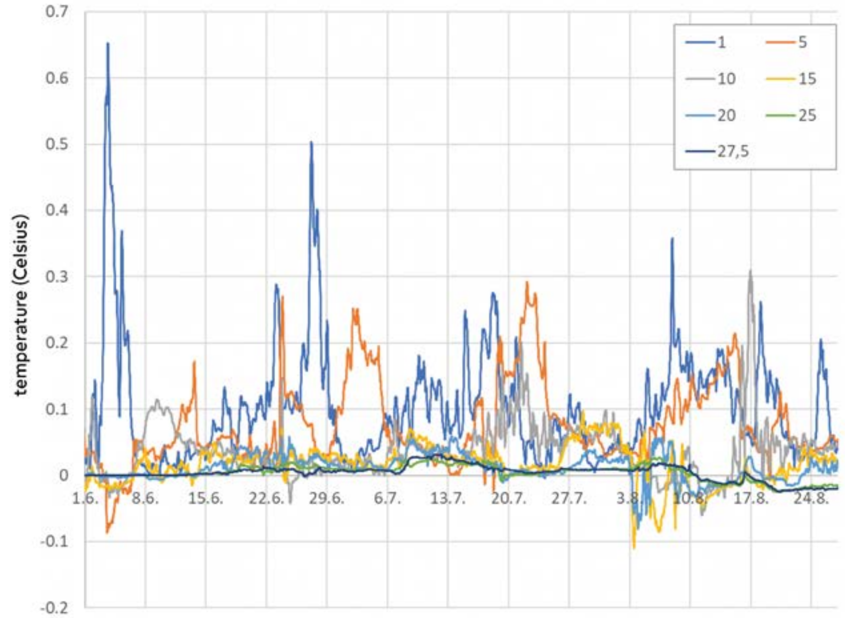


Figure 5-4. The difference in water temperature modelled at different depths (power plant in operation – power plant decommissioned) in Orrengrundsfjärden at point K3 during the 2011 ice-free season.

(Figures 5-5...5-7). However, under some weather conditions, the surface temperature can occasionally rise by a maximum of 2 °C in the parts of Hudöfjärden close to Hästholmen.

At observation point K2, located in front of the straits leading from Hästholmsfjärden to Vådholmsfjärden, a thermal effect occurs at the very surface of the sea, according to the modelling results. Based on the results, the temperature of the seawater during the power plant's operation is roughly 0–4.5 °C warmer at a depth of one metre and 0–1.5 °C warmer at a depth of five metres than it would if the power plant were decommissioned (Figure 5-3). Deeper still, at 10 metres, no temperature increase can be detected. Based on maps prepared on the basis of the modelling results, the effect is at its greatest in Vådholmsfjärden near the mouth of the strait between the islands of Myssholmen and Lindholmen, where the water temperature at the surface can occasionally increase by a maximum of approximately 5 °C. In the southern part of Vådholmsfjärden, the temperature increase is estimated to be around 1 °C at maximum (Figures 5-5...5-7). The average increase in surface temperature in the northern parts of Vådholmsfjärden is in the region of 2 °C. The temperature difference nevertheless diminishes when moving south so that as early as in the mid-sections of Vådholmsfjärden, the thermal effect that the power plant's operation has on the average surface temperature of the seawater is difficult to detect.

At observation point K3 in Orrengrundsfjärden, the thermal effect on the surface layer is very small (Figure 5-4). In a small area in the northwestern part of Orrengrundsfjärden, the effect is close to 0.5 °C, the maximum being approximately 1.5 °C at the part leading to Vådholmsfjärden.

Based on the modelling, a thermal effect caused by the power plant during the ice-free season is mainly detectable in Hästholmsfjärden and occasionally on the surface of the straits south of it.

The 2011 ice-free season reviewed represents an exceptionally warm summer in the conditions of the 2010s. The year selected for review was 2011, primarily because of the extensive additional monitoring of seawater temperatures conducted during the year, which allows for a more precise calibration of the cooling water model. On the other hand, the selection of an exceptionally warm year provides a per-

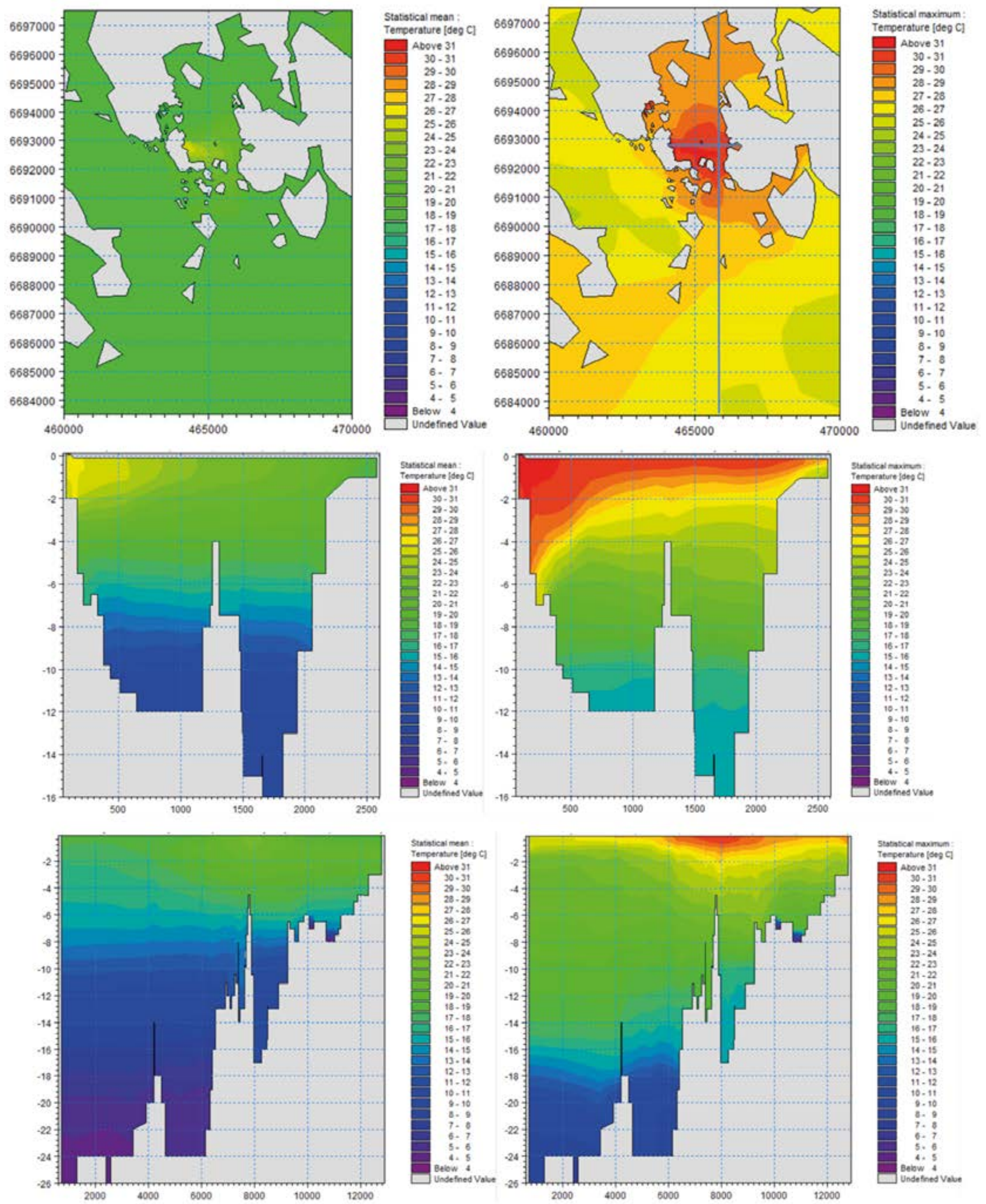


Figure 5-5. Temperature, power plant in operation, average (column on the left) and maximum (column on the right); map (top row), east-west cross section form the intake (in the middle, left boundary westward) and north-south cross section (bottom row, left boundary southward), period 1 June – 1 September 2011. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

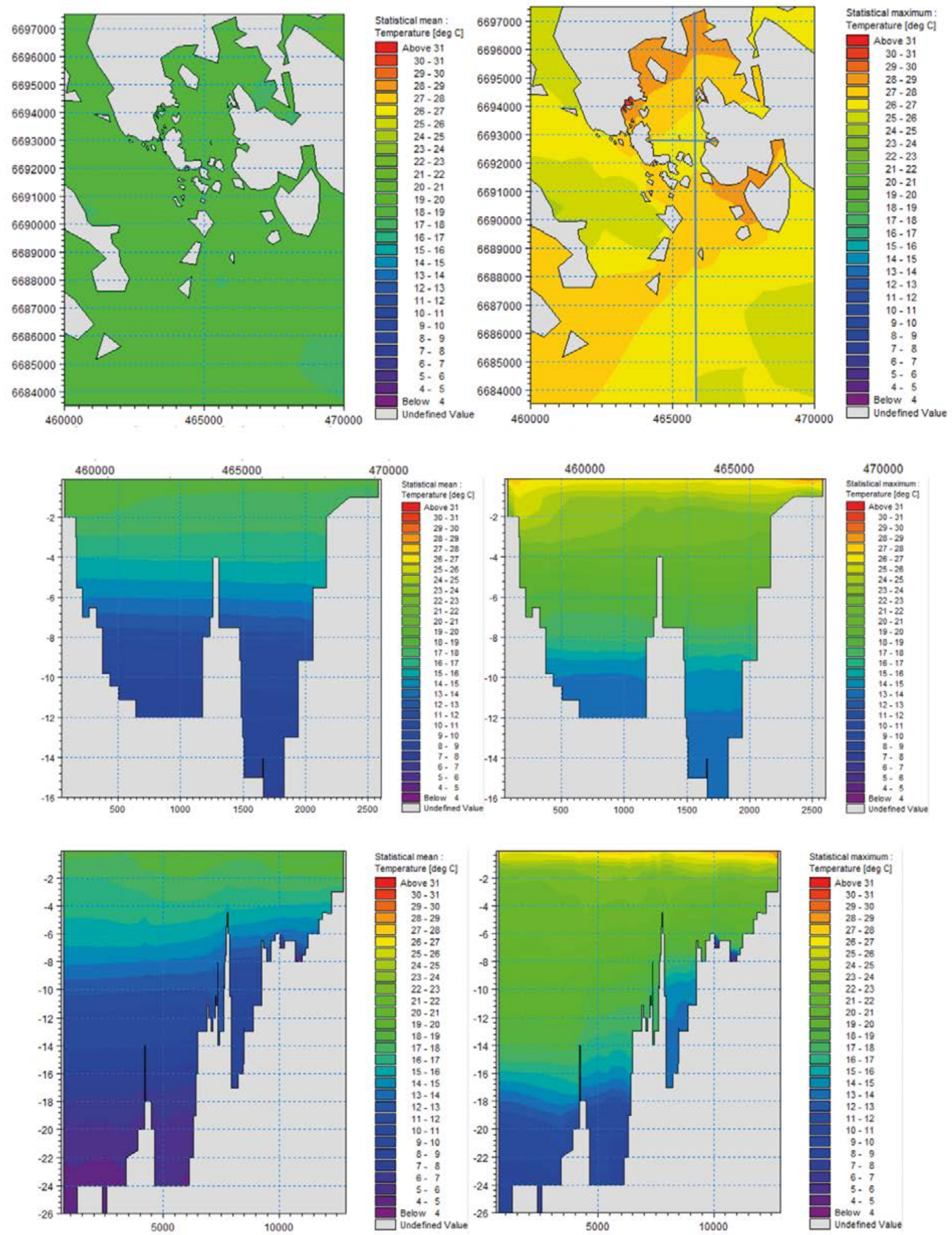


Figure 5-6. Temperature, power plant not in operation, average (column on the left) and maximum (column on the right); map (top row), east-west cross section form the intake (in the middle, left boundary westward) and north-south cross section (bottom row, left boundary southward), period 1 June – 1 September 2011. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM-35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

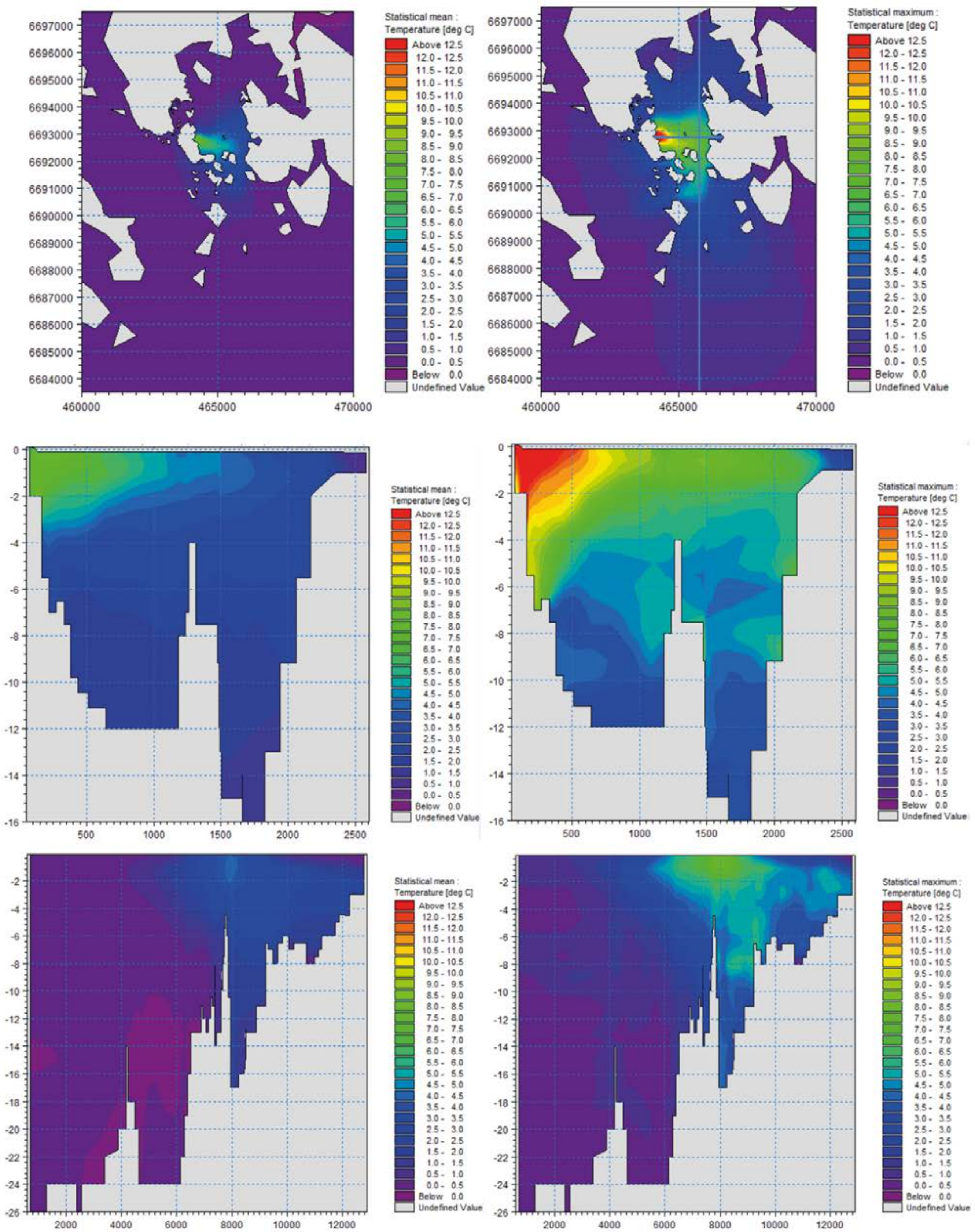


Figure 5-7. Effect of power plant's operation on temperature (difference: power plant in operation – power plant not in operation), average (column on the left) and maximum (column on the right); map (top row), east-west cross section form the intake (in the middle, left boundary westward) and north-south cross section (bottom row, left boundary southward), period 1 June – 1 September 2011. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

spective to the development of the temperature conditions of seawater in the future, as the climate grows warmer. As explained in Chapter 3.3, the summer temperatures in 2011 are likely to be fairly ordinary in the climate conditions of 2030–2050 or at least significantly more common than at the beginning of the 2010s. The modelling results of the review period therefore give an idea of seawater temperatures around the middle of this century in a situation where the power plant is in operation, and in a situation where it is not in operation. The absolute temperatures with regard to the ice-free season are specified in Appendix 2.

When examining the results at the temperature measuring buoys on Hästholmsfjärden's discharge side (Figures L2-1 and L2-2 in Appendix 2), for example, one can see that the surface temperature of the seawater during the power plant's operation is at its highest, or slightly above 30 °C, at buoy C, whereas the surface temperature at the same point and same time in a situation in which the power plant is not in operation is around 25 °C. According to Loviisa power plant's environmental permit, the hourly average temperature of the cooling water fed into the sea may be a maximum of 34 °C. In other words, when the temperature of the cooling water taken from the sea rises to a degree where the power plant's power must be limited for the temperature of the discharged cooling water to remain below 34 °C, the relative share of the power plant's thermal effect will also reduce. When moving away from Hästholmsfjärden, the temperature differences in the seawater are fairly small and at their highest, in the region of 20–25 °C (Figures L2-3...L2-8 in Appendix 2).

5.2 ICE SEASON

Figures 5-8...5-11 show the differences in seawater temperatures between situations in which the power plant is in operation or is not in operation, modelled under ice-cover conditions. The time series of the modelling results of seawater temperature at different receiver points and in different situations (power plant in operation or not in operation) are presented in Appendix 3. The reviews are presented at the points of the buoys on the discharge side, K1, K2 and K3 (Figures 3-1 and 3-3). Figures 5-12...5-14 show maps of the average and maximum temperature in situations where the power plant is in operation and is not in operation as well as the difference between them.

When the power plant is in operation, the seawater temperature at buoys A, B and C, located close to the discharge location of cooling water in Hästholmsfjärden, is approximately 5–16 °C and approximately 5–9 °C at depths of 1m and 4 m, respectively, and close to the seabed, approximately 3–5 °C higher than in a situation where the power plant is not in operation (Figure 5-8).

A temperature increase of 0–3 °C attributable to the recirculation of warm cooling water can be detected at point K1 on the side of Hudöfjärden when the power plant is in operation. This increase is primarily confined to a depth of 4–5 m (Figure L3-3 in Appendix 3). In a situation where the power plant is not in operation, the seawater temperature remains even throughout the water body (Figure L3-4 in Appendix 3). Figure 5-9 illustrates the warming of seawater attributable to recirculation.

At observation point K2 in front of the straits leading from Hästholmsfjärden to Vådholmsfjärden, the thermal effect is visible to a varying degree at all depths. The difference in temperature in a situation where the power plant is in operation vis-à-vis a situation where it is not operation is at its greatest approximately 5 °C higher at a depth of 5 m (Figure 5-10). Nevertheless, the thermal effect seems to be situated primarily at a depth of 5 m and deeper than that, being at its smallest near the surface.

The thermal effect is very small at Orrengrundsfjärden's observation point K3. The seawater temperature is only around 0–0.8 °C higher during the power plant's operation than in a situation where the power plant is no longer in operation (Figure 5-11). As is the case with point K2, the thermal effect at this observation point also concentrates at a depth below 5 m.

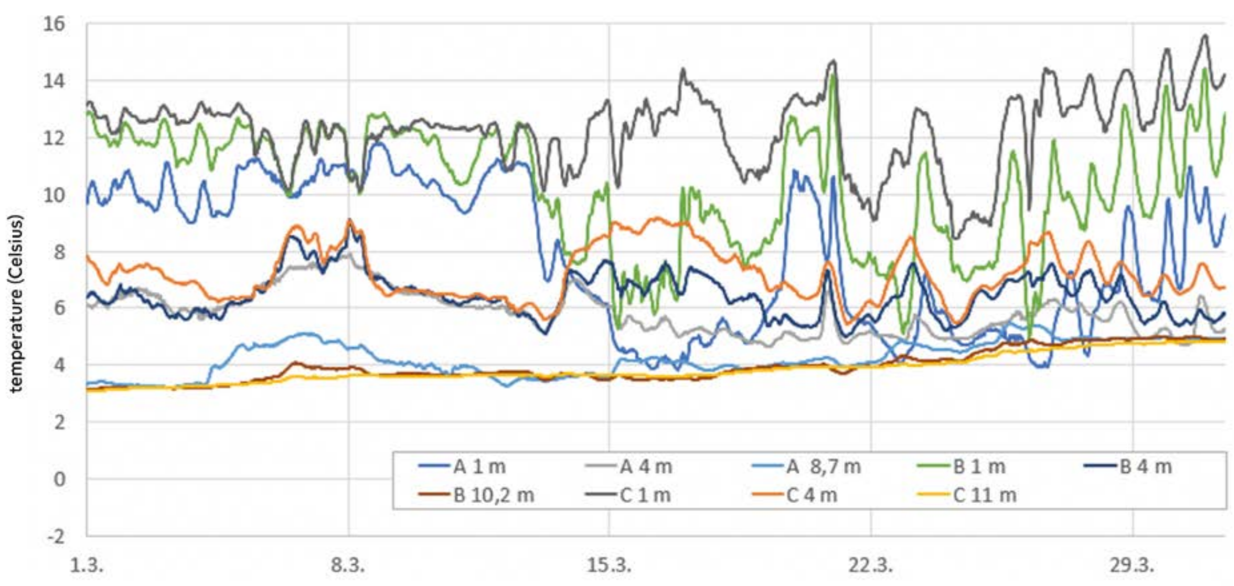


Figure 5-8. The difference in water temperature modelled at different depths (power plant in operation – power plant not in operation) in Hästholmsfjärden on the discharge side's buoys A, B and C in March 2018.

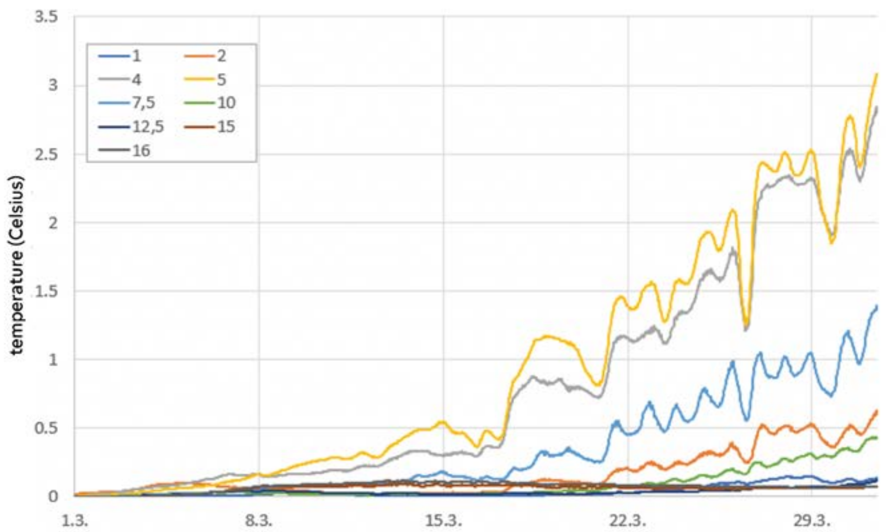


Figure 5-9. The difference in water temperature modelled at different depths (power plant in operation – power plant decommissioned) in Hudöfjärden at point K1 in March 2018.

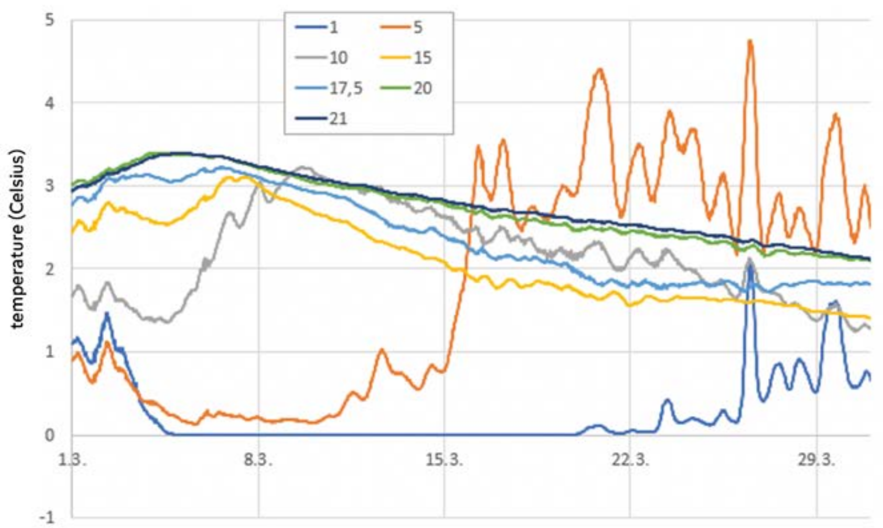


Figure 5-10. The difference in water temperature modelled at different depths (power plant in operation – power plant decommissioned) in Vådholmsfjärden at point K2 in March 2018.

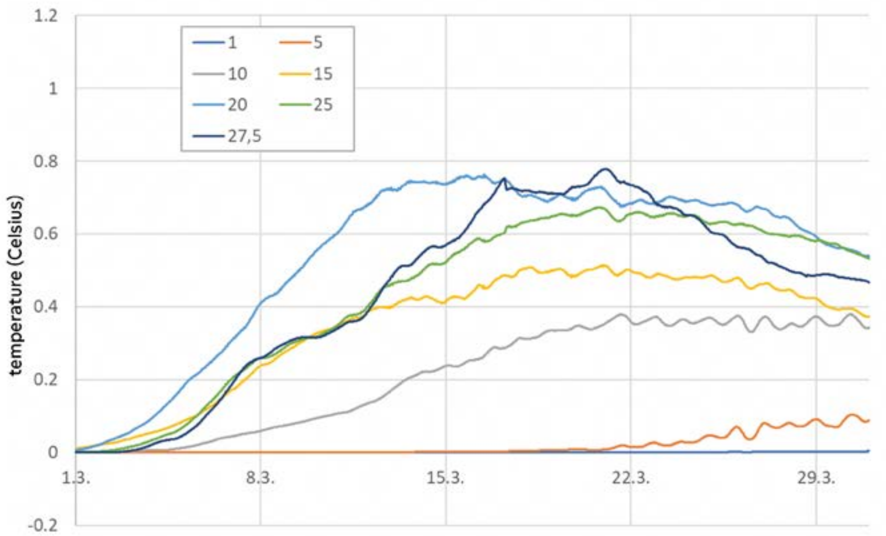


Figure 5-11. The difference in water temperature modelled at different depths (power plant in operation – power plant decommissioned) in Orrengrundsfjärden at point K3 in March 2018.

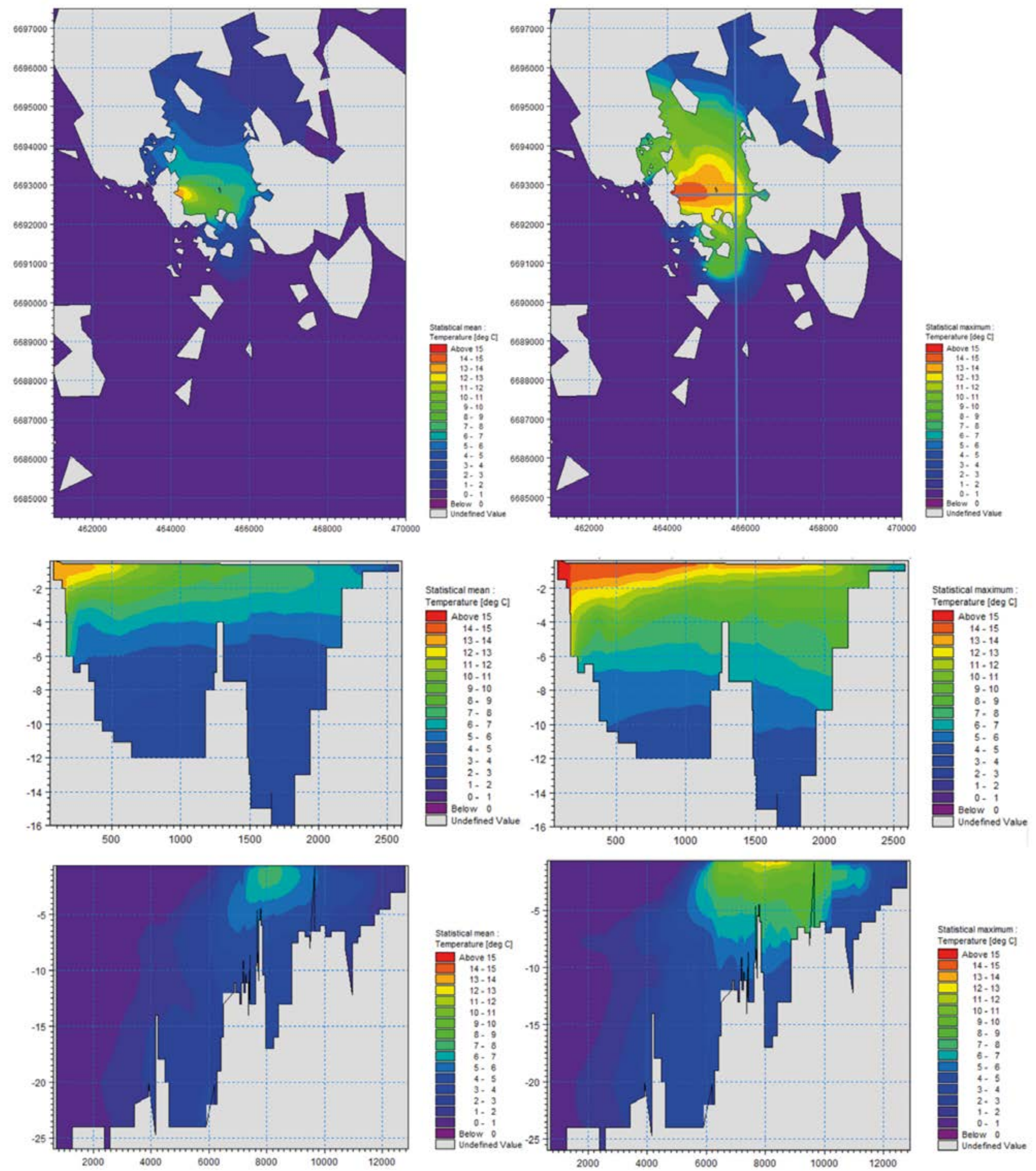


Figure 5-12. Temperature, power plant in operation, average (column on the left) and maximum (column on the right); map (top row), east-west cross section from the intake (in the middle) and north-south cross section (bottom row), period March 2018. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

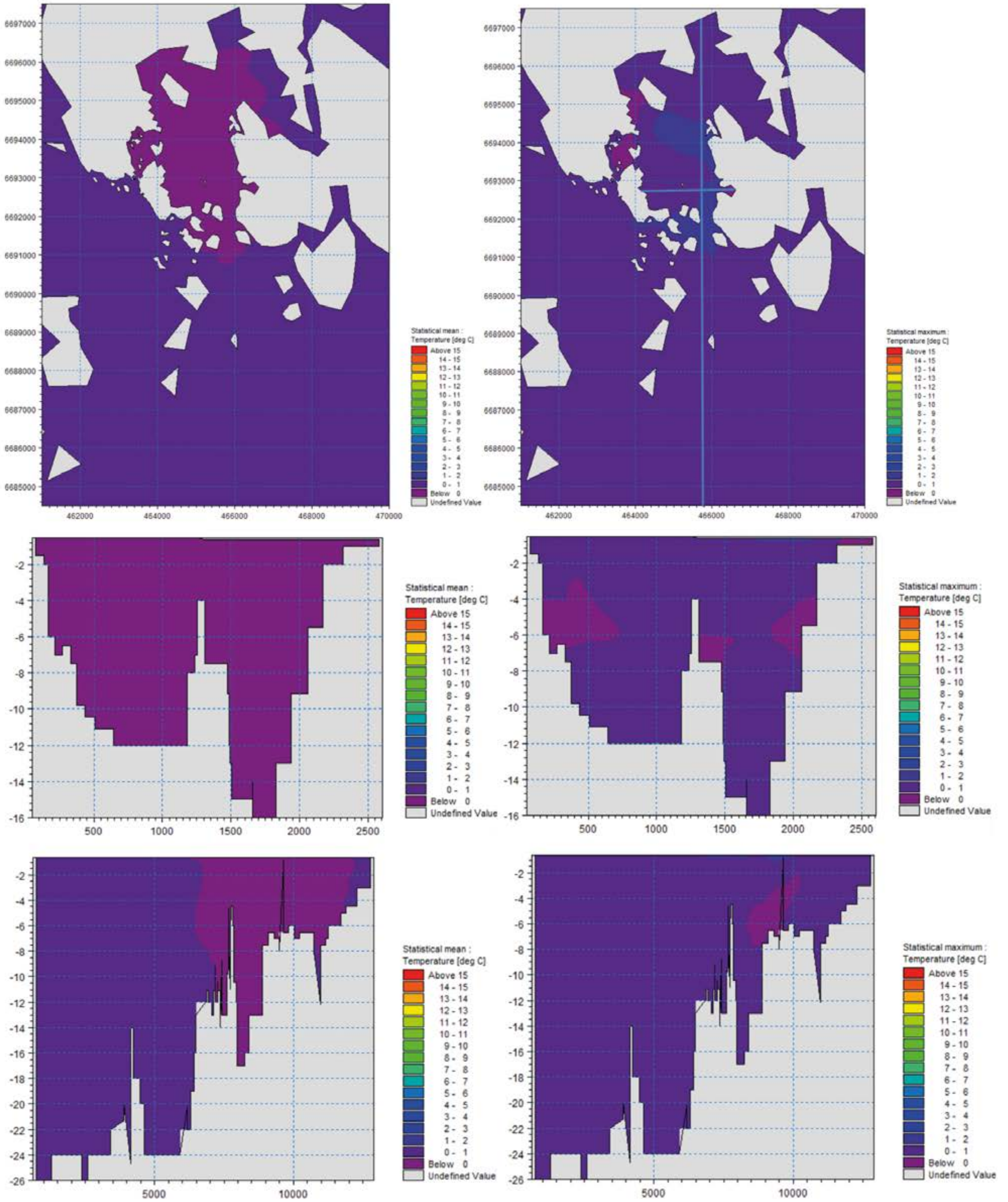


Figure 5-13. Temperature, power plant not in operation, average (column on the left) and maximum (column on the right); map (top row), east-west cross section from the intake (in the middle) and north-south cross section (bottom row), period March 2018. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

The thermal load's impact on the nearby sea area is the easiest to detect in winter, when the warm cooling water keeps the sea area close to the discharge location free of ice. The ice cover is effective in preventing the heat from transferring to the atmosphere once the cooling water has sunk more deeply and passed beneath the ice. During the ice season, the greatest thermal effect is detectable near the surface particularly in the southern part of Hästholmsfjärden, but also on a wider scale in the area of Hästholmsfjärden. At Vådholmsfjärden, the thermal effect is still detectable near the surface, but at distances further than this, the effect extends only to the deeper water, with hardly any effect on the surface (Figures 5-12...5-14).

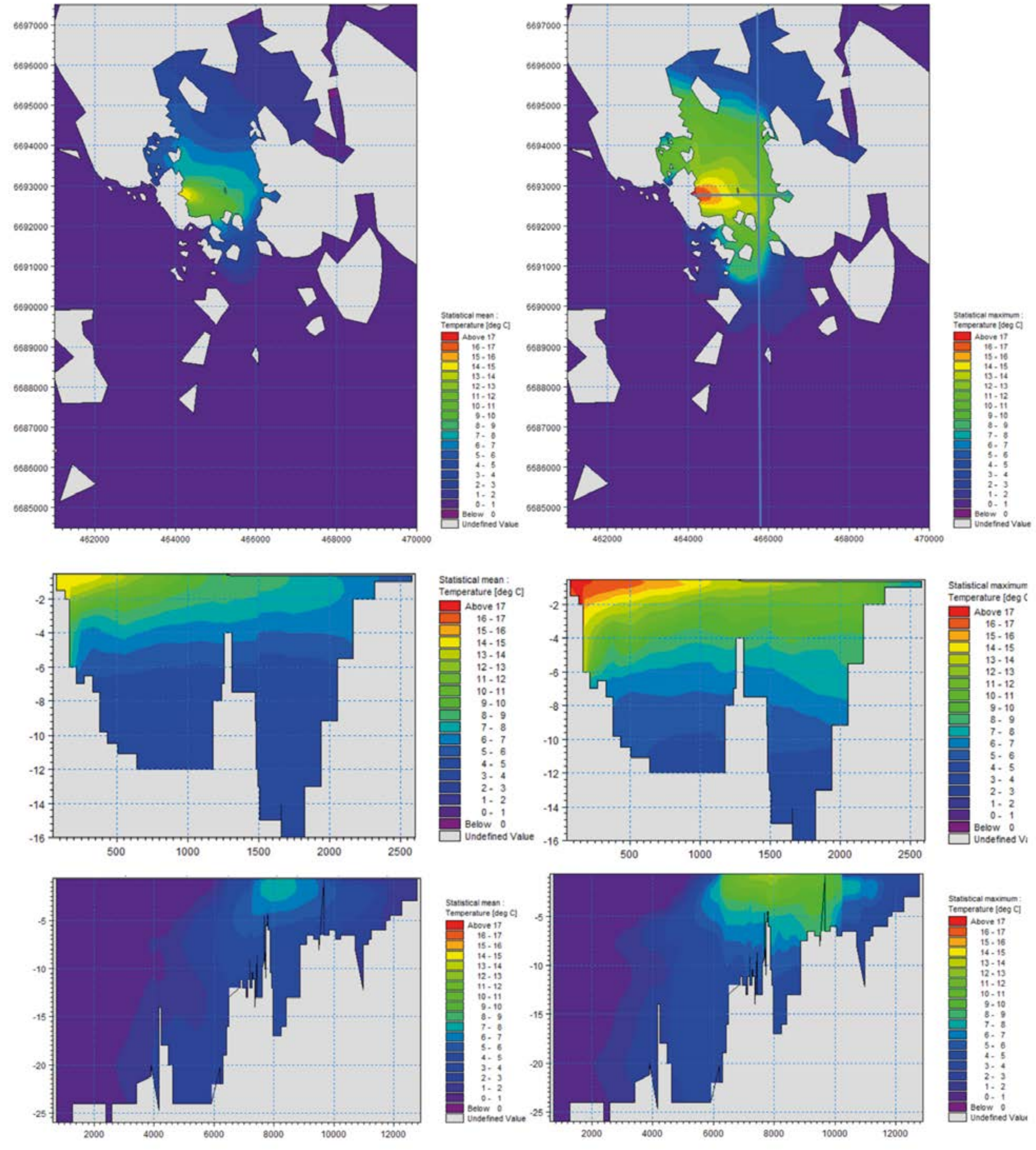


Figure 5-14. Effect of power plant's operation on temperature (difference: power plant in operation – power plant not in operation), average (column on the left) and maximum (column on the right); map (top row), east-west cross section from the intake (in the middle) and north-south cross section (bottom row), period March 2018. The lines of the cross-sectional views are shown in the map image of maximum temperatures. The coordinate system in the map images is ETRS-TM35FIN. In the other figures, the distance (horizontal axis) and depth (vertical axis) is indicated in metres.

The seawater temperatures according to the modelling in a situation where the power plant is in operation and in a situation where it is not in operation during the ice season are presented in Appendix 3. At the temperature measuring buoys on Hästholmsfjärden's discharge side, where the thermal effect of the cooling water is the greatest, surface temperatures are a maximum of 10–14 °C when the power plant is in operation. In a situation where the power plant is not in operation, the temperatures throughout the water body are -2–0 °C.

6. Comparisons

6.1 ICE-FREE SEASON

Figure 6-1 shows the results of the cooling water modelling carried out in 2008 and the cooling water modelling carried out in this work with regard to surface water temperatures in summer conditions. The environmental conditions in the 2008 modelling were described with the help of averages

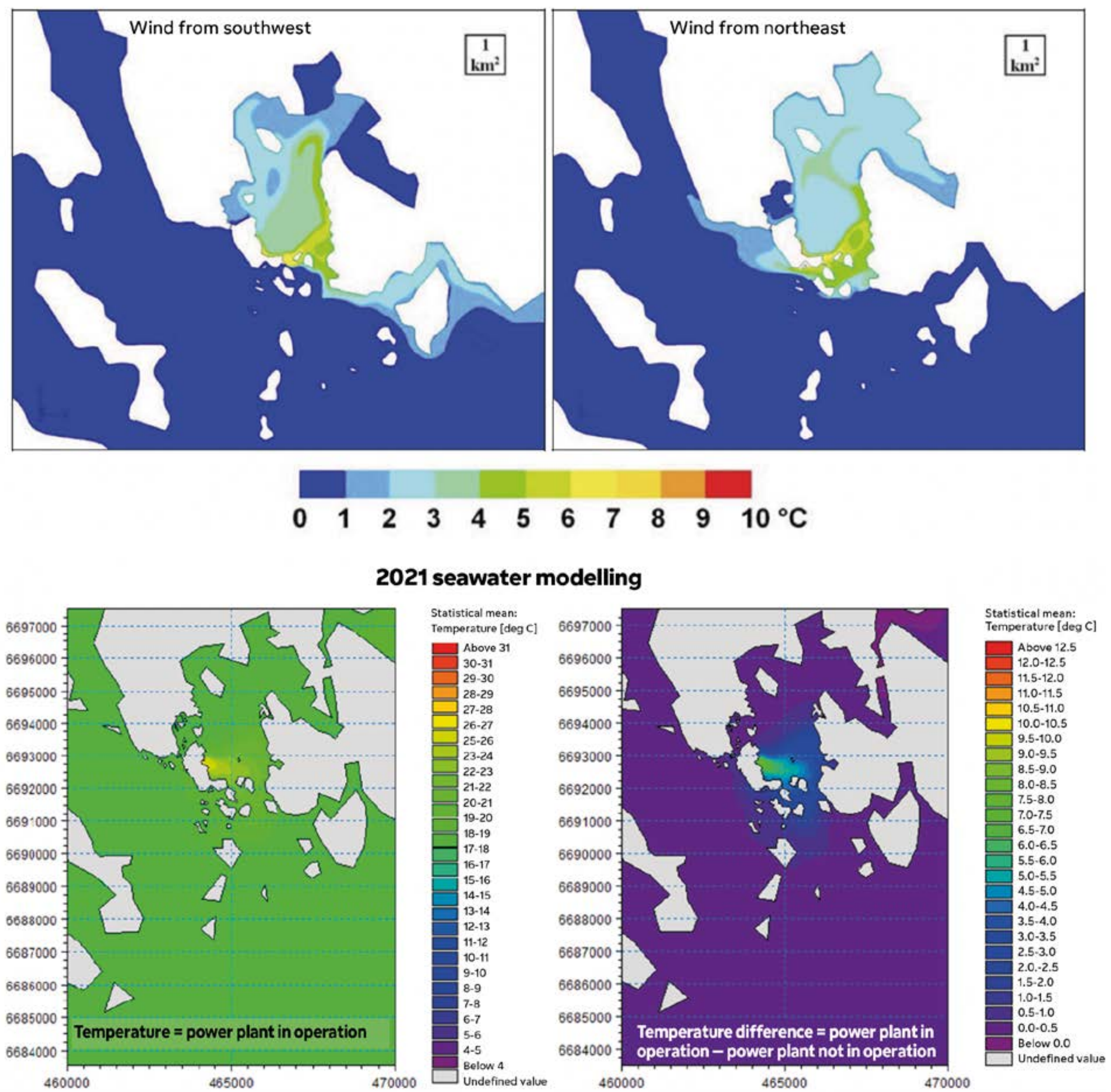


Figure 6-1. The results of the 2008 cooling water modelling (above; Toppila 2008) and the modelling results of this work (below). The maps show the average surface temperature of seawater in summer conditions.

concerning a longer period of time, due to which the temperatures' numerical values are not entirely comparable with the modelling results of this work (Toppila 2008). Comparisons can nevertheless be made in terms of the directions in which the cooling water is carried. Based on the graphs, the dispersion of the warm cooling water in the 2008 modelling into the area of Hästholmen and Klobbfjärden is significantly stronger, but the temperatures immediately in front of the discharge location of the cooling water are significantly lower than in the modelling results in this work. The 2008 cooling water modelling was carried out with a markedly simpler model, which explains the differences between the results.

Figure 6-2 presents water temperature time series based on the cooling water modelling at Hästholmsfjärden's point 8 and Hudöfjärden's point 3 (the locations are shown in Figure 4-2) for the ice-free season. The figures on top (a and b) are the results of the modelling carried out for this work, while the figures at the bottom (c and d) are the results of a cooling water modelling carried out by an external organisation of experts in 2010 (DHI 2010). The modelled situations are from different years (2011 and 2008), due to which the results are not comparable. However, the modelling results are accompanied by the results of temperature measurements, due to which a comparison of the modelled and measured temperature allows for assessing the success of the modelling.

What can be concluded above all on the basis of Figure 6-2 is that the water body's stratification in the summer of 2011 was significantly stronger than in 2008, given that the temperature difference between the seabed and the surface was greater. The 2008 conditions were therefore more favourable from the perspective of modelling. This is also evident in the results, because the seawater temperatures modelled in 2008 are closer to the observations than the seawater temperatures modelled in 2011. Nevertheless, the modelling results of the surface temperatures in both years are fairly close to the observations.

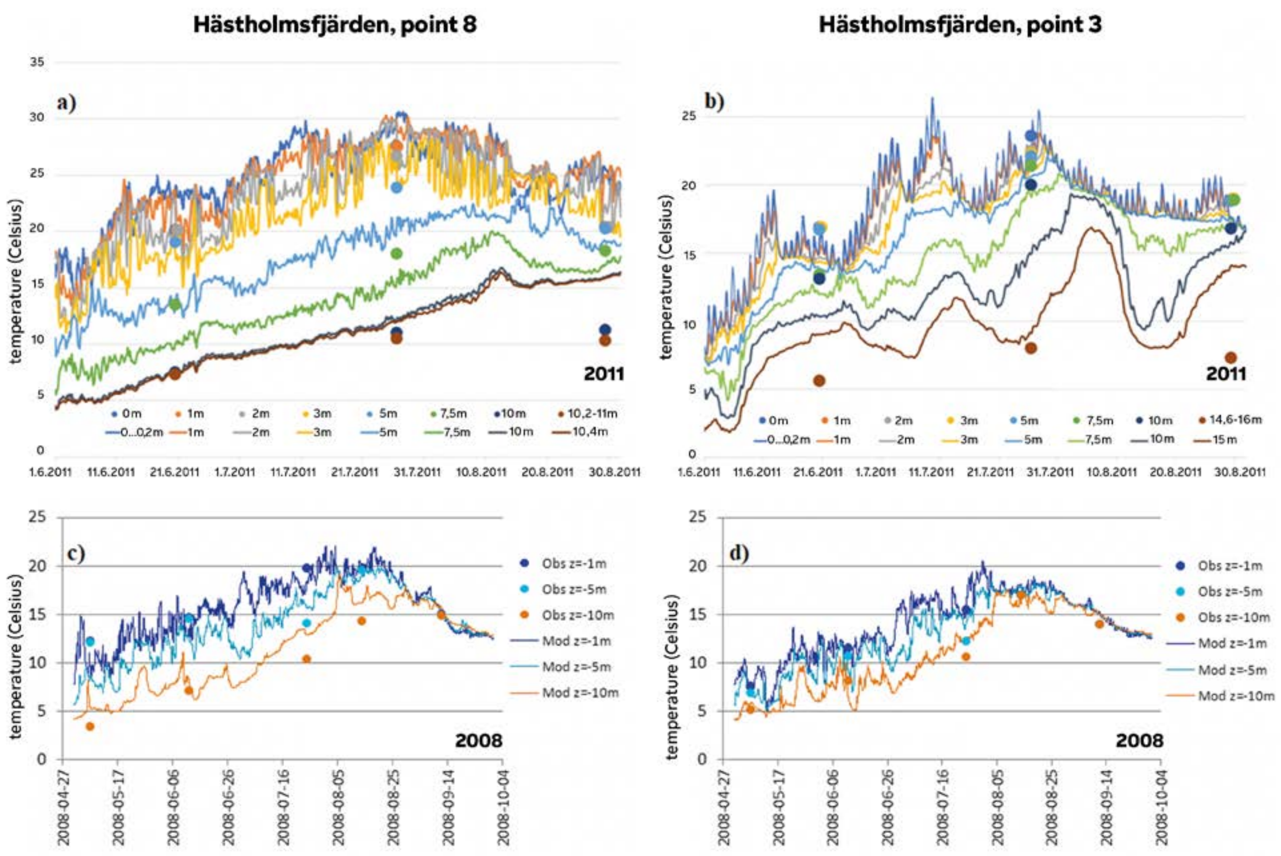


Figure 6-2. The modelled (unbroken lines) and observed (circles) seawater temperatures at Hästholmsfjärden's point 8 and Hudöfjärden's point 3 based on the modelling carried out in this work (2011) and the modelling carried out in 2010 (2008; DHI 2010).

Figure 6-3 shows the average and maximum surface temperatures of water based on the cooling water modelling estimated for the ice-free seasons in 2011 and 2009. The 2011 images are the modelling results of this work, and the 2009 images are the results of the cooling water modelling carried out in 2010 (DHI 2010). When comparing the images, attention should be paid to the different colour schemes of the temperatures. One should also note that the modelling has been carried out in different years, due to which the temperatures cannot be expected to entirely correspondent, particularly since 2011 was quite warm.

Based on the average images (Figure 6-3, the top images), it can be concluded that in both cooling water modellings, the cooling water spreads nearly to the same area on the surface. Regarding 2011, warm water would also seem to be spreading to a wider area south of Hästholmen, but this impression is largely attributable to differences in the scopes of the colour schemes. This also becomes clear when the maximum surface temperatures are examined, given that Figure 6-3 d) also shows the cooling water spreading beyond Hästholmsfjärden. The difference between the years can also be seen from the images of maximum surface temperatures, because the 2011 surface temperatures are significantly higher than the 2009 surface temperatures, even beyond the power plant's thermal effect. However, in terms of their general characteristics, the results are fairly conformable.

The results of the cooling water modelling carried out in this work depart to some degree from the 2008 cooling water modelling, conducted with a considerably simpler model. Indeed, the differences between the results of the models primarily describe the constraints of the simpler model. When comparing the results of the cooling water modelling in this work to the modelling conducted in 2010, the results correspond with each other quite well in terms of their general characteristics. The 2010 modelling was conducted with software similar to the software used in this work.

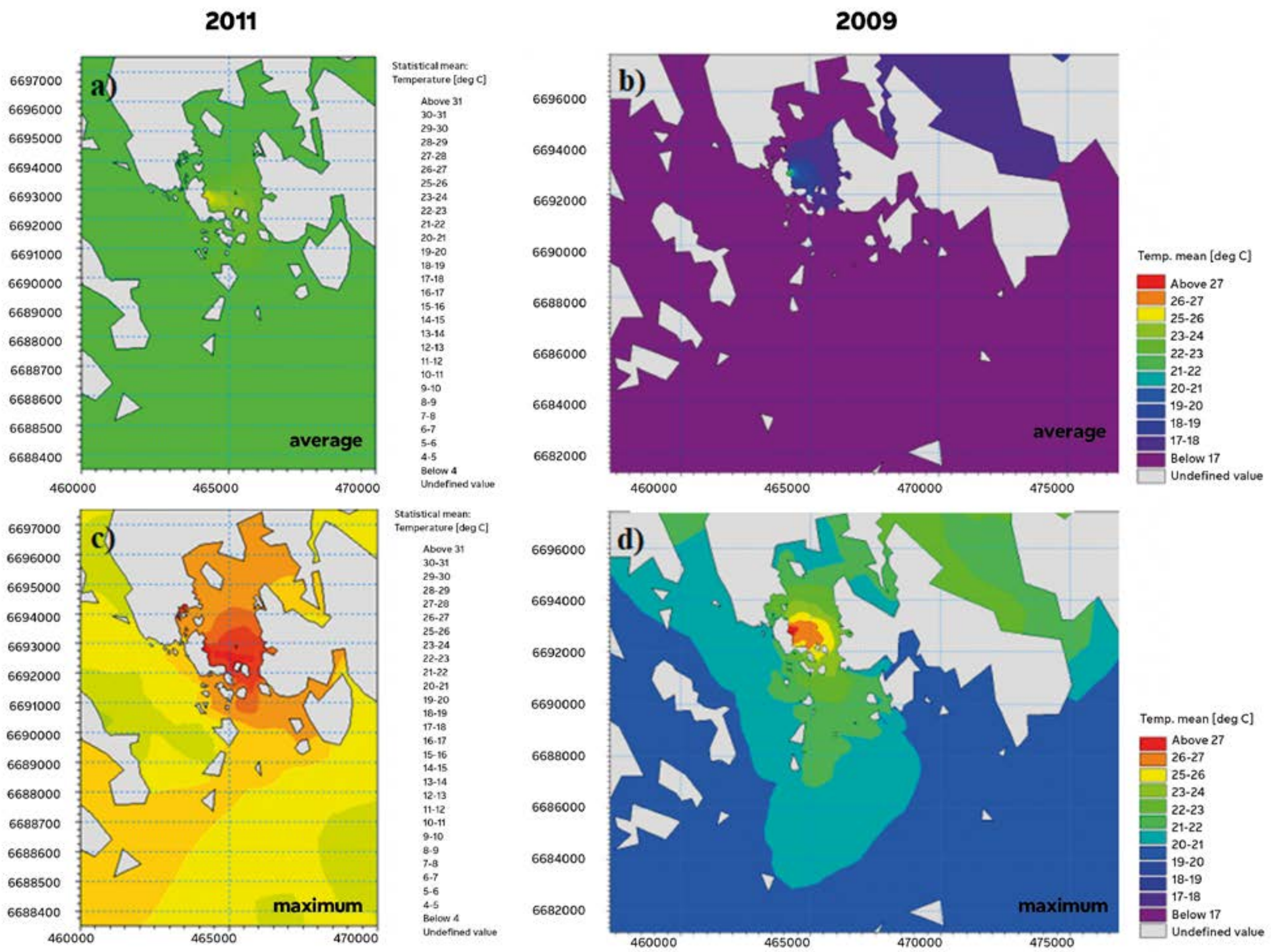


Figure 6-3. The modelled average (a and b) and maximum (c and d) surface temperatures of seawater for 2011 and 2009. The 2011 results were the results of this work.

6.2 ICE SEASON

The effect that Loviisa power plant's warm cooling water has on the ice cover of the nearby sea area has been investigated several times and with different methods during the power plant's history. Figure 6-4 is an example of an ice chart of the power plant's environment drawn up on 14 March 1986. The figure shows that during the time in question, the area of meltwater in the power plant's discharge area was fairly small. The ice winter in 1986 has indeed been classified as a severe ice winter (SMHI 1986).

The carry-over of Loviisa power plant's cooling water and its effect on the surrounding sea area's ice situation was assessed with cooling water modelling in 2008 (Figure 6-5). The figure on the left shows the areas of meltwater (blue) and weakened ice (turquoise) caused by the power plant's operation based on the modelling when, at the beginning of the modelling, the ice cover was absolute and the situation otherwise undisrupted. The figure on the right shows the area into which the cooling water disperses according to the modelling. The 2008 cooling water modelling was conducted with average environmental conditions, due to which the results are not representative of any particular period and describe the situation more broadly over a longer period of time. Based on the results of the 2008 modelling, the entire area of Hästholmsfjärden, part of Vådholmsfjärden and areas located close to Hästholmen in Hudöfjärden are typically areas of meltwater or weakened ice during the winter. The estimate of the area into which the cooling water spreads based on the modelling follows the area of meltwater and weakened ice, with the exception of the branch moving west underneath the ice. (Toppila 2008)

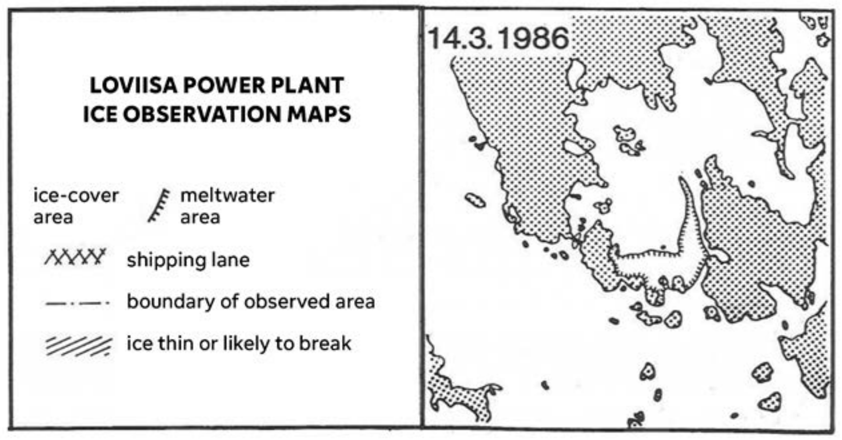


Figure 6-4. An ice chart from the vicinity of Loviisa power plant on 14 March 1986 (Hari 1986).

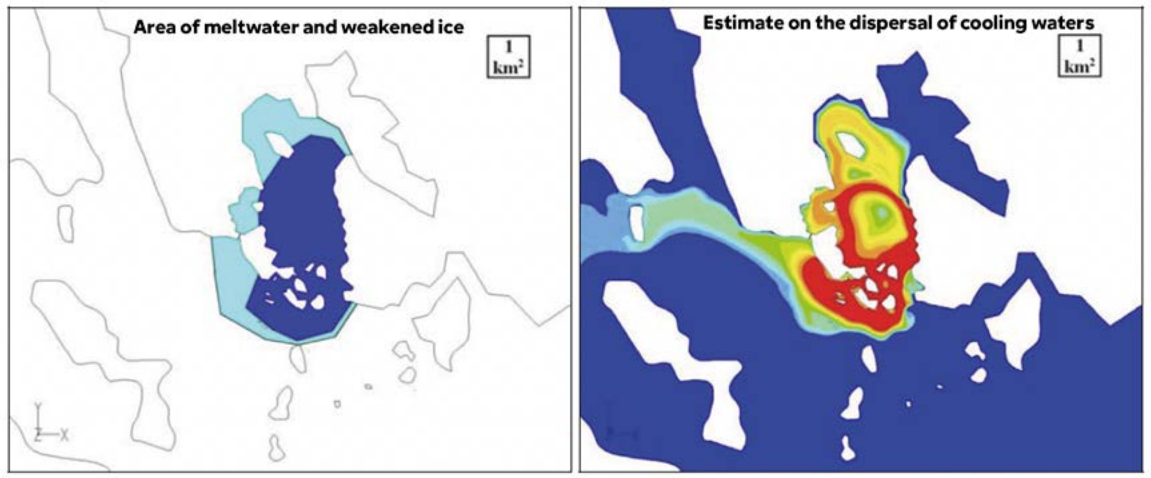


Figure 6-5. Results of the cooling water modelling conducted in 2008: area of meltwater and weakened ice (on the left), and an estimate of the area into which cooling water spreads (on the right). The modelling was conducted under the average environmental conditions of a longer period of time (Toppila 2008).

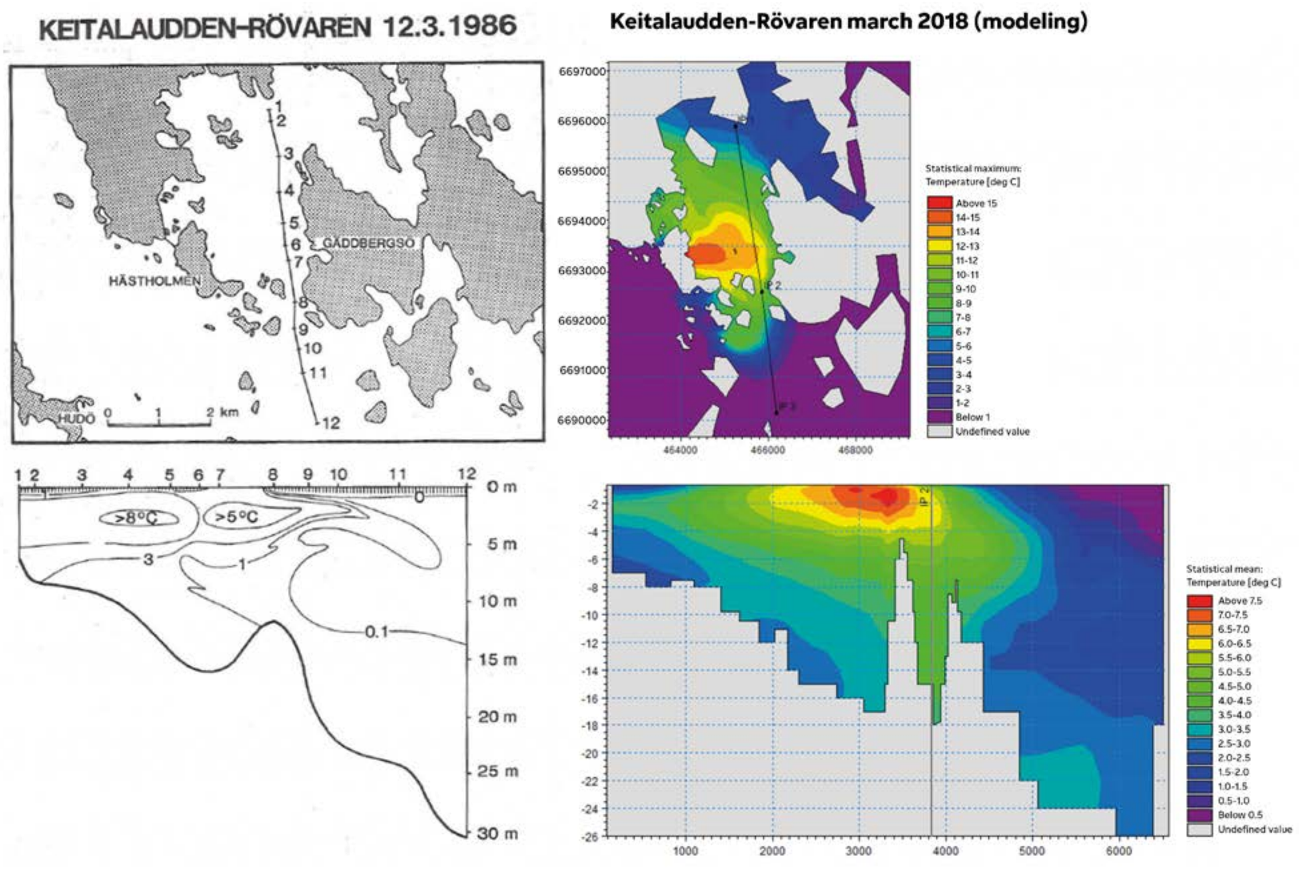


Figure 6-6. The temperature profile (lower left) measured along the line (upper left) on 12 March 1986 (Hari 1986) and the profile of the seawater temperature modelled for this work in the conditions of March 2018 (lower right) determined along a line (upper right) nearly identical to the measurements.

Figure 6-6 shows the seawater's measurement-based temperature profile on a line extending from Hästholmsfjärden to Vådholmsfjärden on 12 March 1986 (images on the left). The figure also shows a map image of the maximum surface temperatures based on the seawater temperature modelling carried out in this work (upper right-hand side) and along a line close to the measurement results, a profile of the average temperature from March 2018 according to the modelling (lower right-hand side). The measurement and modelling results are from different years, so their absolute temperature values cannot be expected to correspond with each other. In addition, the modelling results in terms of the surface temperature describe the maximum temperatures in March, and in terms of the profile, the average temperatures in March, whereas the measurement results describe the seawater's temperature conditions on an individual day. However, in accounting for these differences, clear similarities in the shapes of the temperature profiles can be observed. In both cases, the maximum temperatures occur around the mid-section of the cross-sectional line, although in terms of the measurements, the warmest water is located slightly further to the north than in the modelled situation. Another thing common to both cases is the rapid drop in temperatures when entering Vådholmsfjärden. Furthermore, the temperature values in the profile images (Figure 6-6, bottom images) are in the same region.

Figure 6-7 shows satellite images taken on a few days in March 2018. The area of meltwater is visible in the figure as black and dark blue in the power plant's environment. The areas which have been frozen for a longer period of time are visible in the figure as white, whereas the grey area between the melt and long-term ice is recently formed ice. The series of images shows that the ice situation varied quite a lot over the month. By comparing the surface water's maximum monthly temperature according to the cooling water modelling (Figure 6-6, upper right) with the satellite observations in Figure 6-7, we can see that the model map's 3–4 °C isotherm quite precisely limits the area which, according to the satellite observations, has been ice-free at some point during the month. The model has also been quite successful in depicting the extent of melting in the straits leading to Hudöfjärden and Vådholmsfjärden.

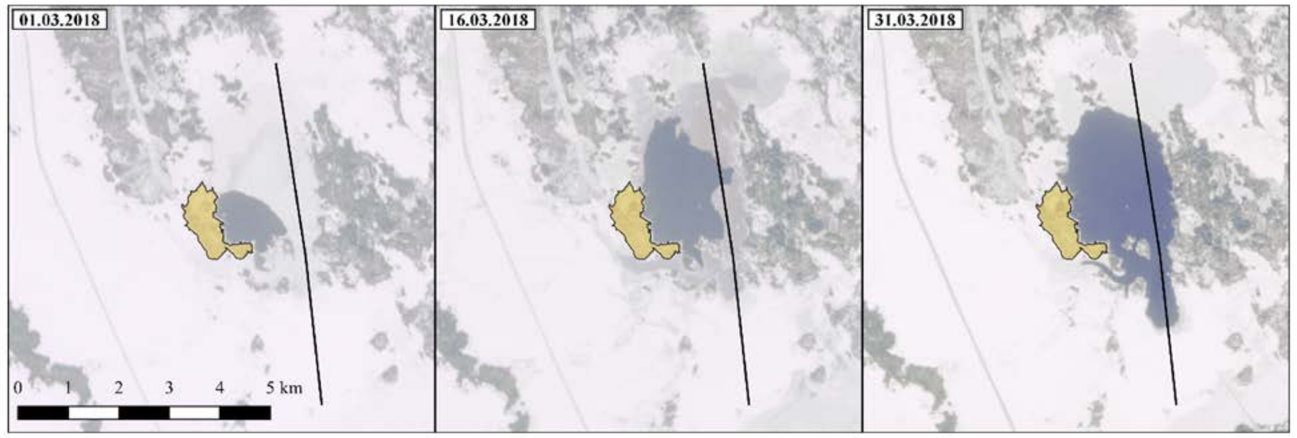


Figure 6-7. Satellite images from the environs of Hästholmen on 1 March, 16 March and 31 March 2018. Hästholmen is marked on the image in orange and the cross-section line of Figure 6-6 as a black line. ESA Copernicus Sentinel Data, Syke (2018).

Assessments based on previous reviews have assumed that after leaving Hästholmsfjärden through the southern straits, the warmed cooling water turns west, in line with the average flow conditions in the Gulf of Finland. Typically, the warmed cooling water settles at a depth of 2–3 m, but occasionally, the settlement depth is 4–5 m. (Ilus 2009)

With regard to the modelling results of this work, the review also covers the westward dispersion of the cooling water beneath the ice, projected by the model. Figure 6-8 shows the cross-sectional line under examination from the discharge location of the power plant's cooling water through the straits in the south to the strait between Hudö and Lindholmen. Figure 6-9 shows the average temperature profile of the cross-sectional line pursuant to Figure 6-8, and Figure 6-10 shows the profile of maximum temperatures during March 2018. It can be seen from the profile images that based on the modelling, and in terms of both average and maximum temperatures, after sinking under the ice, the core of the warm cooling water settles at a depth of around 4 m. This corresponds well with the views of the behaviour of the cooling water based on earlier reviews. Based on the profile of the maximum temperature, the warm cooling water is carried all the way to the strait between Hudö and Lindholmen underneath the ice, although at this distance, its temperature departs from that of the surrounding water only slightly, or by roughly 0–0.5 °C. However, due to the shortish calculation period, the long-range transport of the cooling water does not reach an equilibrium, which means that, in reality, the warm cooling water is transported even further. Based on the profile images (6-9 and 6-10), the warm cooling water remains close to the surface in the area of the straits south of Hästholmsfjärden, where, forced by bed formations, it can rise to the underside of the ice cover, causing the ice to melt or weaken. This makes safe passage on ice in the area more difficult.

The results of the cooling water modelling during the ice season carried out in this work conform quite well with the measurement results and satellite images. In addition, the modelling results of this work correspond quite well with the results of the modelling carried out with the simpler cooling water model in 2008. Based on these comparisons, the results of the cooling water modelling for the ice season in this work are sensible and credible.

6.3 NATURA AREA

Figure 6-11 shows the maximum difference of the water's surface temperature according to the cooling water modelling during the ice-free season. The difference has been calculated by subtracting the surface temperature of the situation "power plant not in operation" from the surface temperature of the situation "power plant in operation". In other words, the figure indicates the degree to which the power plant's operation affects the surface temperature of the seawater in nearby areas. The boundaries of the nearby Natura area are also shown in the figure. As is evident from the figure, the thermal effect on the Natura area attributable to the power plant on the basis of the modelling, even in the case of the maximum temperature differences, is small, principally in the region of 0–1°C. At its greatest, the effect can be 1.5–2.0 °C at the Natura area's sharp headland extending to Vådholmsfjärden. Any situations involving maximum temperature differences are nevertheless short-lived, and in average conditions, the thermal effect of the power plant's operation does not, in essence, extend to the Natura area at all during the ice-free season.

Figure 6-12 shows the maximum difference of the water's surface temperature according to the cooling water modelling during the ice season. As in Figure 6-11, the boundaries of the nearby Natura area are marked in the figure. Based on the modelling, the figure shows that the thermal effect caused by the power plant does not extend, during the ice season and in terms of surface temperatures, to the Natura area, even in the case of maximum temperature differences.

Nevertheless, based on Figures 6-8...6-10, it can be concluded that the warm cooling water may be transported to the Natura area beneath the ice. However, even in the case of maximum temperatures, the thermal effects are small (in the region of 0–1 °C).

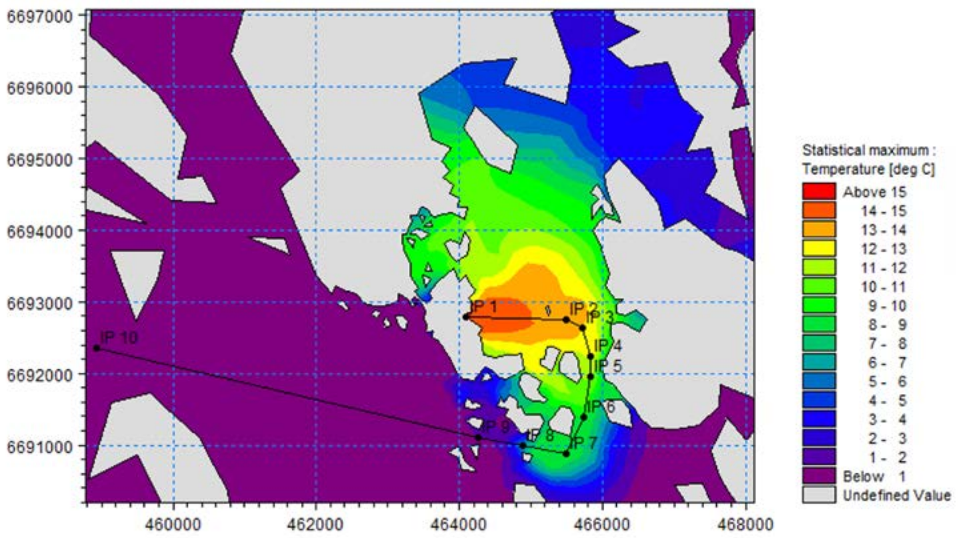


Figure 6-8. The maximum surface temperatures in March 2018 according to the cooling water modelling in this work. The figure also shows the cross-sectional line as a black line.

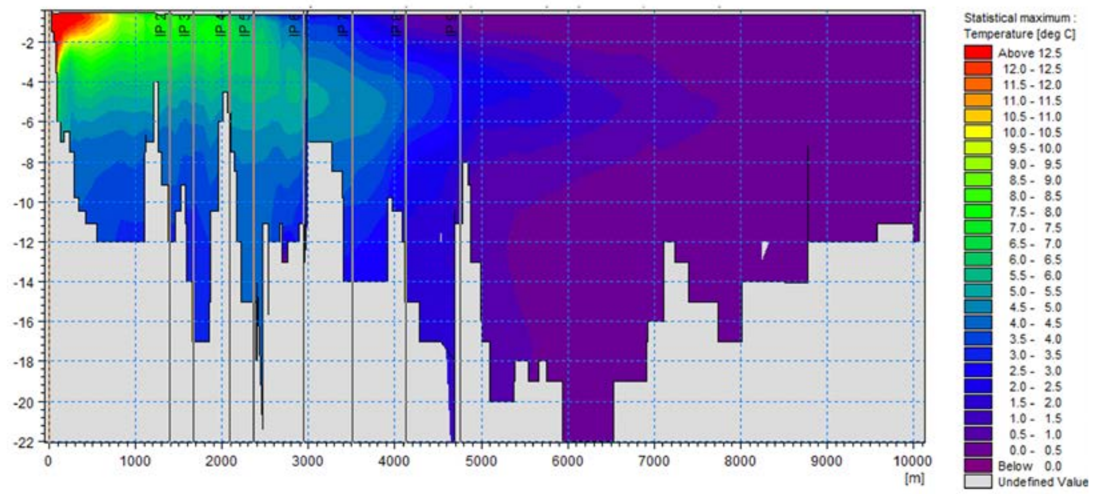


Figure 6-9. The profile of the average temperature according to the cooling water modelling in this work along the cross-sectional line of Figure 6-8.

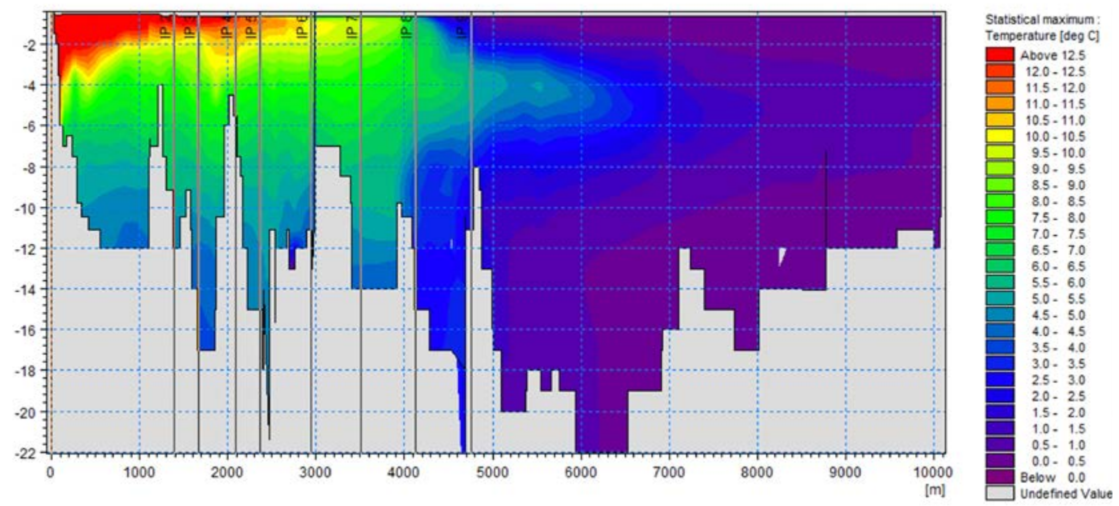


Figure 6-10. The profile of the maximum temperature according to the cooling water modelling in this work along the cross-sectional line of Figure 6-8.

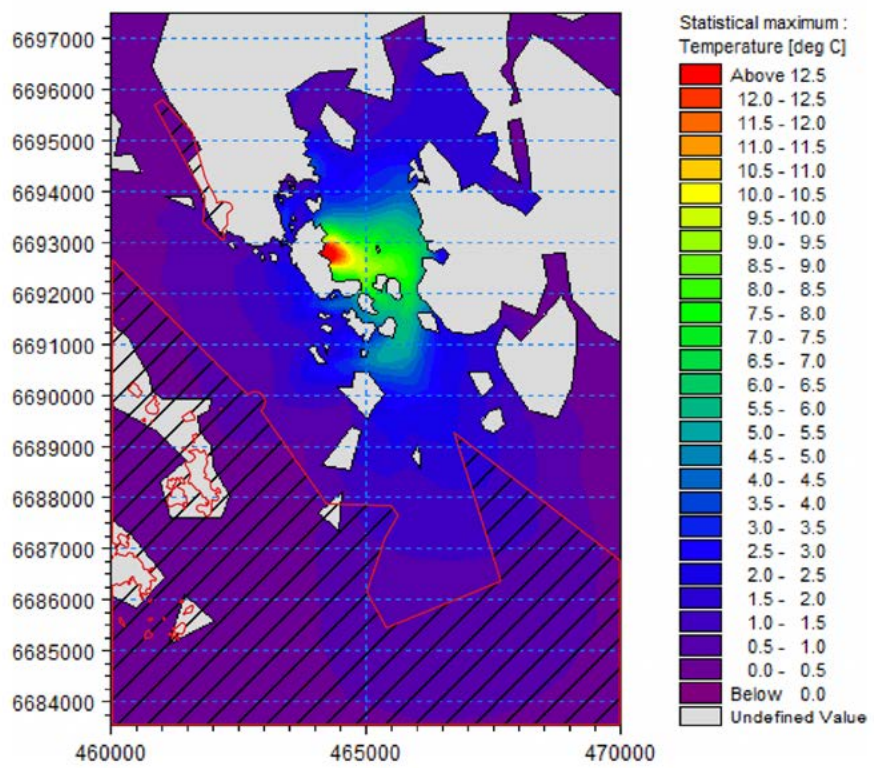


Figure 6-11. The maximum difference in surface temperature (power plant in operation – power plant not in operation) according to the modelling during the ice-free season. The hatched area delimited in red is the Natura area (Syke 2020, Creative Commons 2021).

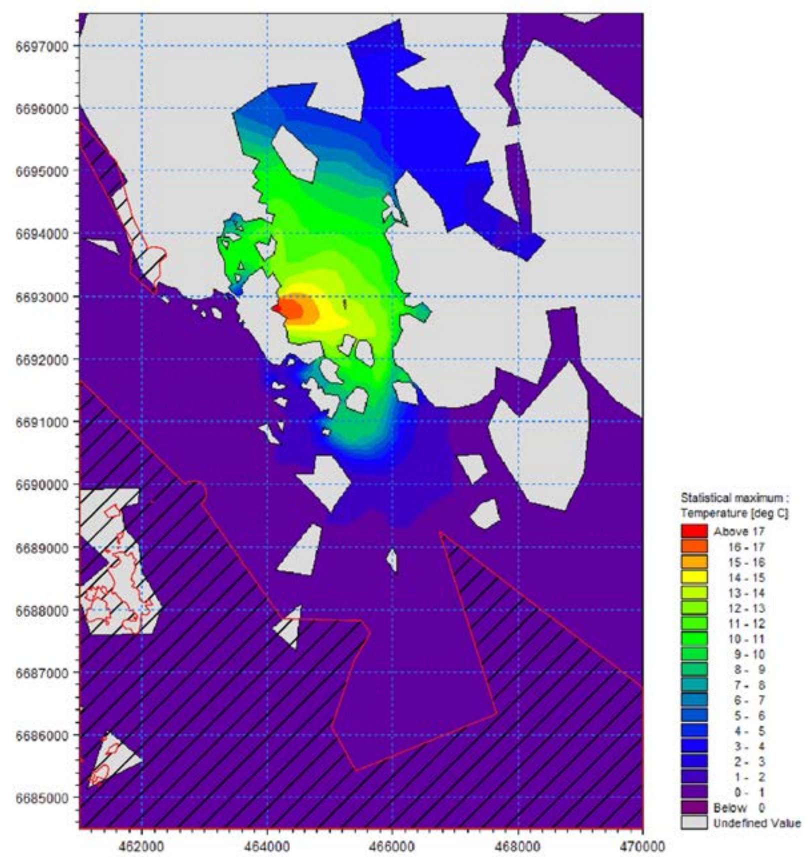


Figure 6-12. The maximum difference in surface temperature (power plant in operation – power plant not in operation) according to the modelling during the ice season. The hatched area delimited in red is the Natura area (Syke 2020, Creative Commons 2021).

7. Summary

The cooling water modelling in this work was conducted with DHI's Mike 3 FM non-hydrostatic flow model (DHI 2017), the baseline data of which include wind conditions, the sea level (variations included), air temperature, ice cover, and components of the net radiation of the sea and atmosphere. The model was calibrated by comparing the calculated values to the observations made during the 2011 ice-free season. Comparisons with earlier modelling results and observations show that the results of the cooling water modelling conducted for this report are sensible and credible from a qualitative perspective.

Based on the results of this modelling report and the results of Loviisa power plant's impact monitoring, the warming effect attributable to the cooling water is primarily visible in the surface layer of the sea area's discharge side, i.e. Hästholmsfjärden. During the summer, the average temperature of the seawater, based on the modelling, may rise by several degrees at the surface, but only in a small area of Hästholmsfjärden, in the immediate vicinity of the discharge location. Based on the modelling, the average increase in temperature in the surface water of Klobbfjärden's entire body of water (Hästholmsfjärden + Klobbfjärden) is, at maximum, only around 1 °C. Temporarily, the surface temperature of the seawater may rise in a broader area on the discharge side, given that the cooling water is often transported for some distance, according to the wind conditions, before mixing with the water column.

During the ice-free season, heat is also transferred efficiently from the seawater into the atmosphere, which contributes to a reduction in the warming effect of the power plant's cooling water during the growth season, for example. In winter, the cooling water can be transported even further underneath the ice, because the ice cover prevents the transfer of heat into the atmosphere and the wind's impact on mixing layers of water. In winter, the warm cooling water also weakens the ice cover in the nearby sea areas of Hästholmsfjärden, particularly in the area of the southern straits, where land forms may direct the warm water towards the surface of the water and the ice cover. According to the modelling results, cooling water that is warmer than the surrounding water column is transported beneath the ice fairly far to the west across Hudöfjärden, at a depth of approximately 4 m. This corresponds very well with the results of earlier studies.

Based on the modelling results, the cooling water's thermal effect in the nearby Natura area is very small during both the ice-free season and the ice season. During the ice-free season, the thermal effects extend to the Natura area only temporarily, when the wind drives the flow of water towards the area. During the ice season, the warmed cooling water discharged by the power plant can be transported further beneath the ice, often all the way to the Natura area, but the thermal effect is typically small.

When thinking about average temperatures, climate change will warm the surface of the sea by several degrees across the entire area, compared to which the warming caused by the power plant is limited to a very small area, particularly since the power plant's operating conditions restrict the temperature of the water to be discharged during warmer times.

References

An, N., Hemmati, S. and Cui, Y.-J., 2017 Assessment of the methods for determining net radiation at different time-scales of meteorological variables. Journal of Rock Mechanics and Geotechnical Engineering 9 (2017) 239–246.

BACC Author Team, 2008, Assessment of Climate Change for the Baltic Sea Basin. Springer Verlag, Berlin, Heidelberg. 474 p. (4–31, 93–96, 198–201, 281–283, 309–358), website: http://www.hzg.de/imperia/md/content/baltex/springer_bacc_complete.pdf (22 March 2021).

Creative Commons, 2021, licence to use the open data of the Finnish Meteorological Institute, website: https://creativecommons.org/licenses/by/4.0/deed.fi (22 February 2021).

Danish Wind Energy Association, 2021, website: http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/stat/unitsw.htm#roughness (22 March 2021).

Davies, A.M., Luyten, P. J. ja Deleersnijder, 1995, Turbulence Models in Shallow Sea oceanography, in Lynch E.R. & Davies A.N., Quantitative Skill Assessment for Coastal Ocean Models, Coastal and Estuarine Studies Volume 47, Pages 97-123 Copyright 1997 by the American Geophysical Union.

DHI, 2010, Numerical Modelling of Cooling Water Intake and Discharge at the Loviisa Nuclear Power Plant, Finland.

DHI, 2017, Hydrodynamic Module, User Guide, website: https://manuals.mikepoweredbydhi.help/2017/Coast_and_Sea/MIKE_FM_HD_3D.pdf (22 March 2021).
https://manuals.mikepoweredbydhi.help/2017/Coast_and_Sea/MIKE3HD_Scientific_Doc.pdf (22 March 2021).

Elliott, Z. A. and Venayagamoorthy, S. K., 2010, Evaluation of turbulent Prandtl (Schmidt) number parameterizations for stably stratified environmental flows, Dynamics of Atmospheres and Oceans 51 (2011) 137–150.

Esbensen, S. K. and Reynolds, R.W., 1980, Estimating monthly-averaged air-sea transfers of heat and momentum using the bulk aerodynamic method (Oregon state university) 35 p. HC A03/MF A01. Climatic Research Institute Oregon State University Corvallis, Oregon 97331.

Hari, J., 1986, Meriveden lämpötila, suolaisuus ja jääpeite talvella 1985–1986.

HELCOM, 2007 Climate Change in the Baltic Sea Area – HELCOM Thematic Assessment in 2007 Balt. Sea Environ. Proc. No. 111, website: https://helcom.fi/wp-content/uploads/2019/08/BSEP111.pdf (22 March 2021).

HELCOM, 2013 Climate change in the Baltic Sea Area: HELCOM thematic assessment in 2013. Balt. Sea Environ. Proc. No. 137.

HELCOM, 2018: HELCOM Thematic assessment of eutrophication 2011–2016. Baltic Sea Environment Proceedings No. 156, website: http://stateofthebalticsea.helcom.fi/wp-content/uploads/2019/09/BSEP156-Eutrophication.pdf (22 March 2021).

Climate Guide, 2021a, website: https://ilmasto-opas.fi/en/ilmastonmuutos/suomen-muuttuva-ilmasto/-/artikkeli/63e8e231-2d68-45cb-97c8-6bbdd9b5bae5/itameren-jaaolot-muuttuvat.html (16 March 2021).

Climate Guide, 2021b, website: https://ilmasto-opas.fi/fi/ilmastonmuutos/suomen-muuttuva-ilmasto/-/artikkeli/dfe79a73-08ea-4686-8463-811b87f53e44/lampotilat-kohoavat.html (16 March 2021).

Finnish Meteorological Institute, 2020a, website: https://www.ilmatieteenlaitos.fi/vuosi-2011 (22 March 2021).

Finnish Meteorological Institute, 2020b, website: https://www.ilmatieteenlaitos.fi/vuosi-2018 (22 March 2021).

Finnish Meteorological Institute, 2021, Open Data, website: https://en.ilmatieteenlaitos.fi/open-data (22 February 2021).

Ilus E., 2009, Environmental effects of thermal and radioactive discharges from nuclear power plants in the boreal brackish-water conditions of the northern Baltic Sea. STUK-A238.

IPCC, 2019, The Ocean and Cryosphere in a Changing Climate - Summary for Policymakers.

Luode Consulting Oy, 2012, Lämpötila- ja virtausmittaukset Loviisan voimalaitoksen edustan merialueella avovesikaudella 2011.

Marjamäki, M., 2012, Meriveden lämpötilat ja jäähdytysvesien kulkeutuminen Loviisan edustalla satelliittimittausten perusteella.

Omstedt, A. , Elken, J. , Lehmann, A. , Lepparanta, M. , Meier, H. E. M. , Myrberg, K. & Rutgersson, A., 2014, Progress in physical oceanography of the Baltic Sea during the 2003-2014 period, Progress in Oceanography, vol. 128, pp. 139–171. DOI: 10.1016/j.pocean.2014.08.010.

SMHI, 1986, Maximum ice extent in the Baltic Sea in 1986 – Ice chart, website: http://www.smhi.se/oceanografi/istjanst/produkter/arkiv/maxis/maxis_1986.pdf (22 March 2021).

SMHI, 2018, Maximum ice extent in the Baltic Sea in 2018 – Ice chart, website: http://www.smhi.se/oceanografi/istjanst/produkter/arkiv/maxis/maxis_2018.pdf (22 March 2021).

Finnish Environment Institute (Syke), 2020, Finnish Environment Institute's downloadable open spatial datasets – Natura 2000 areas, website: https://www.syke.fi/en-US/Open_information/Spatial_datasets/Downloadable_spatial_dataset (15 March 2021).

Toppila, T., 2008, Loviisa 3, Jäähdytysveden leviämisen mallinnus, tarkastelutapausten kuvaus ja tulokset.

Appendices

APPENDIX 1: MAXIMUM ICE EXTENT IN THE BALTIC SEA DURING ICE WINTER 2017–2018 – ICE CHART

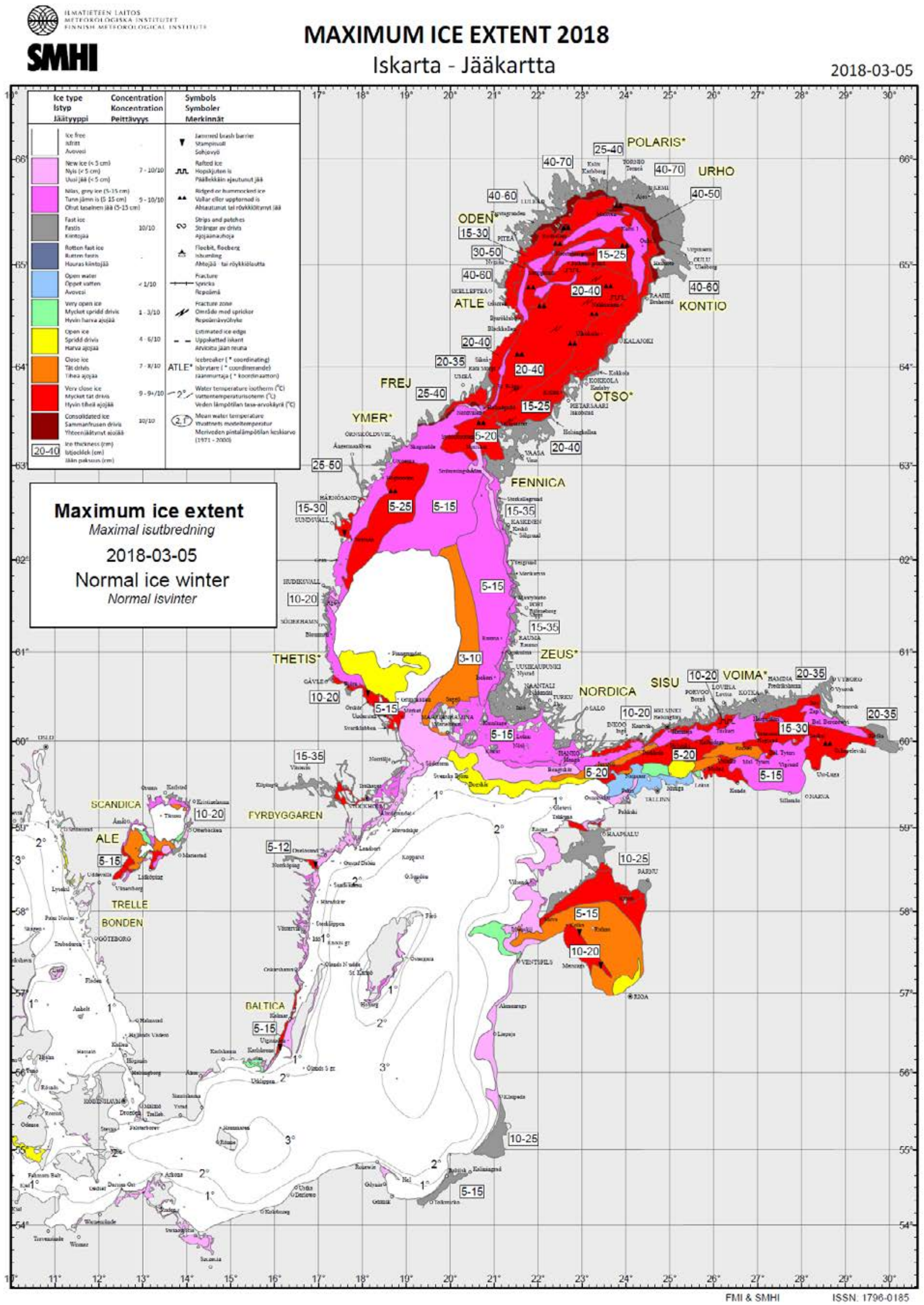


Figure L1-1.

APPENDIX 2: TIME SERIES OF MODELLING RESULTS BY RECEIVER POINTS DURING ICE-FREE SEASON

Figure L2-1. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden in 2011 weather conditions, operation of power plant continues.

Figure L2-2. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden in 2011 weather conditions, power plant decommissioned.

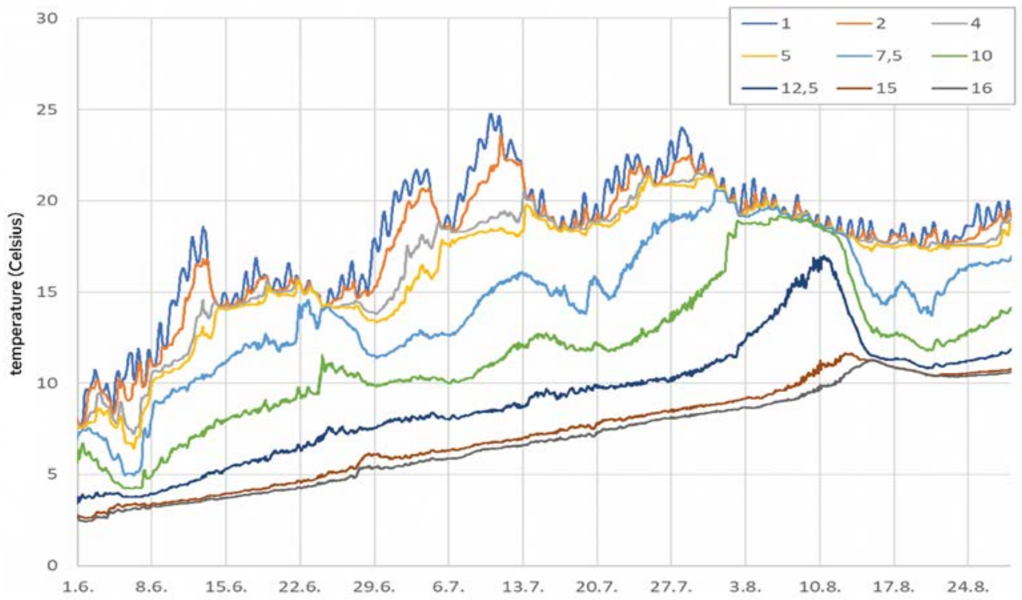


Figure L2-3. The modelled water temperature at various depths and point K1 in Hudöfjärden in 2011 weather conditions, operation of power plant continues.

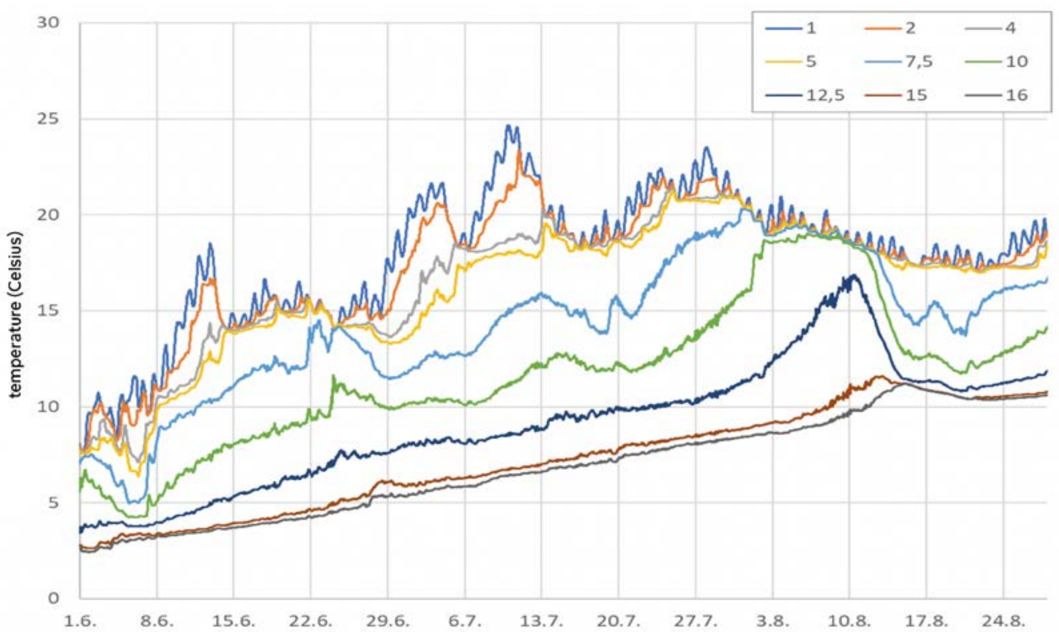


Figure L2-4. The modelled water temperature at various depths and point K1 in Hudöfjärden in 2011 weather conditions, power plant decommissioned.

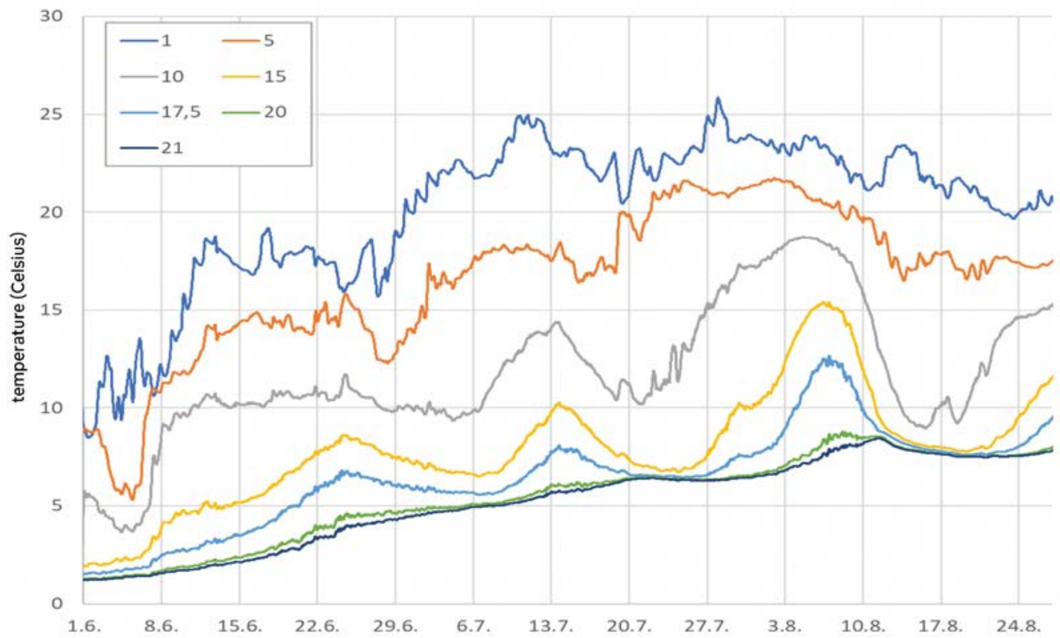


Figure L2-5. The modelled water temperature at various depths and point K2 in Vådholmsfjärden in 2011 weather conditions, operation of power plant continues.

Figure L2-6. The modelled water temperature at various depths and point K2 in Vådholmsfjärden in 2011 weather conditions, power plant decommissioned.

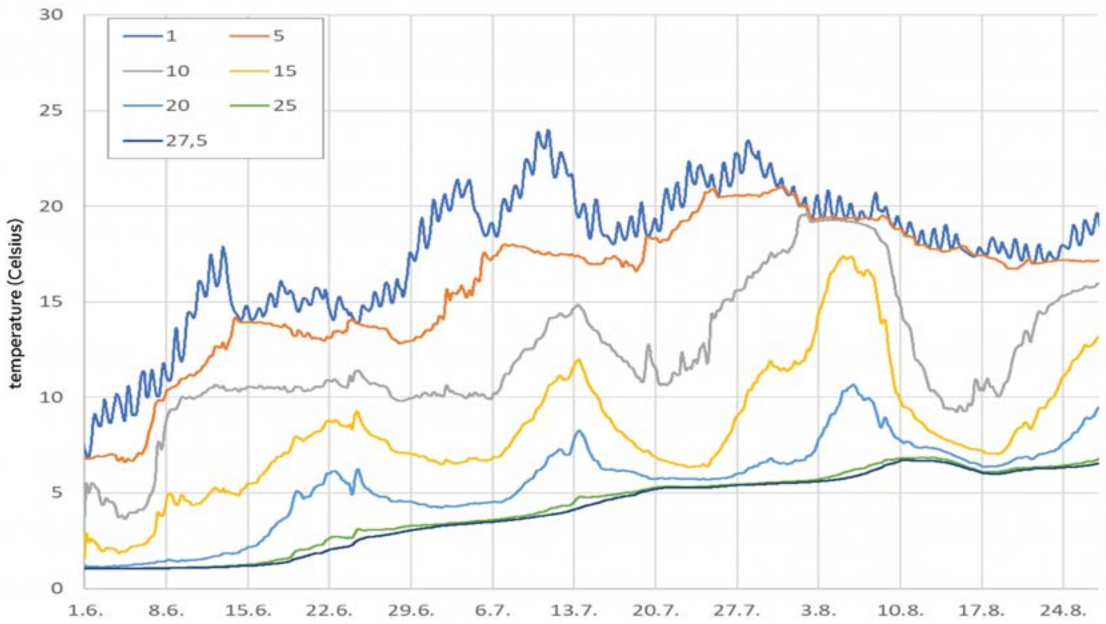


Figure L2-7. The modelled water temperature at various depths and point K3 in Orrengrundsfjärden in 2011 weather conditions, operation of power plant continues.

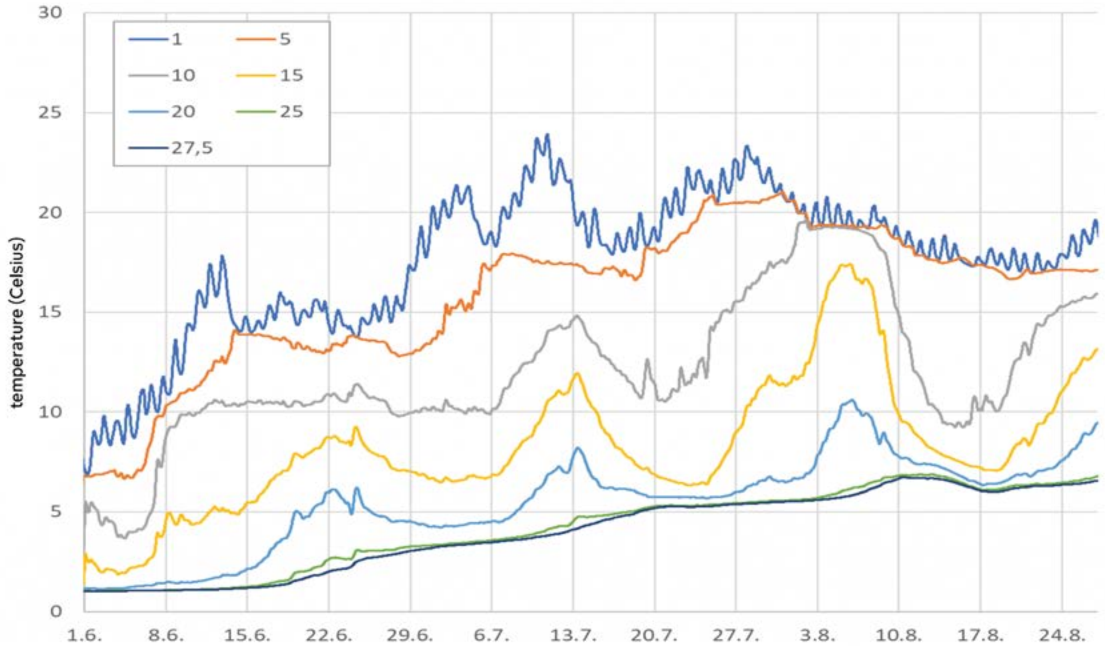


Figure L2-8. The modelled water temperature at various depths and point K3 in Orrengrundsfjärden in 2011 weather conditions, power plant decommissioned.

APPENDIX 3: TIME SERIES OF MODELLING RESULTS BY RECEIVER POINTS DURING ICE SEASON

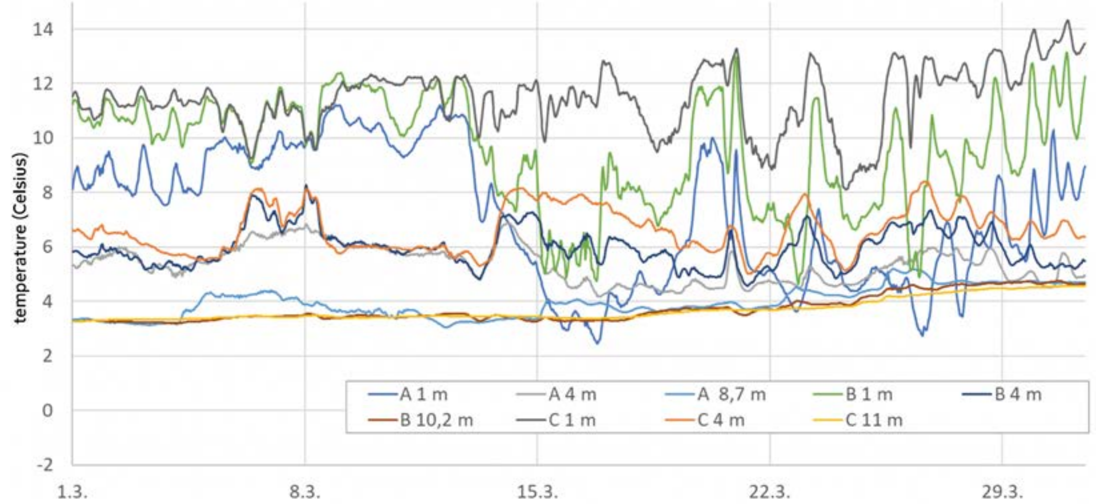


Figure L3-1. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden (Figure 3-3) in March 2018, operation of power plant continues.

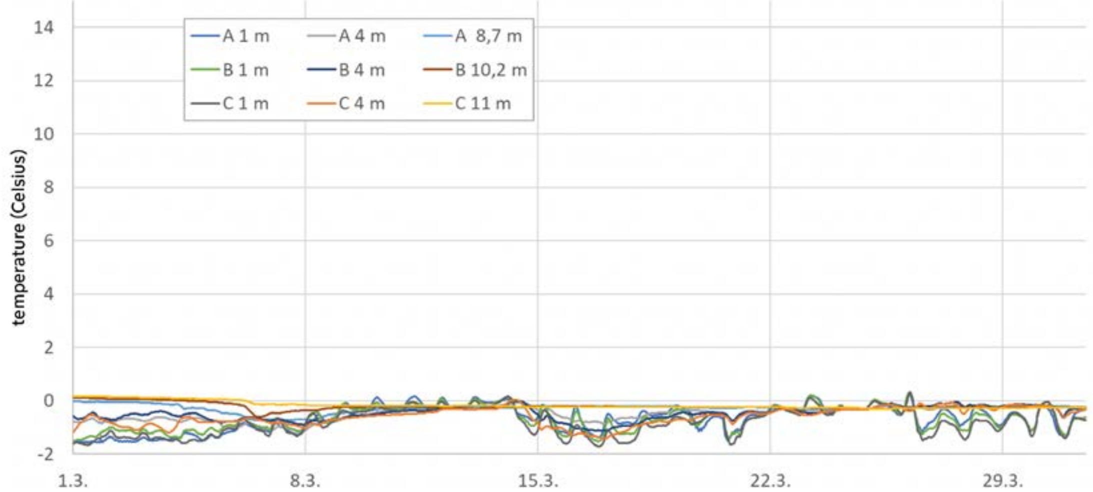


Figure L3-2. The modelled water temperature at various depths and buoys A, B and C on the discharge side in Hästholmsfjärden (Figure 3-3) in March 2018, power plant decommissioned.

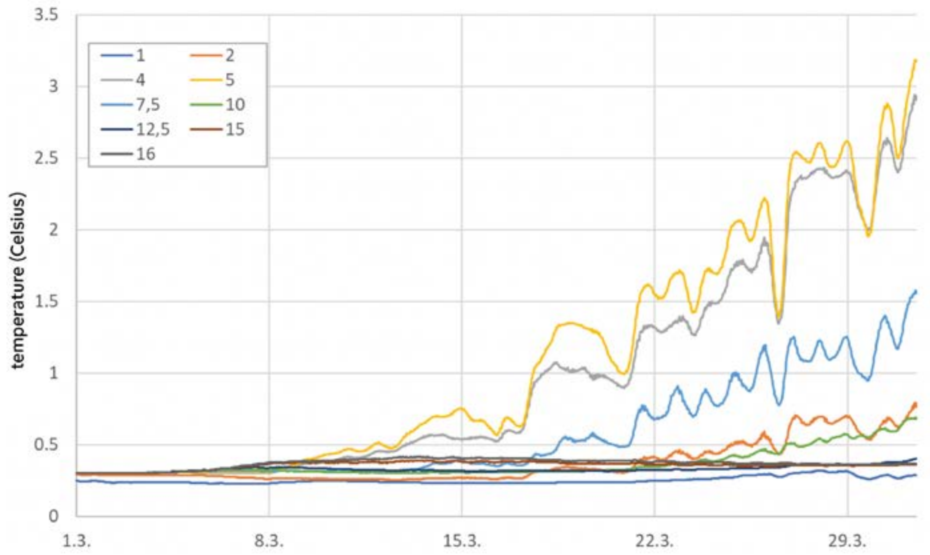


Figure L3-3. The modelled water temperature at various depths and point K1 in Hudöfjärden in March 2018, operation of power plant continues.

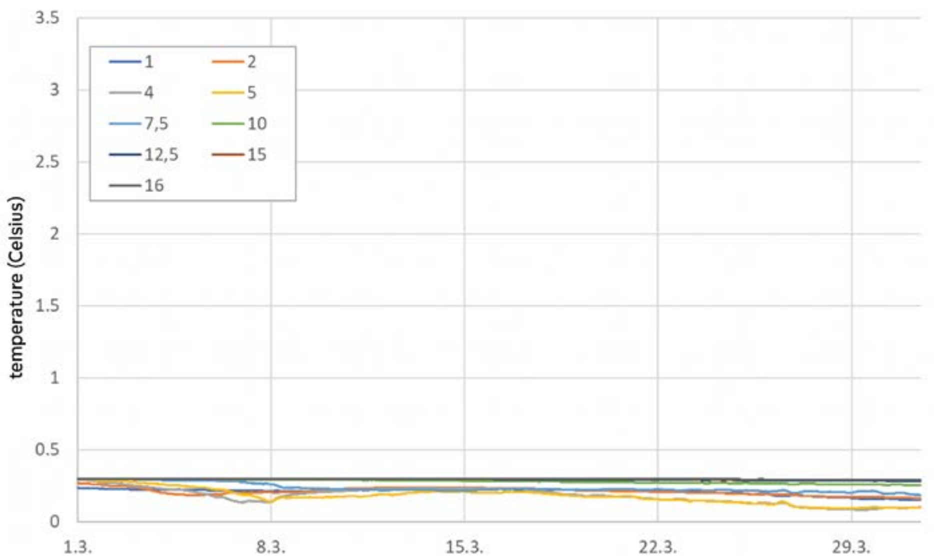


Figure L3-4. The modelled water temperature at various depths and point K1 in Hudöfjärden in March 2018, power plant decommissioned.

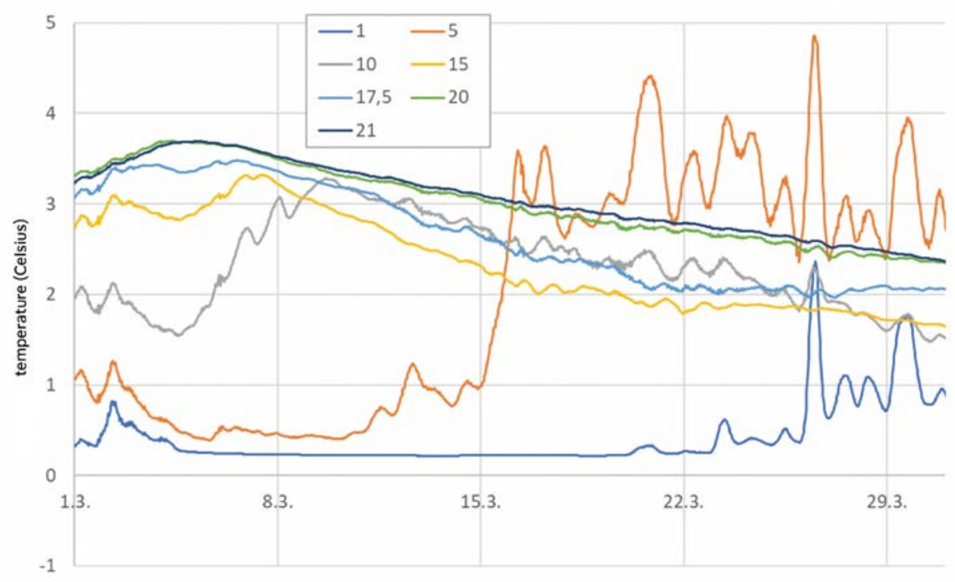


Figure L3-5. The modelled water temperature at various depths and point K2 in Vådholmsfjärden in March 2018, operation of power plant continues.

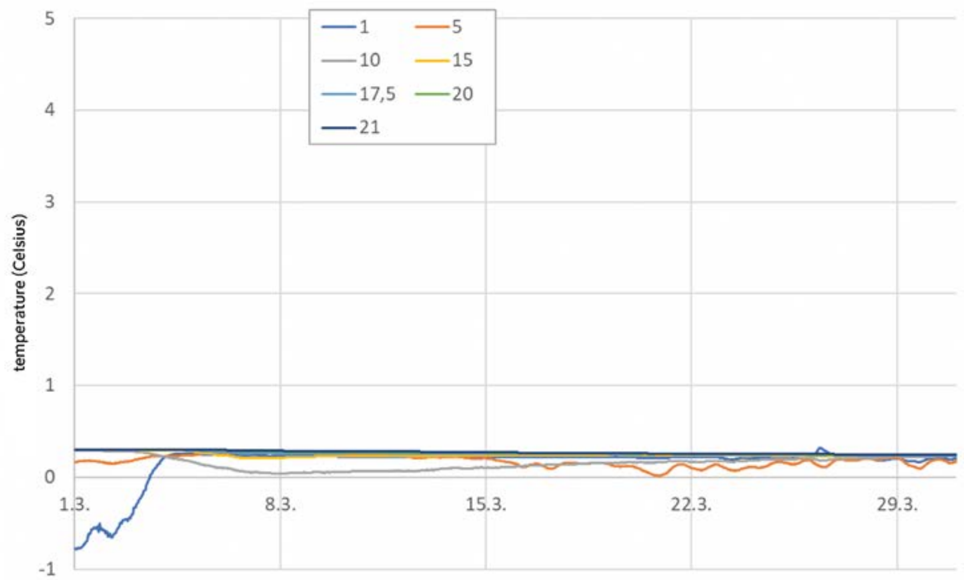


Figure L3-6. The modelled water temperature at various depths and point K2 in Vådholmsfjärden in March 2018, power plant decommissioned.

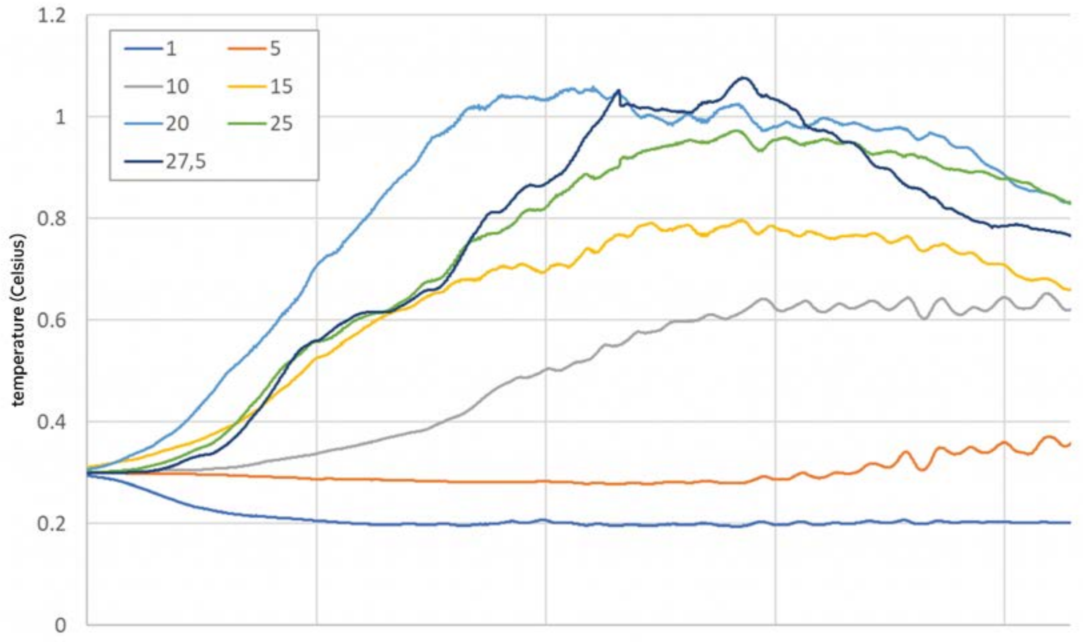


Figure L3-7. The modelled water temperature at various depths and point K3 in Orrengrundsfjärden in March 2018, operation of power plant continues.

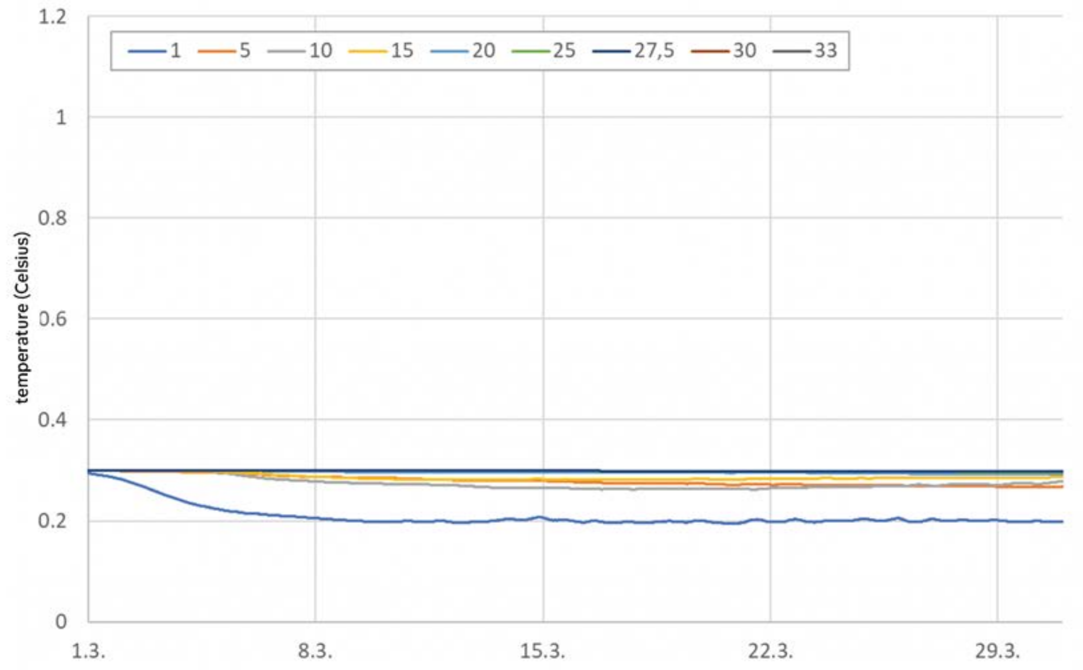


Figure L3-8. The modelled water temperature at various depths and point K3 in Orrengrundsfjärden in March 2018, power plant decommissioned.