FENNOVOIMA

Environmental Impact Assessment Report for a Nuclear Power Plant

February 2014

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Summary

Project

Background of the project

Fennovoima Ltd. (hereinafter "Fennovoima") is studying the construction of a nuclear power plant of approximately 1,200 MW at Hanhikivi headland in Pyhäjoki, Finland. As part of the studies, Fennovoima will carry out an environmental impact assessment as laid down in the Act on Environmental Impact Assessment Procedure (468/1994; hereinafter "the EIA Act") to study the environmental impacts of the nuclear power plant's construction and operation.

In 2008, Fennovoima implemented an environmental impact assessment (EIA) to assess the impacts of the construction and operation of a nuclear power plant of approximately 1,500–2,500 megawatts that consists of one or two reactors at three alternative locations: Pyhäjoki, Ruotsinpyhtää, and Simo. An international hearing procedure pursuant to the Espoo Convention was also performed in connection with the EIA procedure.

Fennovoima received a Decision-in-Principle in compliance with section 11 of the Nuclear Energy Act (990/1987) on May 6, 2010. Parliament confirmed the Decision-in-Principle on July 1, 2010. The Hanhikivi headland in Pyhäjoki was selected as the plant site in the autumn of 2011 (Figure 1).

The nuclear power plant of approximately 1,200 MW which is the object of this environmental impact assessment and the supplier of which is a company belonging to the Russian Rosatom Group was not mentioned as one of the plant alternatives in Fennovoima's original application for a Decision-in-Principle. This is why the Ministry of Employment and the Economy required that Fennovoima updates the project's environmental impact assessment with this EIA procedure. The international hearing procedure in compliance with the Espoo Convention is simultaneously implemented.

Figure 1. The project site and the Baltic Sea region countries, including Norway.

Assessed alternatives

The implementation alternative being assessed consists of the environmental impacts from the construction and operation of a nuclear power plant of approximately 1,200 MW. The plant will be constructed on the Hanhikivi headland in Pyhäjoki. The plant will consist of one nuclear power plant unit of the pressurized water reactor type. The zero-option assessed is not implementing Fennovoima's nuclear power plant project.

In addition to the nuclear power plant itself, the project will include interim storage of spent nuclear fuel on site, as well as treatment, storage, and final disposal of low and intermediate level operating waste. The following are also included in the project scope:

- Intake and discharge arrangements for cooling water
- Supply and handling systems for service water
- Treatment systems for wastewater and emissions into the air
- Constructing roads, bridges, and banks
- Constructing a harbor area, wharf, and navigation channel for sea transport.

The report also describes the nuclear fuel supply chain, the final disposal of spent nuclear fuel, and decommissioning of the nuclear power plant. A separate EIA procedure will be applied to the latter two at a later date. A separate EIA procedure will also be applied to the transmission line connection to the national grid.

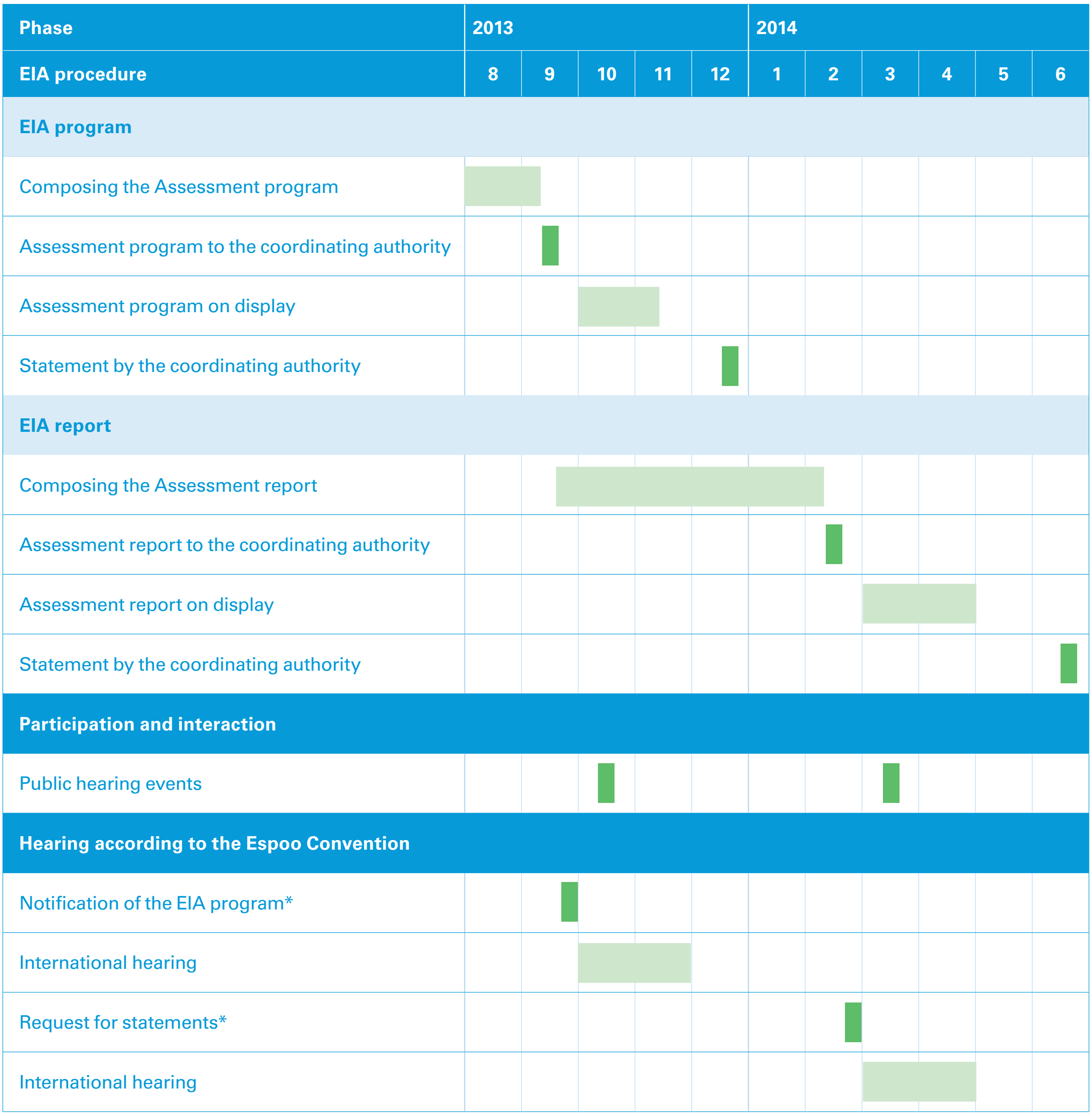
Schedule

Key stages and planned schedule of the EIA procedure are presented in Figure 2.

Environmental impact assessment and stakeholder hearing procedure

EIA procedure

The environmental impact assessment procedure is based on the Council Directive on the assessment of the impacts of certain public and private projects on the environment (85/337/EEC) that has been enforced in Finland through the EIA Act (468/1994) and the EIA Decree (713/2006). The objective of the EIA procedure is to improve the environmental impact assessments and to ensure that environmental impacts are consistently taken into account in planning and decision-making. Another objective is to increase the availability of information to citizens and the possibility for them to participate in the planning of projects. The EIA



*by the Ministry of the Environment

Figure 2. Schedule of the EIA procedure.

procedure does not involve any project-related decisions nor does it solve any issues pertaining to permits or licenses.

The EIA procedure consists of the program and the report stages. The environmental impact assessment program (EIA program) is a plan for arranging an environmental impact assessment procedure and the required investigations. The environmental impact assessment report (EIA report) describes the project and its technical solutions, and offers a consistent assessment of the environmental impacts based on the EIA procedure.

The environmental impact assessment in a transboundary context as laid down in the Espoo Convention is also applied to the Fennovoima nuclear power plant project. Parties to the Convention have the right to take part in an environmental impact assessment procedure carried out in Finland if the state in question may be affected by the adverse environmental impacts of the project to be assessed. The Finnish Ministry of the Environment coordinates the international hearing procedure. The Ministry submits all statements and opinions it has received to the coordinating authority to be taken into account in the coordinating authority's statements regarding the EIA program and the EIA report.

The stages of the EIA procedure are presented in Figure 3.

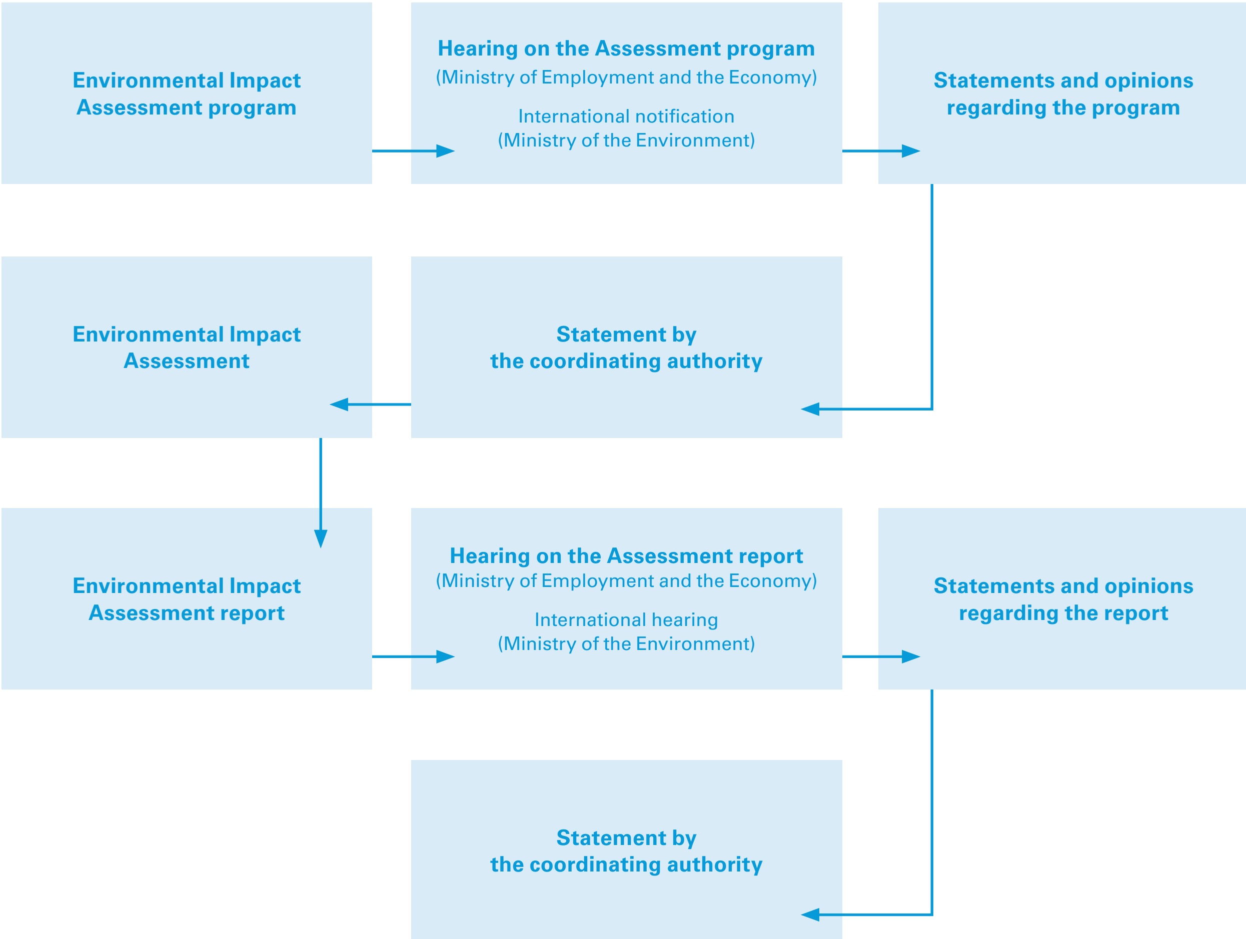


Figure 3. Stages of the EIA procedure.

National and international hearing

On September 17, 2013, Fennovoima submitted the EIA program concerning the nuclear power plant project of approximately 1,200 MW to the Ministry of Employment and the Economy, which acts as the coordinating authority. The Ministry of Employment and the Economy requested statements on the EIA program from various authorities and other stakeholders, and citizens also had the opportunity to present their opinions. The EIA program was available for reviewing in Finland from September 30 to November 13, 2013 and available for international reviewing from September 30 to November 28, 2013.

A total of fifty-one statements and opinions regarding the EIA program were submitted to the Ministry of Employment and the Economy. Fifty-seven statements and notifications were submitted in the international hearing process. Sweden, Denmark, Norway, Poland, Germany (two federated states), Latvia, Estonia, Russia, and Austria announced that they will participate in the EIA procedure.

The Ministry of Employment and the Economy issued its statement on the EIA program on December 13, 2013.

The opinions of Finnish stakeholders on the project were studied by implementing a resident survey in the area surrounding the planned plant site and by arranging group interviews during the EIA procedure. The opinions received were taken into account in assessing the environmental impacts.

The environmental impact assessment report has been drawn up on the basis of the EIA program and the related opinions and statements. The EIA report was submitted to the coordinating authority in February 2014. Citizens and stakeholders will have the opportunity to voice their opinions on the EIA report by the deadline specified by the Ministry of Employment and the Economy. The EIA procedure will end when the Ministry of Employment and the Economy issues its statement on the EIA report.

Project description and plant safety

Operating principle of the plant

Nuclear power plants produce electricity in the same manner as condensing power plants using fossil fuels: by heating water into steam and letting the steam rotate a turbogenerator. The main difference between nuclear power plants and conventional condensing power plants is in the heat production method: in nuclear power plants, the heat is produced in a reactor using the energy released by splitting atom nuclei, whereas in condensing power plants, the water is heated by burning suitable fuel, such as coal, in a boiler.

The most widely used reactor type is the light water reactor. The reactors of the nuclear power plants currently in operation in Finland are light water reactors. The alternative types of light water reactors are the boiling water reactor and the pressurized water reactor. The type considered for this project is the pressurized water reactor.

In a pressurized water reactor, fuel heats the water but high pressure prevents the water from boiling. The heated high-pressure water is led from the reactor to steam generators. In the steam generators, the water is distributed into small-diameter heat transfer tubes. The heat transfers through the walls of the tubes into the water circulating in a separate circuit, which is the secondary circuit. The water in the secondary circuit turns into steam, which is then led to the turbine rotating a generator (Figure 4). As the reactor system and the secondary circuit are completely separated from each other, the water circulating in the secondary circuit is not radioactive.

In nuclear power plants, more than one third of the thermal energy generated in the reactor can be converted into electric energy. Rest of the heat produced is removed from the power plant using condensers. In the condensers, low-pressure steam from the steam turbines releases energy and turns back into water. Condensers are cooled using cooling water taken directly from a water system. The cooling water, the temperature of which rises by 10–12 °C in the process, is then returned back to the water system.

Nuclear power plants are best suited as base load plants, which mean that they are used continuously at constant power except for a few weeks' maintenance outages at 12–24-month intervals. Plants are designed for an operational lifetime of at least 60 years.

Description of the plant type

The Rosatom AES-2006 pressurized water reactor that is being studied in this project is a modern, third-generation nuclear power plant. The AES-2006 plants are based on VVER technology, which has been developed and used for more than 40 years and consequently offers the benefit of long-term operational experience. The version of the plant under consideration for Fennovoima's project is the latest development step in the VVER plant series. VVER plants have a history of safe operation spanning over 30 years in the Loviisa nuclear power plant.

Table 1 shows the preliminary technical data of the planned new nuclear power plant.

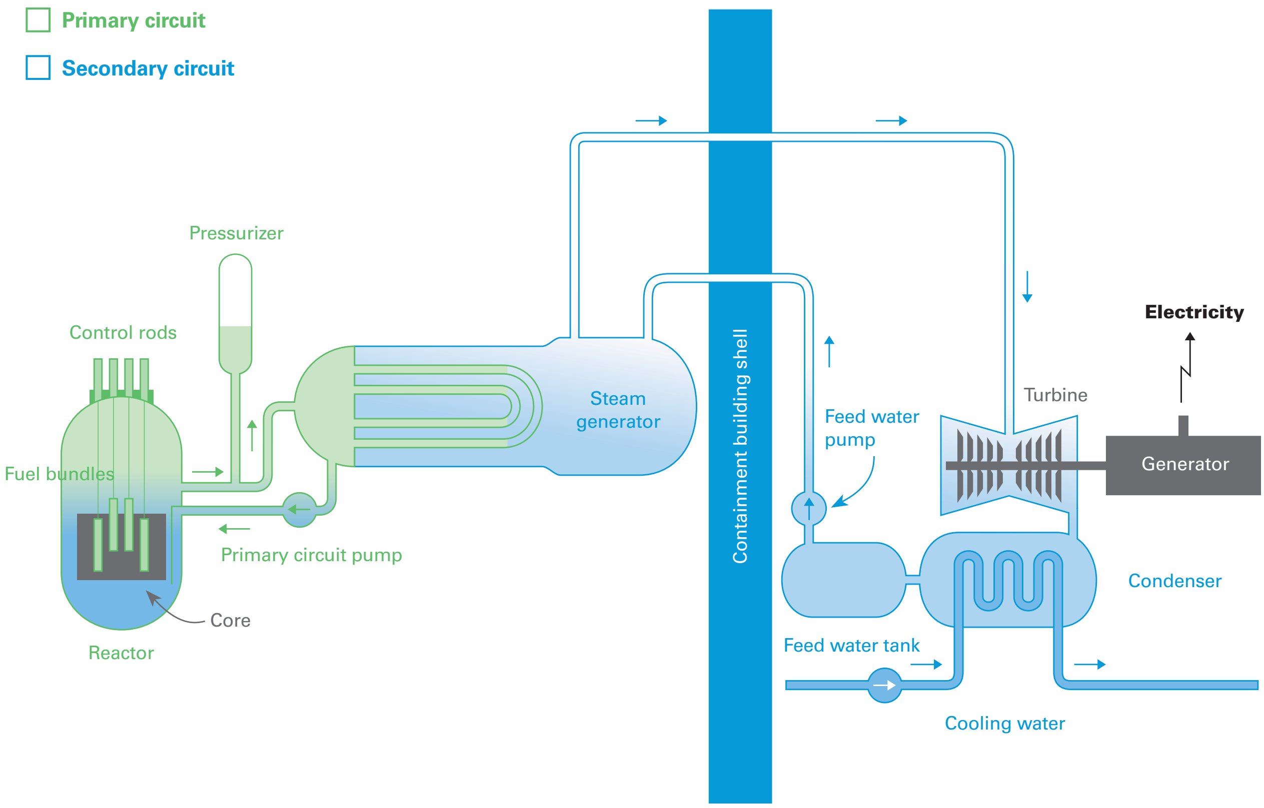


Figure 4. Operating principle of a pressurized water reactor.

Table 1. Preliminary technical specifications of the planned new nuclear power plant.

Description	Value and unit
Reactor	Pressurized water reactor
Electric power	Approximately 1,200 MW (1,100–1,300 MW)
Thermal power	Approximately 3,200 MW
Efficiency	Approximately 37 %
Fuel	Uranium dioxide UO_2
Fuel consumption	20–30 t/a
Thermal power released in cooling to the water system	Approximately 2,000 MW
Annual energy production	Approximately 9 TWh
Cooling water consumption	Approximately 40–45 m^3/s

The safety of the plant is based on both active and passive systems. Active systems are systems that require a separate power supply (such as electric power) to operate. Among the important safety features of the AES-2006 are additional passive safety systems, driven by natural circulation and gravity. Being independent from the supply of electric power, they will remain in operation even in the unlikely event of total loss of power supply and unavailability of the emergency power generators. The possibility of a severe reactor accident, meaning a partial meltdown of the reactor core, will be considered in the design of the plant. To cope with a severe accident, the containment building will be equipped with a core catcher. The plant type features a double-shell containment building. The outer containment shell is a thicker structure made of reinforced concrete that is capable of withstanding external collision loads, including a passenger airplane crash.

Nuclear safety

The safety requirements related to the use of nuclear energy are based on the Finnish Nuclear Energy Act (990/1987) which states that nuclear power plants must be safe and shall not cause any danger to people, the environment, or property.

The regulations of the Nuclear Energy Act are further specified in the Nuclear Energy Decree (161/1988). The general principles of the safety requirements set for nuclear power plants are laid down in Government Decrees (734/2008, 736/2008, 716/2013, and 717/2013). Their scope of application covers the different areas of the safety of nuclear energy use. Detailed regulations on the safety of nuclear energy use, safety and emergency preparedness arrangements, and nuclear material safeguards are given in the regulatory guides on nuclear safety (YVL Guides) issued by the Radiation and Nuclear Safety Authority (STUK). Various national and international regulations and standards also control the use of nuclear energy.

The safety of nuclear power plants is based on the defense-in-depth principle. Several independent and supplementary protection levels will be applied to the design and operation of the Fennovoima nuclear power plant. These include the following:

- Prevention of operational transients and failures through high-quality design and construction, as well as appropriate maintenance procedures and operation.
- Observation of operational transients and failures and returning the situation to normal using protection, control, and safety systems.
- Management of design basis accidents using existing and planned safety features.
- Observation and management of severe accidents using the accident management system.
- Mitigation of the consequences of releasing radioactive substances through emergency and rescue operations.

The nuclear power plant will be equipped with safety systems that will prevent or at least limit the progress and impact of failures and accidents. The safety systems will be divided into several parallel subsystems, the combined capacity of which will be designed to exceed the requirement several times over (the redundancy principle). The overall system consisting of multiple redundant subsystems will be able to perform its safety functions even in the case of the failure of any single piece of equipment and the simultaneous unavailability of any piece of equipment contributing to the safety function due to maintenance or any other reason. This redundancy ensures the operational reliability of the safety systems. Reliability can be further improved by utilizing several pieces of equipment of different types to perform the same function. This eliminates the chance of type-specific defects preventing the performance of the safety function (the diversity principle). The redundant subsystems will be separated from each other so that a fire or a similar incident cannot prevent the performance of the safety function. One alternative for implementing the separation is to place the subsystems in separate rooms (the separation principle).

The nuclear power plant will be designed to withstand the loads resulting from various external hazards. These include extreme weather conditions, sea and ice-related phenomena, earthquakes, various missiles, explosions, flammable and toxic gases, as well as intentional damage. Other factors that will be taken into account in the design include the eventual impacts of climate change, such as the increasing frequency of extreme weather phenomena, increase in the temperature of seawater, and rises in the average sea level.

Construction of the nuclear power plant

The construction of a nuclear power plant is an extensive project. The first phase of construction, which will take approximately three years, will feature the construction of the infrastructure required for the plant and performance of civil engineering work.

The earthworks will include bedrock blasting and rock excavation work performed for the purpose of constructing the cooling water tunnels and the power plant excavation, as well as the filling, raising, and leveling of the plant area and the supporting areas. Hydraulic engineering works, including soil and rock excavation work performed for the purpose of building the navigation channel, the harbor area, and the cooling water intake and discharge structures, will be carried out simultaneously with the earthworks.

The harbor basin, the navigation channel, the auxiliary cooling water inlet channel, and the cooling water intake structures will be located in the western and northwestern parts of the Hanhikivi headland. The cooling water discharge structures will be located on the northern shoreline. According to the plan, the cooling water will be taken from the harbor basin located on the western shore of the Hanhikivi headland using an onshore intake system and discharged at the northern part of the headland.

The actual power plant construction work will begin after the completion of the infrastructure and the civil engineering works. The construction of the power plant will take 5–6 years, including installation work carried out at the plant. The commissioning of the plant will take 1–2 years. The objective is to put the plant into operation by 2024.

Radioactive emissions and their control

Radioactive emissions into the air

According to the Government Decree (717/2013), the radiation dose to individual inhabitants of the surrounding area caused by the normal operation of a nuclear power plant may not exceed 0.1 millisieverts per year. This limit value is the basis for determining the limits for emissions of radioactive substances during normal operation. Emission limits will be established for iodine and inert gas emissions. The emission limits are separately specified for each nuclear power plant. In addition to iodine and inert gas emissions, the nuclear power plant will release tritium, carbon-14, and aerosols into the air. Even at the theoretical maximum level, the annual emissions of these substances will remain so low that setting separate emission limits for them is not necessary in Finland. However, these emissions will still be measured.

The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Furthermore, Fennovoima will determine its own emission targets for the nuclear power plant. These targets will be stricter than the set emission limits.

The radioactive gases generated in the nuclear power plant will be processed using the best available technology. Gaseous radioactive substances will be directed into a cleaning system, where the gases will be dried, delayed, and filtered using charcoal filters, for example. Gaseous emissions can also be filtered using efficient high-efficiency particulate air (HEPA) filters. The cleaned gases will be released into the atmosphere via the vent stack. Radioactive emissions into the air will be monitored and measured in the several stages of the gas treatment systems, and finally at the vent stack.

Radioactive emissions into the sea

As in the case of emissions into the air, power plant-specific emission limits will be set for radioactive emissions into the sea. Furthermore, Fennovoima will determine its own emission targets, which will be stricter than the set emission limits. In Finland, tritium emissions have been approximately 10 % and other emissions clearly less than 1 % of the set emission limits. The amount of tritium from a nuclear power plant in seawater decreases to an insignificant level at a very short distance from the plant.

Radioactive liquids from the controlled area will be led to the liquid waste treatment plant where they will be cleaned so that their activity level falls well below the set emission limits before they are released into the water system. The water, which will contain only a low level of radioactivity, will be released into the sea after the treatment process. The level of radioactivity in the water released into the sea will be determined using a representative sample and by conducting measurements at the outlet line before the water is released into the cooling water discharge tunnel. The goal is to minimize the volume of emissions into the sea by, for example, recycling the process and pool water and by minimizing the generation of wastewater.

Waste management

In addition to conventional waste, radioactive waste is generated during the operation of a nuclear power plant. This waste is divided into two main categories:

- Very low, low and intermediate level waste, i.e. operating waste (such as low level waste generated during maintenance or repairs and components, and equipment removed from inside the reactor pressure vessel that have been activated by neutron radiation, which are intermediate level waste)
- High level waste, i.e. spent nuclear fuel.

The basic principle for the management of radioactive waste generated in the nuclear power plant will be permanent isolation of the waste from the environment. The party under the nuclear waste management obligation (in practice, the owner of the nuclear power plant) will be responsible for the implementation of nuclear waste management and liable for covering the related expenses. According to the Nuclear Energy Act, nuclear waste must be treated, stored, and permanently disposed of within Finland.

Operating waste

Whenever possible, solid radioactive waste will be sorted at the site where the waste is generated. For storage or final disposal, maintenance waste will be packed in vessels, typically 200-liter drums. Before waste is packed in the storage or disposal vessels, its volume will be decreased using various methods, such as compression or mechanical or thermal cutting. Wet and liquid radioactive waste, ion exchange resins, sludge materials, and concentrates will be processed by drying. Wet waste will be solidified in cement order to facilitate safe handling and final disposal. The properties of the waste will be characterized for further treatment and final disposal of the waste.

For the final disposal of low and intermediate level waste, Fennovoima will build an operating waste repository in the bedrock of the plant site, at a depth of approximately 100 meters. The operating waste repository for low and intermediate level waste may be either a rock silo or a tunnel. Of these, the latter solution is more probable. In the case of a tunnel-type repository, the waste would be transported in via a vehicle access tunnel. Very low level waste may also be placed in a surface repository on ground level. Should Fennovoima decide not to build a surface repository, the very low level waste will be disposed of in the operating waste repository in the same way as low and intermediate level operating waste.

Spent nuclear fuel

Following removal from the reactor, the spent nuclear fuel will be transferred to the reactor hall water pools, where they are allowed to cool down for 3–10 years. From the reactor hall, the spent fuel will be transferred to interim storage, where it will remain for a minimum of 40 years prior to final disposal. During the interim storage period, the activity and heat generation of the spent fuel will continue to decrease significantly. After the interim storage, the spent fuel will be transported to a final disposal site built for this particular purpose.

Water pools or dry storage will be used for interim storage of the spent nuclear fuel. The water pools will be located in a building made of steel-reinforced concrete, for instance. The water will act as a radiation shield and cool the spent fuel. In dry storage, the spent fuel is packed in special containers designed for the purpose.

The spent fuel will be disposed of in the Finnish bedrock. The final disposal will be implemented using the KBS-3 concept developed in Sweden and Finland. In the final disposal solution following this concept, the spent fuel will be encapsulated in copper canisters, surrounded with bentonite clay, and deposited in deposit holes drilled deep in the bedrock. As the disposal of spent fuel will not begin until the 2070s at the earliest, technological developments in the field can also be taken into account in the planning of Fennovoima's final disposal solutions.

At present, Fennovoima is preparing an overall plan on the final disposal of spent nuclear fuel. One of the main goals of the overall plan is to determine an optimal final disposal solution which will be able to, for its part, promote cooperation between Fennovoima and the other Finnish parties under the nuclear waste management obligation.

A condition included in the Fennovoima Decision-in-Principle states that Fennovoima must have an agreement on nuclear waste management cooperation with the parties currently under the nuclear waste management obligation or start its own EIA procedure for the final disposal project by summer 2016. The final disposal of Fennovoima's spent fuel will require the completion of an EIA and a Decision-in-Principle procedure, as well as a construction license and an operating license, regardless of the location of the final disposal facility.

Water supply

Water consumption and water supply

Fresh water (service water) will be needed at the power plant for potable water and for preparing the plant's process waters. The power plant will consume service water approximately 600 m^3/day. The plan is to obtain the service water from the local municipal water utility.

Cooling water

The cooling water consumption will vary depending on the amount of energy produced. A plant of approximately 1,200 MW will require approximately 40–45 m^3/sec of seawater to cool the condensers. According to the plan, the cooling water will be taken from the harbor basin located on the western shore of the Hanhikivi headland using an onshore intake system and discharged at the northern part of the headland. Major impurities and objects will be removed from the cooling water before it is led into the condensers. After the cooling water has passed through the condenser, it will be discharged back into the sea through the cooling water discharge channel. The temperature of the water will rise by 10–12 °C in the process.

Wastewater

The power plant will generate wastewater both as a result of using potable water and through the operation of the plant. Sanitary wastewater will include water from sanitary facilities and shower rooms, for example. The plan is to transfer the sanitary wastewater to the municipal wastewater treatment plant. Wastewater generated during the operation of the plant will include various types of washing water, wastewater resulting from the production of the circulating water, and wastewater from operation. These will be properly treated and either taken to the municipal wastewater treatment plant or discharged into the sea.

Present state of the environment

Location and land use planning

The project site is located in Northern Ostrobothnia on the western coast of Finland on the Hanhikivi headland in the municipalities of Pyhäjoki and Raahe (Figure 5). The Hanhikivi regional land use plan for nuclear power, partial master plans for the nuclear power plant site in the areas of Pyhäjoki and Raahe, and local detailed plans for the nuclear power plant site in Pyhäjoki and Raahe have been ratified for the Hanhikivi headland area.

The immediate surroundings of the Hanhikivi headland site are sparsely populated and no industrial activity is practiced in the immediate surroundings of the headland.

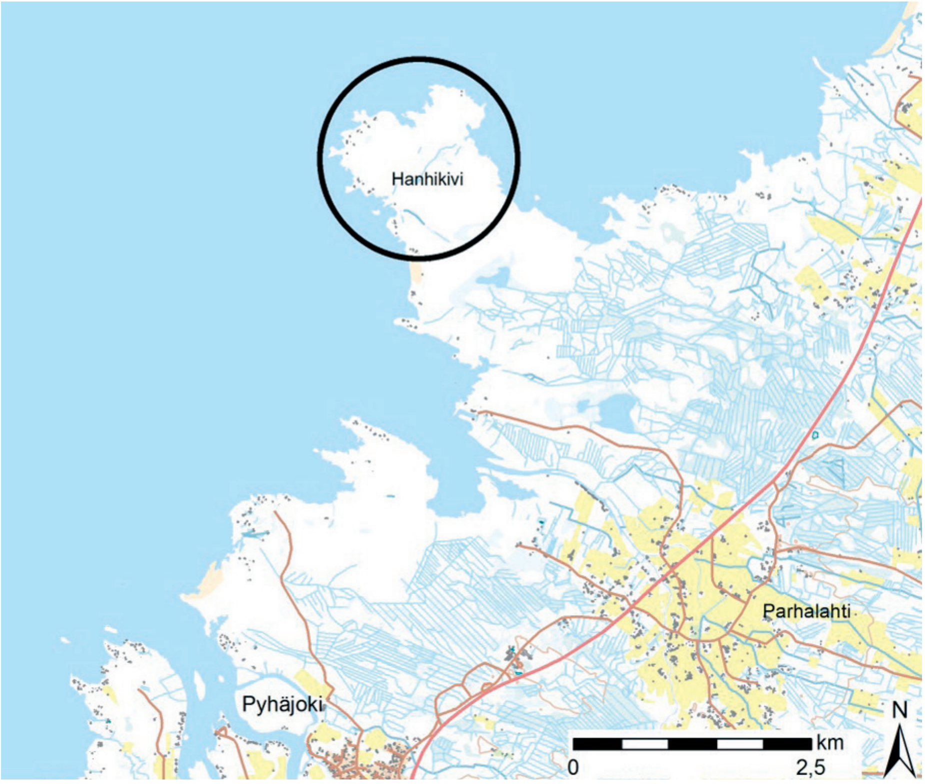


Figure 5. Location of the power plant site in the area of the Hanhikivi headland.

The center of Pyhäjoki is located a little over five kilometers south of the headland. The center of Raahe is located approximately 20 km from the headland. The village of Parhalahti located a little over five kilometers from the nuclear power plant will be included in the plant's five-kilometer protective zone. Approximately 440 permanent residents live within the protective zone. There are 11,600 permanent inhabitants within a twenty-kilometer radius of the site. There are approximately twenty holiday homes on the Hanhikivi headland and a couple of hundred holiday homes with the twenty-kilometer zone.

Main road 8 (E8) is approximately six kilometers from the nuclear power plant site. The closest railway station and port are in Raahe. The closest airport is in Oulu, approximately 100 km from Pyhäjoki.

Natural conditions

The Hanhikivi headland area is low-lying land-uplifting coast, the typical features of which include seaside meadows and paludifing shallow bays. The most prevalent habitat type on the Hanhikivi headland is the forests of land uplift coast. The area is a significant natural forest succession site, but there are no mature forests in the area.

The Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area is located approximately two kilometers to the south of the project site. The Natura 2000 area is also an avifauna area of national significance, and it is included in the Finnish Waterfowl Habitats Conservation Program. There are a Finnish Important Bird Area (FINIBA), several nature conservation areas, and other important objects in the immediate surroundings of the Hanhikivi headland. Five endangered or otherwise protected vascular plant species and the moor frog, a species included in the species listed in Annex IV (a) to the Habitats Directive, have been found in the area.

The most significant bird flocking areas are Takaranta to the east of the project area and Parhalahti. A large number of bird species have been found in the areas due to the varied habitats. Most of the areas important in terms of avifauna are located in the coastal area of the Hanhikivi headland that includes water areas, coastline, and representative forest compartments. The proportion of deciduous forests in the area is large. This is why specific species have been observed in the area in large quantities.

The loose soil in the Hanhikivi headland is mainly moraine. The bedrock is mainly metaconglomerate. The Hanhikivi headland area has been classified as a valuable area in terms of nature and landscape, and it is also a valuable bedrock area. There is a boundary mark originating from historical times, Hanhikivi, on the headland.

The nearest classified groundwater area is located approximately ten kilometers from the Hanhikivi headland.

Water systems

The coastline around the Hanhikivi headland is very open, and water changes efficiently in the area. The depth of the water around the Hanhikivi headland increases very slowly, initially at a rate of one meter per 100 m distance. The water quality at the Hanhikivi headland depends on the general state of the Bay of Bothnia and water coming from the Pyhäjoki river running along the coast. Pyhäjoki river empties approximately six kilometers from the plant site on the south side of the Hanhikivi headland. The quality of the seawater in front of the headland corresponds to the water quality typically found along the coast of the Bay of Bothnia. According to the ecological classification of the Finnish environmental administration, the water quality of the sea in front of the Hanhikivi headland is moderate or good, and excellent farther away from the shore (more than two kilometers away). The state of the coastal waters is affected by eutrophication caused by nutrients carried by rivers, as well as the population centers and industries found in the coastal regions. There are several small gloe lakes and one flada on the Hanhikivi headland.

The shores of the Hanhikivi headland are gently sloping and open to the waves. The most sheltered and diverse areas are the shallow bays on the eastern side of the headland. There are not many species of aquatic vegetation. Charophyte meadows, which have been found all along the coastline, are one of the most representative underwater habitat types.

The sea in front of the Hanhikivi headland is significant both in terms of the fish stock and in terms of fishery. The fish species typically found in the area are those typically found in the whole of the Bay of Bothnia. Species of economic significance include the sea-spawning whitefish (*Coregonus l. widegreni*), common whitefish, perch, herring, vendace, sea trout, salmon, and pike. Spawning river lampreys can also be caught in the rivers emptying into the area. Furthermore, endangered graylings have been found in the area. The surroundings of the Hanhikivi headland are an important spawning area for whitefish, herring, and vendace. There are some whitefish and salmon migration routes close to the project area, but they also migrate further out to sea.

Assessed environmental impacts

Premise of the assessment

In compliance with the EIA Act, the assessment has covered the environmental impacts of the approximately 1,200 MW nuclear power plant on:

- Human health, living conditions, and wellbeing
- Soil, water systems, air, climate, vegetation, organisms and biodiversity
- Infrastructure, buildings, landscape, cityscape, and cultural heritage
- Utilization of natural resources
- Mutual interdependencies of these factors.

The assessment particularly focused the impacts that deviate from the impacts assessed in the EIA of 2008 or those not covered by the 2008 EIA. Environmental impacts considered significant or felt significant by the stakeholders have also been taken into account.

The impact assessment has utilized the studies and surveys executed for the EIA of 2008, as well as environmental studies and impact assessments of the project completed after said EIA. The studies and surveys prepared earlier have been updated when necessary to correspond to the current situation and the 1,200 MW nuclear power plant currently being assessed. The following additional studies and surveys were implemented for the environmental impact assessment described in this EIA report:

- Resident survey and small group interviews
- Modeling of the spread of radioactive releases in the case of a severe accident
- Noise emission modeling
- Cooling water modeling.

Furthermore, calculations included in the 2008 EIA, such as traffic volume calculations, calculations of the impacts on regional economy, and emissions from the zero-option, were updated.

Land use and the built environment

The land use plans for the nuclear power plant site are legally in force and indicate the areas required by the nuclear power plant. The land use plans enable construction of the planned nuclear power plant on the Hanhikivi headland, and implementation of the project will not require any changes to the current land use plans.

The main buildings and operations of the power plant will be located in the middle and northern parts of the Hanhikivi headland, in an area marked as an energy management block area in the local detailed plan for the nuclear power plant by the municipality of Pyhäjoki. The total block area is 134.6 hectares. The local detailed plans of the municipalities of Pyhäjoki and Raahe for the nuclear power plant site also include areas allocated for buildings required for nuclear power plant support operations.

The construction of the nuclear power plant will change the land use at the actual plant site and in its surroundings. The holiday residences on the western shore will be removed, and it will no longer be possible to use the western shore for recreational purposes. The new road connection planned for the nuclear power plant will not cause any significant changes in the land use of the area. Figure 6 is a modified aerial image indicating what the nuclear power plant would look like on the Hanhikivi headland.

The construction of the power plant will have an impact on the municipalities' infrastructure. It will restrict land use in the plant's protective zone but enable new construction in settlements and villages as well as along roads. Densely populated areas, hospitals, or institutions in which a large number of people will visit or reside, or significant industrial activities which could be affected by an accident at the nuclear power plant, cannot be placed inside the protective zone. Plans for holiday homes or recreational activities in the area must ensure that the preconditions for appropriate rescue activities will not be placed at risk.

The project will increase the significance of Raahe as a strong industrial region, which may improve the preconditions needed for the development of land use.

Landscape and cultural environment

In addition to the actual construction site, landscape impacts during construction work will be caused by heavy traffic required by the transport of large building parts and its requirements, new road connections and the improvement of current roads. High cranes will be visible in the landscape from far away.

The power plant will be placed in a visible area at the tip of a headland reaching out into the open sea. The headland is currently a location that is in its natural state in the landscape. The surroundings of the plant will be clearly different from the environment in terms of size and character, and the plant will clearly change the landscape. The landscape status of Takaranta, a seashore meadow of regional importance, will change.

The status of the nationally valuable Hanhikivi monument of antiquity as part of the landscape and the character of its immediate surroundings will significantly change. The monument will remain accessible.

Soil, bedrock, and groundwater

Normal operation of the nuclear power plant will not have any significant impacts on the soil or bedrock. The risk of soil contamination will be eliminated by proper technical means, such as drainage arrangements for overflow water and wastewater.

Excavation of the bedrock will reduce the geological value of the Hanhikivi headland. As indicated by the land use plans, representative parts of the bedrock will be left visible.

Groundwater level and pressure may decrease during construction and also during operation due to the drying measures of the structures. The project may influence the quality of groundwater, mainly during construction, due to the use of explosives and injecting of the bedrock. The impact on groundwater will remain fairly local and minor when the proper mitigation and prevention means are used.

Flora, fauna, and conservation areas

Some of the forests and seashores on the Hanhikivi headland will be changed into constructed environment, which means that species in those areas will disappear or change. The construction activities will not involve any nature conservation areas or seashore meadows protected by the Nature Conservation Act; nor will the construction activities have any direct impacts on them. Hanhikivi headland is an area of regional significance due to its representative as natural forest succession series of the land uplift coast. The construction activities will cause partial fragmentation of this habitat type, which has been classified as highly endangered.

Figure 6. A modified aerial image of the nuclear power plant on the Hanhikivi headland.

No endangered plants grow in the areas where construction will take place, nor have any Siberian flying squirrels or bat nesting or resting places been found there. Two exemptions from the protection measures have been granted to Fennovoima, one concerning the removal of a small breeding place of the moor frogs and one concerning the transfer of moor frogs from the area to a breeding place suitable for the species. The noise during construction may temporarily disturb the birds close to the power plant construction site and the road.

The discharging of warm cooling water into the sea during the operation of the plant may indirectly contribute to the paludification of the seashore meadows and make habitats less favorable to the protected Siberian primrose.

Construction or operation of the nuclear power plant is not expected to cause any significant adverse impacts on the protected habitats or species or the integrity of the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area. The area influenced by noise during construction and operation will be less than one kilometer from the power plant site, which means that the noise will not disturb, even temporarily, the avifauna in the Natura 2000 area. The dredging work will cause some turbidity but not – according to the assessment – in the Natura 2000 area. The turbidity of the seawater off the coast of the Hanhikivi headland also naturally increases during storms or periods of heavy rainfall. The cooling water impacts will not extend to the Natura 2000 area.

Water systems and fishery

Impacts of construction

Dredging during the construction of the navigation channel, the harbor area, the auxiliary cooling water inlet channel, and the cooling water discharge area, as well as the construction of protective piers, will cause temporary turbidity of the seawater. The seabed in the area to be dredged mainly consists of quickly settling rough-grained materials, such as sand and gravel. When such rough-grained materials are dredged, the turbidity will spread to approximately 10–100 meters from the dredging or deposit site, while the dredging of more fine-grained materials may cause turbidity of the water in an area extending up to five kilometers from the site. The dredging is not expected to cause any releases of nutrients or contaminants into the sea. There are Charophyte meadows in the cooling water discharge area. These meadows will be lost. The area that will be changed by the construction is small, however. According to the observations made, Charophyte meadows are fairly common in the sheltered bays which can be found along the north and south coastline of the Hanhikivi headland.

Fishing in the construction areas and in their immediate vicinity will not be possible during the hydraulic construction works. The construction activities in the sea area may also drive away fish from a larger area and temporarily influence the migration routes of fish. Excavation, in particular, will cause powerful underwater noise that may drive away fish from an extensive area. The impact will most likely be significant in an area extending at least one kilometer from each blasting place. The construction activities in the sea will destroy some whitefish (*Coregonus l. widegreni*) and herring spawning areas in the dredging areas. The fishing activities in the area mainly focus on whitefish. Whitefish come to the area to feed on herring spawn. Thus, the project may have adverse impacts on the fishing of whitefish in the project site's immediate vicinity.

Impact of cooling water and wastewater

The impacts on water systems include the impacts caused by warm cooling water, purified process and washing waters, and water intake. The purified process water, washing water, and sanitary wastewater will only cause minor nutrient loads when compared to, for instance, the loads entering the sea area through the local rivers. Since the water will also be mixed with the cooling water and the cooling water will be discharged into the open sea area, the eutrophication caused by the waters will be marginal.

The fact that the cooling water used at the power plant will be discharged into the sea will increase the temperature of the seawater close to the discharge place. The power plant's impact on the temperature of the sea has been studied with the help of a three-dimensional flow model.

The temperature of the seawater will increase by more than 5 °C in an area of approximately 0.7 km^2 in the immediate vicinity of the cooling water discharge place, and the temperature of the seawater will increase by 1 °C in an area of approximately 15 km^2. The thermal impacts will be at the highest in the surface water (0–1 meters below the surface) and decrease at greater depths (Figure 7). According to the modeling results, the temperature increase will cease at a depth of more than four meters.

In the winter, the thermal load from the cooling water will keep the discharge area unfrozen and cause the ice to be thinner, mainly to the north and east of Hanhikivi. The scope of the open water area and the area where the ice is thinner will largely depend on the temperature during the early winter. According to the modeling results, the annual differences in the thickness of the ice will even out further into the winter months, as the ice becomes thicker overall, in such a manner that the open water area will be 2.4–2.5 km^2 by February–March. At this time of the year, the open water area will extend approximately 2-5 kilometers from the discharge place and the area with thinner ice approximately 0.5–2 km further than the open water area.

The project is not expected to have any adverse impacts on the zooplankton population: no significant changes in the zooplankton populations of cooling water discharge areas have been observed in Finnish or foreign studies. The project is expected to increase the total primary production of aquatic vegetation and change the composition of species by increasing the growth of filamentous algae in the warming area, for instance. These impacts are expected to extend to roughly the area where the average temperature increase will be at least one degree Celsius. Since no significant changes to the primary production are expected, the amount of organic matter accumulated on the seabed is expected to remain low, which means that no significant impact on the benthic fauna will occur. The cooling water discharges are not expected to cause anoxia in deep water or significantly increased blooming of cyanobacteria.

Possible adverse impacts on fishing include the build-up of slime in nets and, in the summertime, hindering of whitefish fishing, especially in the fishing grounds north of Hanhikivi. The area that remains unfrozen in the winter will hinder ice fishing but, on the other hand, it will extend the open water fishing season and attract whitefish and trout to the area in the wintertime. The cooling water and the resulting impacts are not expected to influence the ability to use fish as human food.

Radioactive emissions into the sea

Radioactive emissions into the sea will include tritium and other gamma and beta emissions. The emissions will be so low that they will not have any adverse impacts on people or the environment.

The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Furthermore, Fennovoima will determine its own emission targets for the nuclear power plant. These targets will be stricter than the set emission limits. Radioactive liquids will be led to the liquid waste treatment plant where they will be processed so that their activity level will fall well below the emission limits.

The strict emission limits and supervision of the emissions from the nuclear power plant keep the emissions very low. The impact of radiation on the environment will be extremely minor when compared to the impact of radioactive substances existing normally in nature.

Emissions into the air

Radioactive emissions

The radioactive gases generated during the operation of the nuclear power plant will be processed using the best available technology to minimize the emissions. Gaseous radioactive substances will be collected, filtered, and delayed to decrease the amount of radioactivity. Gases containing small amounts of radioactive substances will be released into the air in a controlled manner through the vent stack and the emissions will be measured to verify that they remain below the set limits. The remaining released radioactive substances will be effectively diluted in the air.

The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Furthermore, Fennovoima will determine its own emission targets for the nuclear power plant. These targets will be stricter than the set emission limits. The strict emission limits and continual monitoring will keep the emissions of the nuclear power plant very low. The radiation impact on the environment will be insignificant when compared to the impact of radioactive substances existing normally in nature.

According to the preliminary data, the radioactive emissions into the air will be higher than those of the currently operating Finnish nuclear power plants. The emissions will, however, still remain well below the emission limits set for the currently operating Finnish nuclear power plants. The radiation exposure caused by the emissions will remain low, since with these emission values the radiation dose will remain clearly below the limit value of 0.1 millisieverts per year laid down in the Government Decree (717/2013). For reference, the average annual radiation dose of a person living in Finland is 3.7 millisieverts.

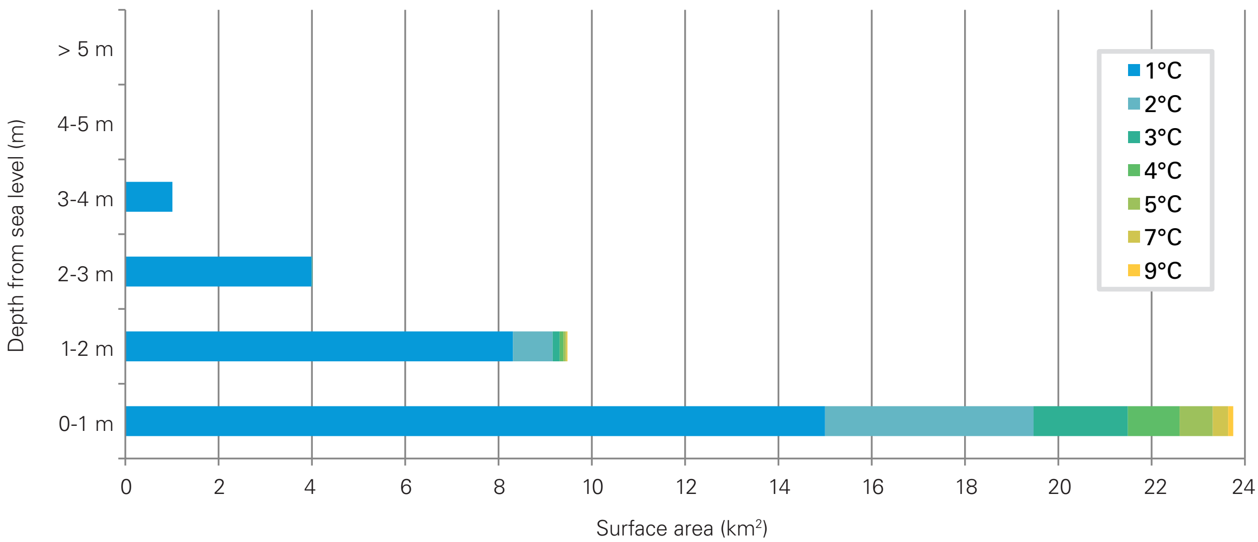


Figure 7. Areas where the temperature increase will exceed 1, 2, 3, 4, 5, 7, and 9 degrees Celsius at the average temperature in June.

Other emissions into the air

Excavation work, construction site traffic, and specific functions, such as rock crushing, will generate dust during the construction of the nuclear power plant. The dust will influence the air quality mainly at the construction site. The traffic emissions will increase significantly during the construction phase, particularly during the period of the heaviest construction activities. Since the air quality in the area is currently good and the period of heavy traffic will be limited in duration, the traffic emissions during construction will not have any significant impacts on the air quality in the area.

During operation of the nuclear power plant, emissions will be generated by the emergency power system and commute traffic. These emissions are not estimated to have any significant impacts on the air quality.

Waste and waste management

The handling and final disposal of the operating waste will not cause any significant environmental impacts when the facilities are properly designed and the waste management actions are properly implemented. Final disposal facilities will be monitored and the radioactive substances contained in the operating waste will become safe for the environment over time.

The handling and interim storage of the spent nuclear fuel will be safe and do not cause any significant environmental impacts due to the careful design and execution of the facilities. During interim storage for decades, the status of spent fuel will be regularly monitored. A separate EIA procedure shall be arranged on the final disposal and transportation of spent nuclear fuel.

The handling of conventional or hazardous waste at the nuclear power plant will not give rise to any environmental impacts. The sorted waste fractions will be processed outside the power plant site in appropriate manner.

Traffic and traffic safety

Traffic volumes will clearly increase during the construction period, particularly during the years when the construction activities are at the heaviest. Traffic volumes on main road 8 to the north of the Hanhikivi headland will increase by approximately 64 %. The increase will be slightly smaller on the south side, approximately 39 %.

The total traffic volume on main road 8 in the immediate vicinity of the intersection leading to the nuclear power plant will increase by approximately 15 %. The volume of heavy traffic will increase by approximately 6 %.

The new road to be built from the main road to the nuclear power plant will be designed to be suitable for power plant traffic. The intersection from the main road will include preselection lanes and the speed limits to ensure the safety and smooth flow of traffic.

Noise

According to noise emission modeling, the noise caused by the project will remain below the guideline values set for residential areas and areas including holiday residences, both during the construction and operation of the plant.

During the noisiest construction phase, i.e. when excavation and rock crushing work is underway, the average daytime noise level at the closest holiday residences will be approximately 40 dB(A). This value still remains clearly below the guideline value for holiday residences of 45 dB(A). The noise level in the closest nature conservation areas (the meadow in the northwestern corner of the Hanhikivi headland and the Siikalahti seashore meadow) may, according to the modeling results, be approximately 50–53 dB(A).

During the heaviest construction phase, the traffic noise of 55 dB(A) and 50 dB(A) from the road leading to the Hanhikivi headland will spread to fairly narrow zones, and there are no residences within the areas affected. The zone where the noise will be approximately 45 dB(A) will extend to a small part of the nature conservation area and an important bird area near the road connection.

The noise carrying from the nuclear power plant during its normal operation to the residential areas and areas including holiday residences will be fairly minor. The average noise level at the closest holiday residences will remain below 30 dB(A). The noise caused by the power plant traffic will also be minor, remaining clearly below the guideline values for residential areas.

People and society

According to the results of the resident survey and group interviews residents and other stakeholders have very different views on the nuclear power plant project and there are local groups both opposing and supporting the project. Opposition is often based on the perceived risks and fears associated with nuclear power plants, and the belief that nuclear power is ethically questionable. The supporters emphasize its positive economic impacts and environmental friendliness.

The municipality of Pyhäjoki will receive major property tax revenue during the construction phase. The revenue will vary in relation to the stage of completion of the nuclear power plant. The annual employment effect of the construction phase in the economic area will be approximately 480–900 man-years. The project will boost business in the economic area, and demand for private and public services will grow.

The property tax revenue to the municipality of Pyhäjoki during the operation phase has been evaluated to be approximately € 4.2 million per year. The annual employment effect in the economic area will be 340–425 man-years. The arrival of new residents, boosted business, and escalated building activity will increase tax revenue. The population base and housing stock will increase.

Normal operation of the nuclear power plant will not cause any radiation impacts on human health. Moving in the power plant site and using the site for recreational purposes will not be allowed, which means that it will no longer be possible to use the area for hunting, etc. Warm cooling water will melt or weaken the ice and, as a result, will restrict recreational activities on ice during the winter, such as fishing or walking. On the other hand, it will extend the open water fishing season.

Impacts of abnormal and accident situations

Nuclear accident

The impacts of a nuclear power plant accident have been assessed based on a severe reactor accident. The spread of any radioactive release caused by a severe accident, the consequent fallout, and the radiation dose received by the general public have been modeled in compliance with the requirements laid down in Government Decree (717/2013) and the YVL Guides of the Radiation and Nuclear Safety Authority. The modeling results are indicative only, and they are based on assumptions in which the radiation doses have been overestimated. More detailed studies of nuclear safety and accident situations, and their consequences required by the nuclear energy regulations will be executed as the project proceeds.

The assumed release in this survey was the severe accident limit value laid down in the Government Decree (717/2013), a cesium-137 release of 100 TBq, which corresponds to an INES 6 accident.

The modeled severe reactor accident would not cause any direct or immediate health impacts on people in the immediate vicinity of the facility. The radiation doses during the first two days after the accident would be a maximum of 23 mSv if no civil protection actions were implemented. The dose is clearly below the limit for showing changes in the blood count, which is 500 mSv. The radiation dose caused by the release during the entire lifetime of a person living five kilometers from the plant would be approximately 150 mSv for a child (over the course of 70 years) and approximately 76 mSv for an adult (over the course of 50 years). Theses doses are lower than the dose received by the average Finn during their entire lifetime from natural sources.

In the case of the modeled severe accident, all the people living less than two kilometers from the plant would have to be evacuated. People living up to three kilometers from the plant would have to take shelter indoors. Children living up to five kilometers from the plant should take an iodine tablet. There would be no need for adults to take an iodine tablet, however.

Short-term restrictions on the use of agricultural and natural products could be necessary. The use of mushrooms as food might have to be restricted in an area extending to around 50 km from the plant in the direction the emissions have spread. The use of freshwater fish as food might have to be restricted in an area extending to around 300 km from the plant. The use of reindeer meat might have to be restricted in an area extending up to 1,000 km from the plant in the direction the emissions have spread.

Other abnormal and accident situations

Other potential abnormal and accident situations mainly include chemical and oil leaks that may contaminate the soil or groundwater. Furthermore, situations posing a radiation danger may occur due to fire or human error, for example. Such situations will be prevented by means of technical measures and by training personnel.

Decommissioning of the power plant

The impacts of decommissioning will remain minor, provided that the radiation protection of the people participating in the decommissioning is properly arranged. Waste generated during the demolition phase will be similar to the waste generated during the plant's operation, and it can be treated in the same way as operating waste. Most of the waste generated during the decommissioning of the nuclear power plant will not be radioactive.

A separate EIA procedure will be executed to assess the environmental impacts of the decommissioning phase of the nuclear power plant.

Nuclear fuel production chain

There will be no impacts from the nuclear fuel production chain in Finland. The impacts will be assessed and regulated in each country producing nuclear fuel according to national regulations.

The environmental impacts of uranium mining operations are connected with the radiation of the uranium ore, the radiation impacts of the radon gas released from the ore, and wastewater. Any environmental impacts caused by the conversion, enrichment, and production of fuel assemblies are related to the handling of dangerous chemicals and, to a lesser extent, the handling of radioactive substances. The environmental impacts of the different stages of the production chain, beginning with mines, will be governed by legislation as well as international standards and audits by independent parties.

Intermediate products transported in the nuclear fuel production chain are, at the most, slightly radioactive. The transport of radioactive substances will be carried out in compliance with national and international regulations on the transport and storage of radioactive substances.

Energy markets

The Fennovoima nuclear power plant will improve the maintenance reliability of electricity supply by reducing Finland's dependence on fossil fuels and imported electricity as well as maintaining the Finnish electricity production capacity. The fact that Fennovoima's nuclear power plant will be built in a new location will also improve the maintenance reliability concerning potential failures in power transmission.

The new nuclear power plant will make Finland more self-sufficient in terms of electricity production.

Zero-option

The assessed zero-option is that Fennovoima's nuclear power plant project will not be implemented. In this case, the impacts of the project described in this environmental impact assessment report will not be realized.

If the new nuclear power plant unit is not constructed in Finland, the same amount of electricity must be produced by other means. The assumption is that, in such a case, 20% of the nuclear power plant's electricity production capacity of 9.5 TWh would be replaced with separate electricity production in Finland. The remaining 80 % would be produced abroad. The replacement electricity would most likely be produced in coal-fired power plants. The production to replace the Fennovoima nuclear power plant in Finland and abroad would cause a little less than seven million tonnes of carbon dioxide emissions, a little less than six thousand tonnes of both sulfur dioxide and nitrogen oxide emissions, and a little less than a thousand tonnes of particle emissions per year. The impacts of the sulfur dioxide, nitrogen oxide, and particle emissions would be mainly local, while the impact of the carbon dioxide emissions would be global.

Cumulative impacts with other known projects

The nuclear power plant and wind farm projects currently active in the region will create an energy production area of national significance. The area that is currently in its natural state or used for agricultural production will become a large-scale energy production zone.

The project may have a cumulative impact with the planned Parhalahti wind farm project in terms of recreational activities, as both the nuclear power plant and the wind farm project will limit land use opportunities and make hunting in the area more difficult.

Dredging to be implemented in connection with the sea wind farm project and a project of soil extracting from the sea could have a cumulative impact on the fish stock and thus fishing as the result of increased turbidity of the water if the dredging and extracting operations are simultaneously implemented.

The environmental impacts of the construction and operation of the grid connection will be assessed in a separate EIA procedure.

Transboundary environmental impacts

The normal operation of the nuclear power plant does not cause any transboundary environmental impacts.

In order to assess the impacts of a nuclear power plant accident, the EIA procedure has included dispersion modeling of a radioactive release caused by a severe reactor accident as well as the consequent fallout and radiation dose to population. The studied release was the cesium-137 release of 100 TBq laid down in the Government Decree (717/2013), which corresponds to a severe reactor accident (INES 6). The impacts of a release five times higher than that were also assessed. The release that is five times higher corresponds to an INES 7 accident.

Impacts of the modeled severe nuclear accident

The modeled severe reactor accident would not cause any immediate health impacts on the population in the surrounding areas under any weather conditions. Civil protection measures would not be necessary outside Finland. The radiation dose caused by the accident would remain outside Finland statistically insignificant.

The Hanhikivi nuclear power plant site is located approximately 150 km from the coast of Sweden. If the wind were to blow to the west and the weather conditions were unfavorable, a child living on the coast of Sweden would receive a lifetime dose of a maximum of 8 mSv, and an adult a lifetime dose of 4 mSv at most. At the Norwegian border approximately 450 km from the power plant site, the release would cause a dose of a maximum of 4 mSv for children and 2 mSv for adults. On the coast of Estonia approximately 550 km from the power plant site, the maximum lifetime dose for children would be 3 mSv and 2 mSv for adults. The dose on the coast of Poland approximately 1,100 km from the power plant site would remain below 1 mSv for adults and below 2 mSv for children. The plant site is approximately 1,850 km from the Austrian border in Central Europe. Even if the weather conditions were unfavorable, the release would cause a lifetime dose of 1 mSv at most for a resident of Austria. In comparison, a resident of Austria may during their lifetime receive a dose of more than 200 mSv from natural background radiation.

A severe accident may increase the radioactivity of reindeer meat or freshwater fish species to a level that requires temporary restrictions on their use as food. The use of freshwater fish may have to be restricted in the coastal areas of northern Sweden. The restrictions on freshwater fish can be limited to specific rivers and lakes in the worst fallout zone. The use of reindeer meat may have to be restricted in Sweden, Norway, and the northwestern part of Russia. However, the radioactivity of reindeer meat can be reduced by preventing reindeer from eating lichen, because cesium accumulates in lichen. This could mean that reindeer would have to be transferred from the worst fallout zone. The reindeer could also be kept in enclosures feeding on clean food until the radioactivity in the fallout zone has decreased to an acceptable level. If these restrictions were followed, the radioactivity in reindeer meat or freshwater fish would not pose any danger to people.

Assessment of the impacts of an INES 7 accident

If the release were the release that is five times higher than the 100 TBq release discussed above (more than 50,000 TBq of iodine-131 equivalents), the accident would be classified as an INES 7 accident. Such a high release is theoretically impossible in terms of noble gases, because the release would mean that five times more noble gases than the reactor contains would be released.

Such a fivefold release would not cause any immediate health impacts. If the wind were to blow to the west and the weather conditions were otherwise unfavorable, the lifetime dose of a child on the coast of Sweden would be approximately 37 mSv and the lifetime dose of an adult approximately 18 mSv. Under similar unfavorable conditions, the radiation dose at the Norwegian border could be a maximum of 14 mSv for children and 7 mSv for adults. The radiation doses in the other countries bordering the Baltic Sea would remain below 12 mSv for children and 6 mSv for adults even if the weather conditions were unfavorable. The lifetime radiation dose in Austria would not exceed 5 mSv for children and 2 mSv for adults.

Such a fivefold release would give rise to restrictions on the use of food products outside of Finland. The use of reindeer meat would have to be restricted in the fells of Sweden, Norway, and northwestern Russia, depending on the direction the release has spread. Also depending on the direction the release has spread, restrictions on the use of freshwater fish could be necessary in Sweden, Norway, northwestern Russia, and the Baltic states. If grazing of cattle were not limited, restrictions on the use of meat could be necessary in the coastal areas in northern Sweden.

Comparison of the alternatives

The differences between the impacts caused by the currently assessed plant of approximately 1,200 MW and the impacts caused by the 1,800 MW plant assessed in 2008 are mainly due to updates made in the project's technical design, new data on the present status of the environment, and stricter safety regulations. According to the assessment, the plant size or the specified plant type will not change the environmental impacts in any significant way.

The environmental impacts caused by the 1,200 MW plant are different from the impacts caused by the previously assessed 1,800 MW plant mainly in the following respects:

- The impacts on water systems and fishery will be slightly reduced because, according to the new cooling water modeling results, the cooling water would warm up the seawater in a somewhat smaller area.
- The impacts on flora, fauna, and conservation areas will be slightly reduced due to the lower cooling water load.
- According to the preliminary data for the nuclear power plant type AES-2006, the radioactive emissions into the air will be higher than those from the 1,800 MW plant assessed in the EIA of 2008. The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below the values given in the preliminary data and reach the level of EIA of 2008 and the emission limits of the currently operating Finnish nuclear power plants at the most.
- The relative increase in traffic volumes is slightly lower than in the previous assessment due to the fact that the current traffic volume has increased and the growth forecasts have been changed. The traffic volumes are still the same for both plant alternatives, however.
- The spread of noise emission during operation of the plant is slightly different from the results of the previous noise modeling due to the changed plant layout. The sources of noise, the magnitude of noise, and the volume of traffic are similar for both plant sizes.
- The volumes of operating waste and spent nuclear fuel will be lower, which means that the impacts will be less.

If the zero-option was chosen, i.e. the project was not implemented, neither the negative nor the positive impacts would be realized. The Hanhikivi headland would remain in its current state. The positive financial impacts (such as improved employment rate and tax revenue) would not occur. Substitutive electricity production would cause environmental impacts, such as emissions into the air.

Prevention and mitigation of adverse environmental impacts

An environmental management system will be used to link the nuclear power plant's environmental issues to all of the power plant's functions, and the environmental protection will be continuously improved.

Fears and perceived threats caused by nuclear power can be mitigated by arranging proper communication so that the local residents will have enough information about how the nuclear power plant works and how its safety is ensured. Active communication with all stakeholders can be used to enhance the communication between the organization responsible for the project and the local residents. Furthermore, public events and information events can be arranged locally.

Adverse impacts on people or the environment during construction will be mitigated and prevented by, for instance, performing especially noisy activities at the suitable locations, constructing noise barriers, and guiding and scheduling traffic. The increased turbidity of the seawater due to construction activities in the sea area can be controlled or limited with the data provided by continuously operating measuring buoys on the prevailing flows. Access to the seashore areas at the plant site and other construction site areas including protected species or habitats will be prevented with fences and proper markings.

Social impacts caused by the construction can be mitigated by decentralizing the accommodation facilities of the employees into the neighboring municipalities and arranging a variety of training for foreign and local employees.

The nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. The best available technology will be used to minimize emissions when handling radioactive gases and liquids during operation, and the emissions will always be kept as low as reasonably achievable. Radioactive emissions will be continuously monitored by means of measuring and sampling.

Fish can be prevented from being drifted into the cooling water intake system through a variety of technical methods and with the technical design of the cooling water intake systems.

The general disadvantages caused by the local warming of the seawater to fish and fishery can be compensated by implementing a fishery subsidy. The disadvantages caused to professional fishermen can be compensated on a case-by-case basis. Paludification of the seashore meadows can be prevented by grazing or clearing common reeds and bushes.

Potential accidents involving the use of chemicals and the processing of radioactive waste will be prevented with technical measures and by providing training to the employees. The power plant facilities will contain systems for the safe handling and transportation of waste and the monitoring of the amount and type of radioactive substances. The spent nuclear fuel will be handled safely at all stages of the waste management process.

The plant will be designed in such a manner that the probability of a severe accident is minimal. The risk of radioactive releases will be minimized by applying the defense-in-depth safety principle. The risk of accidents and abnormal situations will be minimized by applying strict quality and safety requirements, and by applying the continuous improvement principle. The impacts of a release caused by an accident can be clearly mitigated by means of civil protection measures. Protection measures influencing the food industry and restrictions on the use of food products can clearly reduce the radiation dose due to food ingestion.

Project feasibility

The project is feasible in terms of the environmental impacts. No such adverse environmental impacts that could not be accepted or mitigated to an acceptable level were identified during the environmental impact assessment.

Furthermore, the project will have positive environmental impacts, such as the impact on the local economy and the fact that the project will increase the local carbon dioxide -free energy production capacity.

Monitoring of environmental impacts

The impacts caused by the nuclear power plant's construction and operation on the environment will be monitored with monitoring programs approved by the authorities. The programs will include the monitoring of emissions and the environment as well as detailed reporting procedures.

Radioactive emissions will be monitored by means of process and emission measurements inside the plant and by monitoring radioactive substances and radiation present in the environment. Radioactive emissions into the water and air will be monitored with reliable radiation monitoring systems. The plant's radiation monitoring program will include measuring external radiation with dosimeters and continuously operating meters as well as analyzing the radioactivity of the outdoor air and representative samples of different stages of food chains. This will ensure that the emissions into the air and water will not exceed the plant-specific emission limits ratified by the Radiation and Nuclear Safety Authority and that the radiation exposure caused by the emissions will remain as low as reasonably achievable.

Conventional emissions will be monitored in compliance with the obligations laid down in the water and environmental permits. The monitoring of emissions will include the following, for instance:

- Monitoring water systems
- Monitoring fishery
- Monitoring emissions into the air
- Monitoring noise emissions
- Monitoring flora and fauna
- Waste management record.

The data obtained during the environmental impact assessment and issues raised in the public display events, statements, group interviews, and resident survey will be utilized in the monitoring of the social impact. The working methods created during the EIA procedure can also be utilized when monitoring the social impacts of the project and when communicating with the stakeholders.

Permits and licenses required by the project

The EIA procedure does not involve any project-related decisions nor does it solve any issues pertaining to permits or licenses; instead, the objective is to produce information to serve as a basis for decision-making.

The Finnish Government has granted Fennovoima a Decision-in-Principle in compliance with the Nuclear Energy Act (990/1987). Since the project that is being assessed in this EIA was not mentioned as a plant alternative in the original application for a Decision-in-Principle, the Ministry of Employment and the Economy has required further surveys.

According to the Decision-in-Principle, Fennovoima must apply for the construction license in compliance with the Nuclear Energy Act by June 30, 2015. The construction license will be granted by the Finnish Government, provided that the requirements for granting the construction license for a nuclear power plant prescribed in the Nuclear Energy Act are met.

The operating license will also be granted by the Finnish Government, provided that the requirements of the Nuclear Energy Act are met and the Ministry of Employment and the Economy has stated that the provisions for nuclear waste management costs have been made as required by law.

In addition, the project will, at different phases, require permits in compliance with the Environmental Protection Act, the Water Act, and the Land Use and Building Act.

Glossary

Activity (Bq)

Activity states the number of nuclear disintegrations in a radioactive substance per one unit of time. The unit of activity is Becquerel (Bq) = one disintegration per second.

Bar

The unit of pressure (1 bar = 100 kPa). The atmospheric pressure is approximately 1 bar.

Base load plant

A large power plant generally used at full power to satisfy the continuous minimum demand for electrical energy.

Bq (Becquerel)

A unit of radioactivity meaning one radioactive disintegration per second. The radioactive content of food products is expressed as Becquerel per mass or volumetric unit (Bq/kg or Bq/l).

Cesium-137 (Cs-137)

Cesium-137 is a radioisotope of cesium, which is mainly formed by the splitting of the nucleus, i.e. fission reaction. Cesium-137 has a half-life of 30 years.

Civil protection measure

The key protective measures implemented to protect the local population in case of a serious nuclear accident include taking shelter indoors, ingestion of iodine tablets, and evacuation.

Contamination

Contamination means pollution. For instance, exposure of tools to radioactive radiation contaminates them, and without isolation, contamination may spread further from them.

Controlled area

At least those premises of the facility where the external radiation dose rate could exceed 3 µSv/h or where 40 weeks of weekly exposure could result in an internal radiation dose of more than 1 mSv per year must be included in the controlled area (YVL C.2).

Cooling water

Cold sea water is called cooling water, with which the steam coming from the turbines is cooled back into water in the condenser (condensate). The condensate is pumped back to the steam generators to be turned into steam. Cooling water does not come into contact or mix with the process waters of a nuclear power plant.

dB (Decibel)

Unit of the volume of sound. An increase of ten decibels in the noise level means that the sound energy increases tenfold. Ambient noise measurements typically employ A-weighting dB(A), which emphasizes the frequencies where the human ear is most sensitive.

Decision-in-Principle

The use of nuclear energy in the production of electricity requires a Decision-in-Principle made by the Finnish Government and confirmed by the Finnish Parliament. Requirements for the Decision-in-Principle include the nuclear power plant's total benefit for society and a positive attitude of the municipality in which the plant will be located towards the project as well as a positive preliminary safety assessment by the Radiation and Nuclear Safety Authority.

Decommissioning waste

Radioactive waste that is generated when decommissioning a nuclear power plant or another nuclear facility after operation.

Defense in depth

According to the defense in depth principle, the planning and use of nuclear power plants require several independent protection levels and methods in order to prevent accidents, to manage operating failures and accident situations, and reduce the consequences of accidents.

Efficiency (η)

The ratio between the electrical energy produced by a power plant and the reactor's thermal energy.

EIA

Environmental Impact Assessment. In addition to assessing the environmental impact, the objective of the statutory EIA procedure is to improve the availability of data for citizens and their possibilities for participating in project planning and expressing their opinions on the project.

EIA 2008

An environmental impact assessment procedure for a nuclear power plant implemented by Fennovoima Oy in 2007–2009. The EIA Report was submitted to the coordinating authority in 2008.

Electric power (W)

The power at which the plant produces electrical energy that is supplied to the power grid.

Final disposal

The permanent disposal of radioactive wastes so that the disposal site does not need to be controlled and the radioactivity does not cause any danger to nature.

Fission

Nuclear fission is the splitting of the heavy atom nucleus into two or more new nuclei, resulting in a release of a large quantity of energy, neutrons, and neutrinos.

Flada

A bay beginning to separate from the sea due to land-uplift; a habitat to be protected pursuant to the Water Act.

Gloe lake

A water area separated from the sea due to land-uplift; a habitat to be protected pursuant to the Water Act.

Half-life

Half-life is the time after which half of the atom nuclei of a radioactive substance have disintegrated into other atom nuclei.

Hazardous waste

Hazardous waste is any substance or object that has been decommissioned and may cause detrimental impacts on human health or the environment. Examples of hazardous waste include compact fluorescent lamps and other fluorescent tubes.

IAEA

The IAEA (International Atomic Energy Agency) is an organization under the UN that seeks to promote the peaceful use of nuclear energy. The IAEA also promotes radiation safety, nuclear safety, and nuclear disarmament.

Impact area

An area where the environmental impact is estimated to appear based on studies.

INES

INES (International Nuclear Event Scale) categorizes events and accidents related to nuclear safety into eight categories (from INES 0 to INES 7).

Iodine-131 (I-131)

Iodine-131 is a radioactive isotope of iodine that forms in small volumes in the fission reaction of uranium-235. Iodine-131 has a half-life of only around eight days.

Ion

An electrically charged atom or molecule. Radiation that creates ions when hitting a medium is called ionizing radiation.

Ion exchange mass

A substance used to remove ion-shaped impurities from water.

Ionizing radiation

Electromagnetic radiation or particle radiation that produces free electrons and ions when hitting a medium. Ionizing radiation can break chemical links within molecules, such as cut a DNA molecule that carries cell genotypes. As a result, ionizing radiation is hazardous to health.

Isotope

Isotopes are different forms of the same element that differ from each other in relation to the number of neutrons in the nucleus and the properties of the nucleus. Almost all elements exist as several isotopes in nature. For instance, hydrogen has three isotopes: hydrogen, deuterium, and tritium, of which tritium is radioactive.

Light water reactor

A reactor type in which regular water is used for cooling and as a moderator in the reactor core. The majority of the world's nuclear power plant reactors are light water reactors.

Low and intermediate level waste

Low and intermediate level waste refers to the operating and maintenance waste of a nuclear power plant. Such waste is also generated when a nuclear power plant is decommissioned. Low level waste can be handled without any radiation protection arrangements because its radioactivity is low (max. 1 MBq/kg). Efficient radiation protection arrangements are needed when handling intermediate level waste (activity 1–10,000 MBq/kg).

Mean sound level, equivalent sound level

A calculated sound level at which sound of varying intensity has been mathematically converted into steady sound.

Mixed oxide fuel

Mixed oxide, or MOX, fuel differs from ordinary uranium fuel of a nuclear power plant in that a part of its fissionable matter is plutonium-239 instead of uranium-235. Plutonium does not occur in significant amounts in nature, so it is obtained for MOX fuel by recycling spent nuclear fuel, or from nuclear disarmament.

MW

Megawatt, the unit of power (1 MW = 1,000 kW).

Natura 2000 area

A Natura 2000 area is a nature conservation area which protects the habitat types and species laid down in the EU Habitats Directive.

Nuclear fuel

A compound containing uranium or plutonium that is used in nuclear power plant reactors. The fuel is packed in such a manner that it can be formed into a reactor core which causes a chain reaction based on the splitting of nuclei.

Nuclear power plant

A nuclear power plant consists of at least one nuclear power plant unit with a reactor, one or two turbines, and generators in each unit.

Operating waste

A common name for low or intermediate level waste produced during the operation of a nuclear power plant.

Pressurized water reactor

A type of light water reactor where the pressure of the water used as the coolant and moderator is kept so high that it will not boil, even at high temperatures. The water that has passed through the reactor core releases its heat to the secondary circuit water in separate steam generators, where the secondary circuit water is vaporized and used to drive a turbine.

Radiation

Radiation is either electromagnetic wave motion or particle radiation.

Radioactivity

Radioactive substances disintegrate spontaneously into lighter elements or transmutations of the same element with smaller energy. The process releases ionizing radiation, which is either electromagnetic radiation or particle radiation.

Radionuclide

A radionuclide is an atom nucleus that emits radiation.

Sievert (Sv)

The unit of radiation dosage. The greater the radiation dosage, the more probable it is that it is hazardous to health. The units millisievert (mSv) or microsievert (µSv) are often used (1 µSv = 0.001 mSv = 0.000001 Sv).

Spent nuclear fuel

Nuclear fuel is called 'spent' when it has been used in energy production in the reactor and taken out of the reactor. Spent nuclear fuel contains uranium splitting products, such as cesium, and is highly radiating.

Strontium-90 (Sr-90)

Strontium generates heat as it splits, and it is used in space crafts and remote weather observation stations, for instance. Strontium is formed as a by-product of fission reaction. Strontium has a half-life of approximately 29 years.

STUK

The Radiation and Nuclear Safety Authority in Finland.

Subcriticality

A nuclear reactor state where the fuel is no longer able to maintain the fission reaction by itself.

Succession

The gradual natural changing of the population at a specific location. For example, the gradual change in the species of a land-uplift coast.

TEM

The Ministry of Employment and the Economy in Finland (the coordinating authority of the EIA procedure).

Thermal power (W)

The power the plant uses to produce thermal energy (thermal power).

TWh

A terawatt hour is a unit of energy (1 TWh = 1,000,000 MWh).

Uranium (U)

An element with the chemical symbol U. An average of 0.0004% of all the materials in the Earth's crust (four grams in a ton) is uranium. All isotopes of uranium are radioactive. The majority of natural uranium is isotope U-238, the half-life of which is 4.5 billion years. Around 0.71% of natural uranium is in the form of isotope U-235, which can be used as a nuclear fuel.

Very low level waste

Very low level waste is operating waste with such a low level of radioactivity that it can be handled without radiation protection. The activity content of such waste is no more than 100 kBq/kg.

VVER

A Russian series of pressurized water reactor designs.

YVL Guides

Regulatory guides on nuclear safety published by the Radiation and Nuclear Safety Authority. The guides describe detailed safety requirements for the use of nuclear energy.

1,200 MW nuclear power plant

In this EIA procedure, the term 'nuclear power plant of approximately 1,200 MW' refers to the nuclear power plant type under assessment. The electric power is around 1,100–1,300 MW.

1

Project

Fennovoima Ltd. (hereinafter "Fennovoima") is studying the construction of a nuclear power plant of approximately 1,200 megawatts at Hanhikivi headland in Pyhäjoki, Finland. The reactor of the nuclear power plant will be a pressurized water reactor. As part of the studies, Fennovoima implements an environmental impact assessment as laid down in the Act on Environmental Impact Assessment Procedure (468/1994; hereinafter "the EIA Act") to study the environmental impact of the nuclear power plant's construction and operation.

1.1 Background of the project

In 2008, Fennovoima implemented an environmental impact assessment (EIA) to assess the impact from the construction and operation of a nuclear power plant of approximately 1,500–2,500 megawatts that consists of one or two reactors at three alternative locations: Pyhäjoki, Ruotsinpyhtää, and Simo (*Pöyry Energy Oy 2008a, 2008b*). An international hearing procedure pursuant to the Espoo Convention was also performed in connection with the EIA procedure.

The coordinating authority, the Ministry of Employment and the Economy, stated in its statement on the environmental impact assessment dated February 20, 2009 (7131/815/2008) that the contents of the EIA report meet the requirements laid down in the EIA legislation and the statement issued by the coordinating authority regarding the EIA program had been taken into account in the report. Furthermore, the coordinating authority stated that the EIA report provides a sufficient description of the project's environmental impacts and the options for mitigating them. The coordinating authority required, however, that Fennovoima submit to the coordinating authority additional reports listed in the statement to be used when processing Fennovoima's application for a Decision-in-Principle. Fennovoima submitted the required additional information to the coordinating authority as two reports in April 2009 and October 2009 (*Fennovoima Oy 2009a, 2009b*).

Fennovoima received the Decision-in-Principle in compliance with section 11 of the Nuclear Energy Act (990/1987) on May 6, 2010. Parliament confirmed the Decision-in-Principle on July 1, 2010. According to the Decision-in-Principle, Hanhikivi in Pyhäjoki and Karsikko in Simo are suitable locations for a nuclear power plant. The Hanhikivi headland in Pyhäjoki was selected as the plant site in autumn 2011. After this decision, the studies and construction engineering work has focused on that location for which land use plans allowing the construction of a nuclear power plant have been obtained at all three levels of land use planning.

The nuclear power plant of approximately 1,200 megawatts with a company of the Russian Rosatom Group as its supplier, which is currently the object of the environmental impact assessment, was not mentioned in the original application for a Decision-in-Principle as one of the plant alternatives. Therefore, the Ministry of Employment and the Economy required that Fennovoima updates the project's environmental impact assessments with this EIA procedure.

1.2 Organization responsible for the project

The organization responsible for the project is Fennovoima, a Finnish nuclear power company established in 2007. Fennovoima's owner is Voimaosakeyhtiö SF, a company currently consisting of 46 industrial, commercial and energy companies (Figure 1-1). The owners of Voimao-

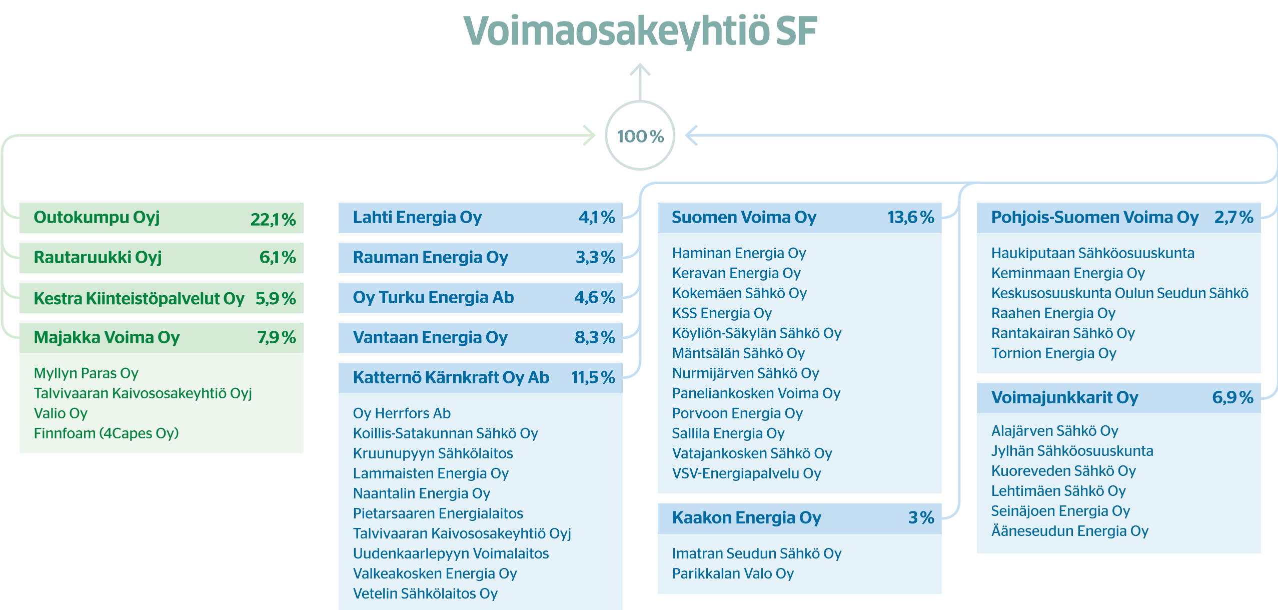


Figure 1-1. Fennovoima's ownership structure. The shares of ownership mentioned in the figure correspond to commitments to Voimaosakeyhtiö SF on November 8, 2013.

sakeyhtiö SF directly employ tens of thousands people in Finland. The shareholders, who represent a variety of sectors, wish to obtain electricity at a stable and foreseeable price. Negotiations regarding Rosatom company becoming Fennovoima's minority shareholder are currently ongoing. Agreements will be made to ensure that the majority of Fennovoima Ltd. remains in the ownership of Voimaosakeyhtiö SF.

Fennovoima is to produce electricity for the needs of its owners at cost price. Each owner will have access to power plant capacity corresponding to their share of ownership. In accordance with this cooperative-like operating model, making a profit is not Fennovoima's objective as a company; instead, profits will be distributed to the shareholders as electrical energy at a lower cost.

Many local Finnish energy companies are partners in the Fennovoima project. The operating areas of the energy companies involved in the project cover most of Finland. By owning a share of the nuclear power plant, these companies will be able to offer their customers – around a million households and local communities – electricity at a reasonable price. The majority of these partner companies are owned by municipalities, which are obliged to deliver electricity in their respective geographical areas of responsibility. The obligation requires the company to deliver electricity at a reasonable cost to all willing consumers in the energy company's area of responsibility.

The industrial and commercial companies taking part in the project represent different aspects of Finnish industry and commerce. The partners include both listed companies and family businesses with thousands of sites and premises around Finland total.

Rosatom is a corporate group owned by the Russian Federation that governs all Russian business sectors related to nuclear energy. Rosatom is one of the leading nuclear technology experts in the world. Its expertise covers R&D, design, construction and operation of nuclear power plants, manufacture of nuclear fuel, and waste management. The Rosatom Group consists of 250 subsidiaries and affiliates that employ a total of 260,000 people. As Fennovoima's plant supplier and minority shareholder, Rosatom's impressive nuclear technology competence would be at Fennovoima's disposal during the different stages of the project.

Fennovoima will compile a management system for the different stages of the project to ensure that nuclear safety and radiation protection always remain a priority. The management system will bring together the different parts of the organization into a balanced whole which ensures that Fennovoima meets all the set goals. The management system complies with all the requirements laid down in the Finnish legislation, different permit conditions, all requirements of the YVL Guides of the Radiation and Nuclear Safety Authority, and recommendations of the International Atomic Energy Agency (IAEA). The system will be compiled based on standards ISO 9001 (quality management), ISO 14001 (environmental management), and OHSAS 18001 (occupational health and safety).

The management system will be submitted to the Radiation and Nuclear Safety Authority for approval in connection with the processing of the Fennovoima construction license application.

Fennovoima will make sure that it has the appropriate organization and sufficient expertise in all stages of the project to proceed with the power plant project and ensure its safety. In addition to its own employees, Fennovoima will use a large number of external experts during the different project stages.

1.3 Purpose and justification for the project

Nuclear power is a cost-effective way to produce electricity. The price of electricity produced with nuclear power is stable and foreseeable. The companies involved in the Fennovoima project consume a large share of all the electricity consumed in Finland. The Fennovoima owners' competitive ability will improve with the better predictability of the costs from electric energy and the stable price of the electricity they produce themselves. This will assist the owners in doing business and making investments in Finland.

In 2012, around 20 % of the electricity used in Finland was imported from abroad. Increasing the country's own electricity production capacity will make Finland less dependent on electricity produced elsewhere and thus improve the national security of supply.

Ownership of electricity production is highly centralized in Finland. The Fennovoima project will introduce dozens of new owners into the Finnish electricity market. This will increase competition that will, in turn, benefit all parties involved.

Being a carbon dioxide-free electricity production method, nuclear power supports the achievement of the Finnish climate goals. Additional nuclear power construction has a key role in the achievement of the national emission reduction goals and the EU's long-term energy and climate goals, according to the national energy and climate strategy that was last updated in 2013 (*Työ- ja elinkeinoministeriö 2013c*).

The Fennovoima nuclear power plant will be constructed at a new location in Pyhäjoki in Northern Ostrobothnia. The project's impact on the regional economy will be significant. Construction of the nuclear power plant will make the business life of Northern Finland more vital and offer plenty of work opportunities for Finnish companies. The project will give rise to new, long-term industrial activity and stabilize the regional economy both at the construction stage and at the operating stage of the plant.

1.4 Assessed alternatives

1.4.1 Implementation alternative

The implementation alternative assessed consists of the environmental impact of the construction and operation of a nuclear power plant of approximately 1,200 MW. The plant will be constructed on Hanhikivi headland in Pyhäjoki. The plant will consist of one nuclear power plant unit of the pressurized water reactor type.

In addition to the power plant itself, the project will include intermediate storage of spent nuclear fuel produced by the new power plant on site as well as treatment, storage, and final disposal of low and intermediate level radioactive waste.

The following are also included in the project scope:

- Intake and discharge arrangements for cooling water
- Supply and handling systems for service water
- Waste water treatment systems
- Constructing roads, bridges, and banks
- Constructing a port, pier, and navigation channel for sea transport.

The EIA report also describes the nuclear fuel supply chain, the final disposal of spent nuclear fuel, and decommissioning of the nuclear power plant. A separate EIA procedure will be applied to the latter two at a later date. A separate EIA procedure will also be applied to the transmission line connection to the national grid.

1.4.2 Zero option

The zero option studied is not implementing Fennovoima's nuclear power plant project. The zero option would mean covering the electric energy corresponding to the nuclear power plant's capacity with separate electricity production based on fossil fuels, mostly in Finland and partly in the other Nordic countries and Continental Europe.

1.4.3 Previously assessed alternatives

The EIA implemented in 2008 studied four alternative locations for the nuclear power plant: Pyhäjoki (Hanhikivi), Ruotsinpyhtää (Kampuslandet and Gäddbergsö), and Simo (Karsikko). The studied power plant alternatives included a plant consisting of one nuclear power plant unit with electric output of 1,500–1,800 MW and a plant consisting of two nuclear power plant units with total electric output of 2,000–2,500 MW.

The EIA implemented in 2008 studied the construction stages and construction activities of the nuclear power plant, and their environmental impact. Studied impacts during the operation of the power plant included the impacts from cooling water and wastewater, waste management, transport and commuting, abnormal and accident situations, combined impacts with other known projects, and impacts crossing the boundaries of Finland. The report also described the nuclear fuel supply chain, the final disposal of spent nuclear fuel, and decommissioning of the nuclear power plant. Based on the results of the diverse studies, Fennovoima selected Hanhikivi in Pyhäjoki as the future location of the nuclear power plant in 2011.

Table 1-1 compares the key characteristics of the approximately 1,200 MW plant studied in this EIA report to those of the 1,800 MW plant studied in the EIA of 2008. The data of the plant of approximately 1,200 MW will be further specified as the design efforts proceed.

1.5 Location and land use requirements

The Fennovoima nuclear power plant will be constructed on Hanhikivi headland in Pyhäjoki, Finland (Figure 1-2). The municipality of Pyhäjoki is located on the coast of the Gulf of Bothnia in between the municipalities of Raahe and Kalajoki, in the southwestern part of the province of Northern Ostrobothnia. Pyhäjoki is approximately 100 kilometers from Oulu and Kokkola.

The Hanhikivi plant site is located in the northern part of the municipality of Pyhäjoki on the Hanhikivi headland, less than seven kilometers from the center of Pyhäjoki. The northeastern part of the Hanhikivi headland is located in the town of Raahe, around 20 kilometers from the center of Raahe. There is no previous industrial activity at the future plant location.

On October 19, 2009, the Radiation and Nuclear Safety Authority (STUK) compiled a preliminary safety assessment on the Fennovoima nuclear power plant project when

Table 1-1. Comparison of the key characteristics of the approximately 1,200 MW plant and the key characteristics of the 1,800 MW plant studied in the EIA of 2008.

Description	Nuclear power plant of approximately 1,200 MW	Nuclear power plant of approximately 1,800 MW
Plant type	Pressurized water reactor	Pressurized water reactor
Electric power	Approximately 1,200 MW	Approximately 1,800 MW
Thermal power	Approximately 3,200 MW	Approximately 4,900 MW
Efficiency	Approximately 37 %	Approximately 37 %
Fuel	Uranium dioxide UO_2	Uranium dioxide UO_2
Thermal power released in cooling to the water system	Approximately 2,000 MW	Approximately 3,100 MW
Annual energy production	Approximately 9 TWh	Approximately 14 TWh
Cooling water requirement	Approximately 40–45 m^3/s	Approximately 65 m^3/s
Fuel consumption	20-30 t/a	30–50 t/a

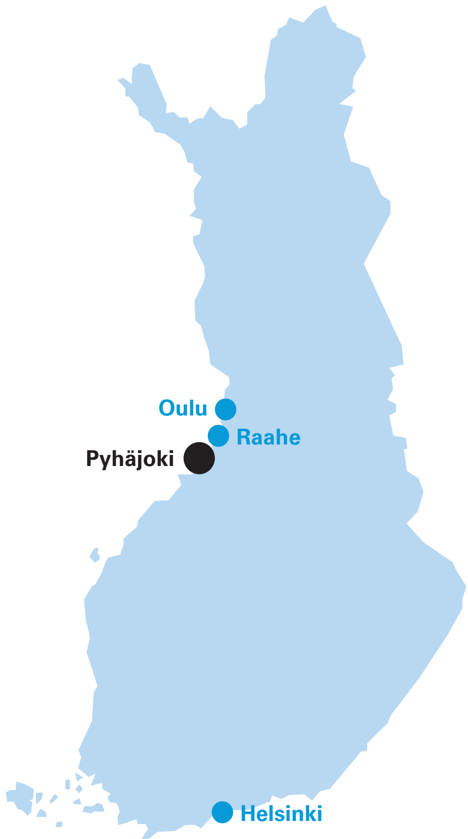


Figure 1-2. Location of the municipality of Pyhäjoki.

processing Fennovoima's application for a Decision-in-Principle. As part of this safety assessment, STUK also assessed the applicability of the Hanhikivi location in Pyhäjoki for a nuclear power plant. According to the STUK statement, no issues that would prevent the construction of a new nuclear power plant in compliance with the safety requirements or implementing the safety or emergency preparedness arrangements were observed at the new plant site. Fennovoima submitted in the autumn of 2013 to STUK a report regarding the plant site which describes the most recent changes onsite and any changed information as well as lists studies important for the plant site's safety. The report is connected to the plant alternative's safety assessment, and it states that most of the plant data listed in the 2009 Decision-in-Principle is still valid.

The nuclear power plant buildings will require a land area of at least 50 hectares. The functions and space required by the nuclear power plant have been taken into account in the land use plans drafted for the plant. The land use planning for the nuclear power plant is legally valid at all three levels of planning, i.e. the provincial plan, the local master plan, and the local detailed plan are all legally valid. For more information about the land use planning at the Hanhikivi headland, please see Section 7.2.

The plan is to construct the nuclear power plant in the middle and north part of the Hanhikivi headland. Most of the area is currently managed by Fennovoima. Fennovoima currently manages around 366 hectares of land and water areas (Figure 1-3). Fennovoima manages these land areas either by owning them, or by having signed preliminary property transaction agreements or leases. The areas have been leased using leases that include a binding letter of intent on the right to purchase the areas.

Figure 1-3. Areas managed by Fennovoima on the Hanhikivi headland. The areas managed by Fennovoima are highlighted in green.

Fennovoima will continue purchasing more areas on the Hanhikivi headland with the goal of owning all of the areas reserved for the nuclear power plant and its supporting functions in the land use plans. The areas will mostly be obtained by signing voluntary agreements, but Fennovoima also submitted in May 2012 an application to the Government for a redemption permit based on the Act on the Redemption of Immoveable Property and Special Rights (603/1977). The redemption permit applies to land and water areas that are currently part of four estates, totaling around 108 hectares. Around 107 hectares of the area to which the redemption permit applies are land and water areas owned by a single group of holdings for redistribution.

1.6 Project schedule

The construction of the nuclear power plant has been estimated to take around six years. However, the necessary infrastructure elements on land and water as well as the necessary excavation works must be completed before the construction can start. The plan is to start this work in 2015. The nuclear power plant is planned to be in operation in 2024 as agreed in the plant supply contract signed in December 2013.

To start construction of the nuclear power plant, Fennovoima will need a construction license in compliance with the Nuclear Energy Act from the Government.

Before starting production at the nuclear power plant, Fennovoima will apply for an operating license according to the Nuclear Energy Act, an environmental permit, and other permits required for the power plant.

1.7 Connections to other projects

1.7.1 Power transmission system

The project involves constructing power transmission connections from the power plant to the main grid, i.e. the high-voltage transmission system covering the whole of Finland. Fennovoima will carry the responsibility for constructing the power plant's connection lines and the national grid operator Fingrid Plc ("Fingrid") will carry the responsibility for the reinforcements required in the main grid. According to the preliminary assessment, the connection between the power plant and the grid will require the construction of two 400 kV transmission lines and two 110 kV transmission lines.

The environmental impacts form the construction and operation of these transmission lines will be assessed in a separate EIA procedure that will probably start in 2014. Fingrid has preliminarily assessed the connection between the plant unit and the main grid as well as the required grid reinforcements. The required new transmission lines have been taken into account in the provincial land use planning of Northern Ostrobothnia. The actual solution to be implemented will depend on the size of the nuclear power plant and its technical characteristics.

The new nuclear power plant may also require an increase in the national reserve power.

1.7.2 Final disposal of spent nuclear fuel

The project involves the disposal of spent nuclear fuel created by the nuclear power plant operations in Finland according to the requirements of the Nuclear Energy Act. The final disposal of spent nuclear fuel requires the completion of an EIA procedure and a Decision-in-Principle by the Government.

Fennovoima's primary plan for the spent nuclear fuel is to join the current Finnish nuclear power plants' spent nuclear fuel final disposal system. In March 2012, the Ministry of Employment and the Economy appointed a workgroup to control the joint studies of the nuclear power companies on the available alternatives for storing spent nuclear fuel. The Ministry published the workgroup's final report in January 2013. The report's most important recommendations were that an optimized solution would be the most cost-efficient way to handle the final disposal and the expertise gained by Posiva Ltd in its project should be utilized.

The Decision-in-Principle for Fennovoima requires that Fennovoima shall at the latest on June 30, 2016 present to the Ministry of Employment and the Economy either an agreement on the cooperation described in the application for the Decision-in-Principle with the parties currently in charge of nuclear waste management or an environmental impact assessment program relating to Fennovoima's own spent nuclear fuel disposal plant. The final report of the nuclear waste workgroup of the Ministry of Employment and the Economy also states that Fennovoima must prove in connection with its construction license application that it has access to the technology required to implement its final disposal plans.

1.7.3 Nuclear power plant projects in Finland

In May 2010, the Government issued a Decision-in-Principle on the Fennovoima project and another Decision-in-Principle on expansion of the Olkiluoto nuclear power plant of Teollisuuden Voima Plc ("TVO") with a fourth unit. The fourth nuclear power plant unit in Olkiluoto will be a 1,000–1,800 MW unit.

2

EIA procedure, communications and participation

2.1 Need and objectives of the EIA procedure

The objective of the EIA procedure is to contribute the environmental impact assessment and to ensure that environmental impacts are always taken into account in planning and decision-making. Another objective is to increase the availability of information to citizens and the possibility for them to participate in the planning of projects. The EIA procedure does not involve any project-related decisions nor does it solve any permitting and licensing issues.

The Directive on Environmental Impact Assessment (EIA, 85/337/EEC) issued by the Council of the European Community (EC) has been enforced in Finland through the Act on Environmental Impact Assessment (EIA Act, 468/1994) and EIA Decree (713/2006). They have also enforced the Convention on Environmental Impact Assessment in a Transboundary Context approved by the United Nations Economic Commission for Europe (UNECE).

According to section 4, subsection 1 of the EIA Act (468/1994), the environmental impact assessment procedure shall be applied to projects where an assessment is required to enforce an international agreement binding on Finland or which may have significant adverse environmental impacts, as well as any changes to such projects.

Issues on environmental impact assessments crossing state borders have been agreed upon in the Convention on Environmental Impact Assessment in a Transboundary Context. Finland ratified this Convention of the United Nations Economic Commission for Europe (67/1997) in 1995. The Convention entered into force in 1997. Furthermore, Finland and Estonia have signed a joint Agreement on Environmental Impact Assessment in a Transboundary Context (51/2002). The nuclear power plant is a project falling under the scope of the Espoo Convention for which an international hearing must be held.

The Ministry of Employment and the Economy acts as the coordinating authority of the EIA for projects associated with nuclear facilities according to the Nuclear Energy Act.

2.2 Main stages of the EIA procedure

The EIA procedure consists of the program stage and the reporting stage. The environmental impact assessment program (EIA program) is a plan for arranging an environmental impact assessment procedure and the required surveys. The environmental impact assessment report (EIA report) describes the project and technical solutions, and offers a consistent assessment of the environmental impacts based on the EIA procedure.

2.2.1 EIA program

An EIA program was established during the first stage of the environmental impact assessment procedure.

The EIA program includes a survey of the project site's current status and a plan (a working program) on the environmental impacts to be assessed and the implementation methods of the assessment. The EIA program also includes basic data of the project and the alternatives being studied, as well as a communications plan during the EIA procedure and an estimate of the schedule of the procedure.

Fennovoima submitted the EIA program to the coordinating authority, the Ministry of Employment and the Economy, on September 17, 2013. The coordinating authority announced the public hearing of the EIA program in, for example, local newspapers and on its website. The EIA program was on display for statements and opinions from September 30 to November 13, 2013. The Ministry of Employment and the Economy made a summary of the opinions and statements, and issued its own statement on the program on December 13, 2013.

2.2.2 EIA report

This EIA report is a summary of the assessment work based on the EIA program as well as statements and opinions on it. This report includes the following:

- Description of the current status of the environment
- Assessed alternatives
- Environmental impacts of the project alternative and the zero-option, as well as the significance of these impacts
- Comparison of the project alternatives and the nuclear power plant of approximately 1,800 MW based on the results of the EIA procedure implemented in 2008
- Measures to prevent and mitigate adverse impacts
- Proposal for an environmental impact assessment monitoring program
- Description of interaction and participation during the EIA procedure
- Description of how the coordinating authority's statement on the EIA program has been taken into account when compiling the EIA report

Citizens and stakeholders will have the opportunity to voice their opinions and issue statements on the EIA report during the display period determined by the Ministry of Employment and the Economy. The coordinating authority will make a summary of the statements and opinions regarding the report, and issue a statement based on them within two months of the termination of the display period. The EIA procedure will end when the coordinating authority submits its statement on the EIA report.

The permit authorities and the project owner will use the EIA report and the coordinating authority's statement on the report as the basis of their decision-making process. The project-related permit decision must state how the EIA report and the related statement were taken into account in the permit decision.

The main stages of the EIA procedure are illustrated in Figure 2-1.

2.3 International hearing

The environmental impact assessment in a transboundary context as laid down in the Espoo Convention is applied to the Fennovoima nuclear power plant project. Parties to the Convention have the right to take part in an environmental impact assessment procedure carried out in Finland if the country in question is potentially affected by the adverse environmental impacts of the project to be assessed. Correspondingly, Finland has the right to take part in an environmental impact assessment procedure of a project located in another country if the project may affect Finland.

The states participating in the EIA procedure have placed the EIA program and report in public display for statements and opinions. The EIA report will also be similarly displayed. Public hearing events may be arranged during the period of display. The Ministry of the Environment is responsible for practical arrangements of the international hearing. The Ministry of the Environment collected the statements and opinions on the EIA program and submitted them to the coordinating authority so that they could be taken into account in the coordinating authority's statement on the EIA program. The same procedure will be applied in the case of the EIA report (Figure 2-1).

2.4 Schedule of the EIA procedure and the international hearing

Main stages and planned schedule of the EIA procedure are illustrated in Figure 2-2. The environmental impact assessment procedure of the project was started in August 2013 with the preparation of the EIA program. The EIA procedure started when the EIA program was submitted to the coordinating authority in September 2013. The environmental impact assessment surveys for the EIA report were implemented between September 2013 and February 2014. The EIA report was submitted to the coordinating authority in February 2014. The EIA procedure will end when the coordinating authority issues its statement in June 2014.

The international hearing of the EIA program, in compliance with the Espoo Convention, started at the same time as the national hearing of the EIA program in Finland, and took 60 days. The international hearing for the EIA report will be held in the same manner.

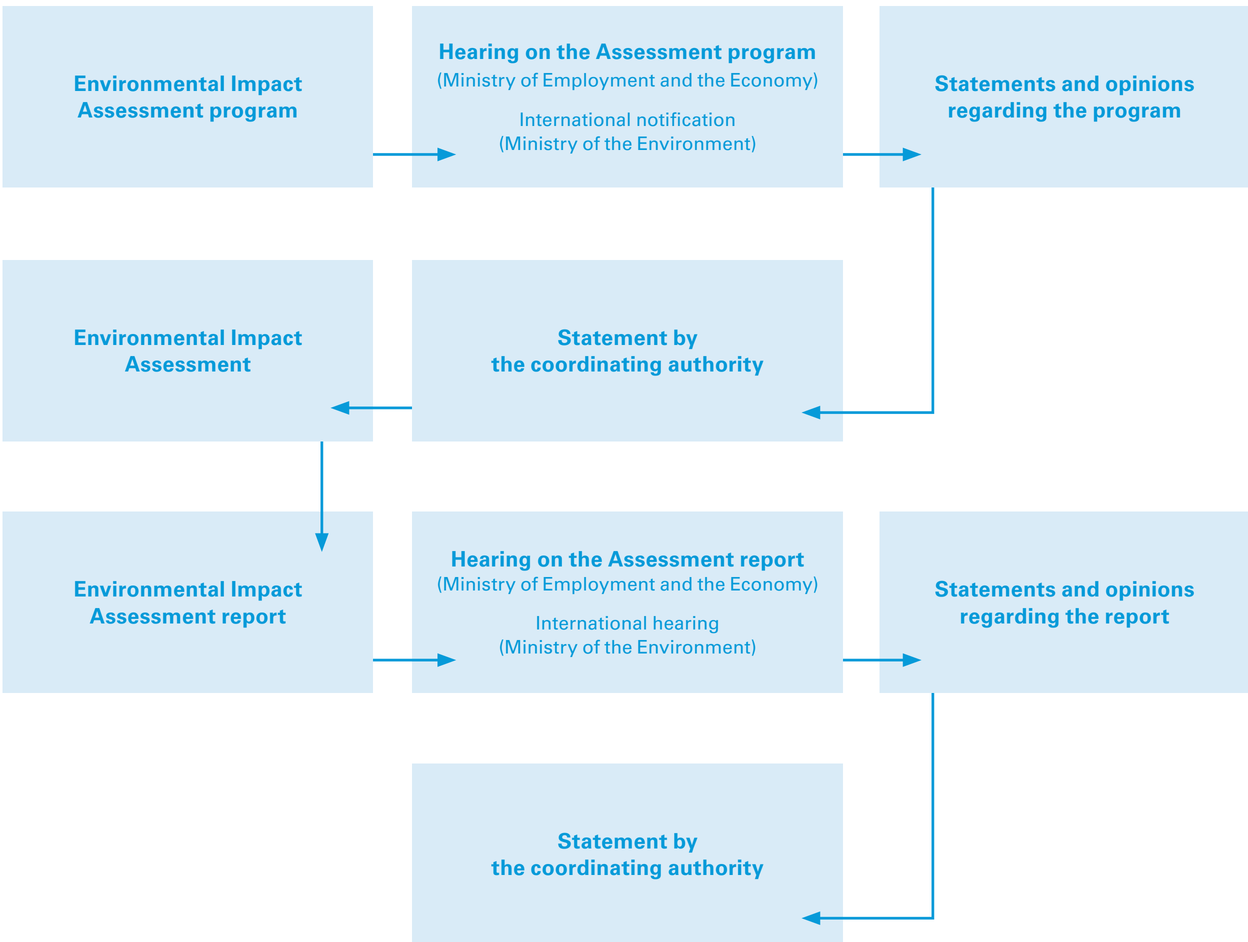


Figure 2-1. Stages of the EIA procedure.

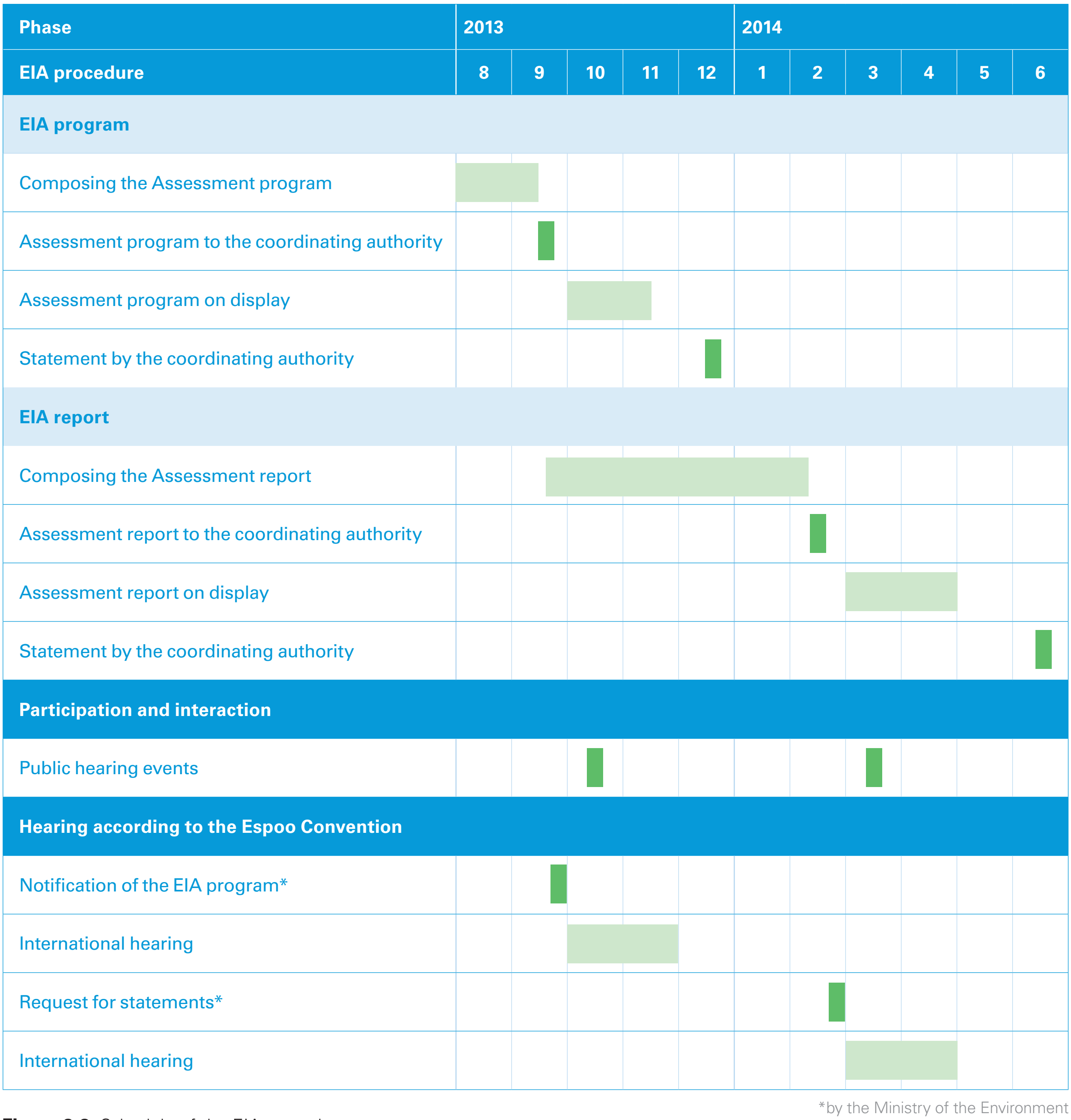


Figure 2-2. Schedule of the EIA procedure.

2.5 Parties to the EIA procedure

The organization responsible for the project is Fennovoima Ltd and the coordinating authority is the Ministry of Employment and the Economy. The coordinating authority for the international hearing is the Ministry of the Environment.

Consultant Pöyry Finland Oy has compiled the environmental impact assessment program and report. Sito Oy, Suomen YVA Oy, Brenk Systemplanung GmbH and several of Fennovoima's experts participated in the preparation of the program and report. . The experts who participated in the impact assessment work and their areas of responsibility are listed below.

- Minna Jokinen, Master of Science (Engineering), project manager (Pöyry)
- Anna-Katri Räihä, Master of Science (Agriculture and Forestry), project coordinator (Pöyry)
- Ville Koskimäki, Master of Science, and Kalle Reinikainen, Master of Science & Licentiate in Social Sciences, Social impacts (Pöyry)
- Carlo di Napoli, Master of Science (Engineering), noise impacts (Pöyry)
- Soile Turkulainen, Master of Science, nature impacts (Pöyry)
- Eero Taskila, Master of Science, impacts on fish fauna and fishery (Pöyry)
- Mariikka Manninen, Landscape Architect, impacts on land use, infrastructure, cultural environment, and landscape (Pöyry)

- Riku Hakoniemi, Master of Science, impacts on soil, bedrock, and groundwater (Pöyry)
- Minna Jokinen, Master of Science (Engineering), impacts on air quality (Pöyry)
- Anna-Katri Räihä, Master of Science (Agriculture and Forestry), traffic impacts (Pöyry)
- Henni Simpanen, Master of Science (Engineering), impacts of waste and waste management, impacts of radioactive emissions (Pöyry)
- Pekka Saijonmaa, Master of Science (Engineering), impacts on energy markets (Pöyry)
- Lauri Erävuori, Master of Science, and Merilin Pienimäki, Master of Science, impacts on water systems (Sito Oy)
- Hannu Lauri, Master of Science (Engineering), cooling water modeling (Suomen YVA Oy)
- Dr Olaf Nitzsche and Dr Ralf Kunz, severe nuclear accident modeling (Brenk Systemplanung GmbH)
- Janne Liuko, Master of Science (Engineering) & Master of Economic Sciences, Ilkka Männistö, Master of Science (Engineering), and Leena Torpo, Doctor of Science in Technology, impacts of abnormal and accident situations (Fennovoima)

Citizens and authorities have a significant role in the EIA procedure: they influence the procedure by, for instance, issuing statements and opinions. The parties involved in the EIA procedure of this project are illustrated in Figure 2-3.

2.6 Communications and participation

The EIA procedure is an open process in which all residents and other stakeholders can participate. One of the key goals with this interaction is to gather the views of different interested parties and utilize them during the EIA procedure.

2.6.1 Information and discussion events

The Ministry of Employment and the Economy arranged apublic hearing event in Pyhäjoki on October 17, 2013. The project and the environmental impact assessment program were presented at the event. The participants were able to provide their views on the project and pose questions regarding the project and the EIA procedure. Approximately 40 people attended the event. Issues discussed in the public hearing event included the project's employment impact, impact on the economy, the nuclear power plant's health impact, safety, and issues involving progress of the project.

A second public hearing event will be arranged in March 2014. Results of the environmental impact assessment will be presented at this event. The participants will be able to provide their views on the environmental impact assessment and its sufficiency. More specific information about the event will be published in the local newspapers and on the coordinating authority's website.

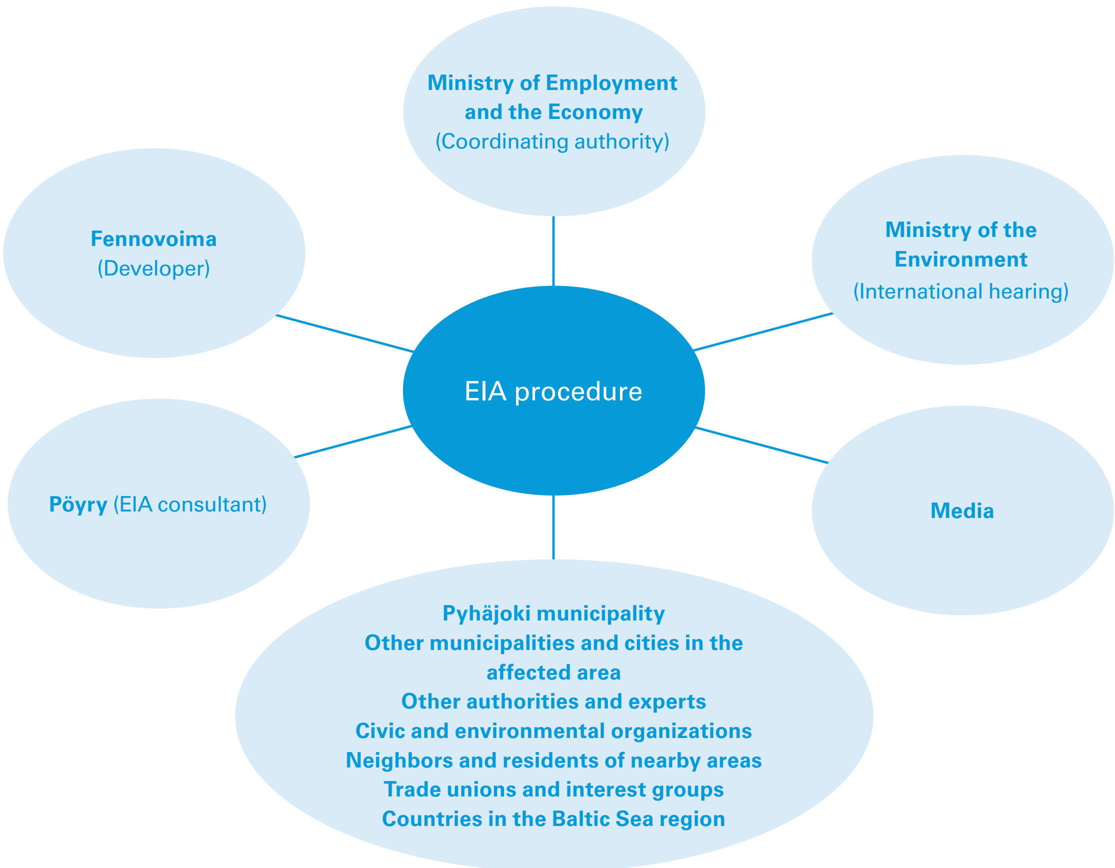


Figure 2-3. Parties involved in the EIA procedure.

2.6.2 Resident survey and stakeholder interviews

As part of the social impact assessment included in the environmental impact assessment, a questionnaire was distributed to permanent and recreational residents of the area surrounding the plant site. The resident survey studied the attitudes of residents towards the project and their views on the project's environmental impacts.

In addition, three interview meetings with stakeholders were arranged to discuss the nuclear power plant project and its positive and negative impacts on society.

Descriptions and results of the resident survey and stakeholder interviews are in Section 7.10.

2.6.3 Other communications

The EIA program and report will be published on the website of the Ministry of Employment and the Economy (www.tem.fi > Energy > Nuclear Energy > EIA procedures for new nuclear power projects). The documents will also be available on the website of Fennovoima. Furthermore, the documents will be available at the Fennovoima office in Pyhäjoki.

2.7 Coordinating authority's statement on the EIA program

The Ministry of Employment and the Economy issued its statement on the project's EIA program on December 13, 2013 (Appendix 1). In its statement, the Ministry of Employment and the Economy finds that the environmental impact assessment program meets the requirements of EIA legislation with regard to content, and it has been processed in accordance with the requirements of EIA legislation.

The matters pointed out by the coordinating authority to take into account when implementing the EIA surveys and compiling the EIA report are listed in the Table 2-1. The column on the right includes a description of how the coordinating authority's statement has been taken into account in the EIA report.

2.8 Statements and opinions on the assessment program

The coordinating authority requested statements on the environmental impact assessment program from the following parties: the Ministry of the Environment, the Ministry for Foreign Affairs of Finland, the Ministry of the Interior, the Ministry of Social Affairs and Health, the Ministry of Defence, the Ministry of Finance, the Ministry of Transport and Communications, the Ministry of Agriculture and Forestry, the Radiation and Nuclear Safety Authority, the Regional State Administrative Agency of Northern Finland, the Finnish Environment Institute SYKE, the North Ostrobothnia Centre for Economic Development, Transport and the Environment, the Finnish Safety and Chemicals Agency (Tukes), the Council of Oulu Region, the Confederation of Finnish Industries, Finnish Energy Industries, the Central Union of Agricultural Producers and Forest Owners, Confederation of Unions for Professional and Managerial Staff in Finland, the Central Organisation of Finnish Trade Unions, the Finnish Confederation of Salaried Employees, the Federation of Finnish Enterprises, WWF, Greenpeace, the Finnish Association for Nature Conservation, the National Board of Antiquities, Fingrid Oyj, Posiva Oy, the Jokilaakso Rescue Services, and the following municipalities: Pyhäjoki, Raahe, Alavieska, Merijärvi, Siikajoki, Oulainen, and Kalajoki.

The Ministry of Employment and the Economy did not receive any statement from the following organizations: the Ministry for Foreign Affairs of Finland, the Finnish Environment Institute SYKE, the Central Union of Agricultural Producers and Forest Owners , the Finnish Confederation of Salaried Employees , the Federation of Finnish Enterprises, WWF, and the following municipalities: Raahe and Alavieska.

In terms of the transboundary EIA in compliance with the Espoo Convention, the Ministry of the Environment notified of the project to the following authorities: Swedish Environmental Protection Agency (Sweden), the Ministry of Environment (Denmark), the Ministry of Environment (Norway), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany), the Ministry of Environment (Poland), the Ministry of Environment (Lithuania), the Ministry of Environment (Latvia), the Ministry of Environment (Estonia), the Ministry of Natural Resources (Russia), and the Federal Ministry of Agriculture, Forestry, Environment and Water Management (Austria).

Sweden, Denmark, Norway, Poland, Germany (the states of Schleswig-Holstein and Niedersachsen), Latvia, Russia, Estonia, and Austria will participate in the EIA procedure and have issued statements on the EIA program. Lithuania has opted not to participate in the EIA procedure, but it wants to receive the project's EIA report and the construction licence (when one is granted).

The coordinating authority also received a total of 24 statements and opinions from other parties. Four of these statements and opinions came from Finnish organizations and 20 from private persons. Two organizations and five private persons from outside of Finland submitted their statements and opinions.

The coordinating authority noted in its statement that attention should be paid to the issues raised in the statements and opinions of other parties where necessary when compiling the EIA report while also taking into account the requirements on the content of the EIA report laid down in the EIA Act and EIA Decree. In the case of the international hearing, the coordinating authority required that the English version of the EIA report address the issues raised in the statements.

Tables 2-2, 2-3, 2-4, and 2-5 include a summary of the contents of the statements and opinions submitted by Finnish and foreign parties to the coordinating authority and how they have been addressed in the EIA report. Some of the issues are addressed directly in the said tables. The Appendix 2 of this EIA report includes further responses to the questions and statements of Germany, Austria, Sweden and Denmark.

Table 2-1. Matters pointed out by the coordinating authority's statement and their processing in the EIA report.

Coordinating authority's statement	Processing in the EIA report
The Ministry of Employment and the Economy finds that the Fennovoima environmental impact assessment program meets the requirements of EIA legislation with regard to content, and it has been processed in accordance with the requirements of EIA legislation. The submitted statements mainly considered the program to be appropriate and comprehensive. The Ministry finds that the EIA program must, however, be reviewed and the environmental impact assessment report must be compiled in a manner that properly takes into account all of the different aspects of the coordinating authority's statement listed in this Section. Furthermore, the statements and opinions include other questions, comments, and viewpoints that the organization responsible for the project should address wherever necessary when drafting the EIA report. In the EIA report, the organization responsible for the project must address the questions raised, properly and to a sufficient extent, while also taking into account the requirements on the contents of the EIA report laid down in the EIA Act and EIA Decree.	Statements and opinions from the coordinating authority's statement and responses to these statements and opinions are included in the tables in Section 2.8.
The obvious shortcomings and erroneous information in the EIA program clearly listed in the statements and opinions must be corrected. The Ministry proposes that the organization responsible for the project attach a table to the EIA report specifying the issues pointed out by the coordinating authority, the organization's responses to them, and any references to the appropriate sections of the EIA report.	The coordinating authority's statement was taken into account when drafting this EIA report. There are responses to the issues raised in the statement in this Table 2.1 and the table in Section 2.8. Whenever necessary, there is also a reference to the Section of the EIA report where the issue in question is discussed.
In addition, responses to issues raised during the international hearing must be added to the English version of the EIA report. The materials translated into the local languages must be sufficient and include the information laid down in Appendix II to the Espoo Convention. The EIA report must include a separate chapter on transboundary impacts. The report must describe how the comments of the states participating in the EIA procedure in compliance with the Espoo Convention have been taken into account. Special attention must be paid in statements from various organizations from the neighboring country Sweden.	An appendix to the English version of the EIA report includes responses to the issues raised during the international hearing. There are also responses to some comments in the tables in Section 2.8. The transboundary impacts are discussed in Section 7.14.
The environmental impact assessment must include as diverse comparison as possible of the different project implementation options, and the comparison must also be included in the EIA report.	The project alternatives, including the zero-option and the alternatives assessed in 2008, are described in Section 1.4. A comparison of the properties and environmental impacts of the project and the 1,800 MW plant studied in the EIA of 2008 and a description of the zero-option are given in Chapter 8.
Project description and options	
The Ministry demands that the EIA report must include an advanced data sheet on the selected plant type. Furthermore, the report must list the safety design bases for a nuclear power plant of that type in terms of limiting radioactive emissions and the environmental impacts, as well as an assessment of the opportunities to comply with the currently valid safety requirements.	A technical description of the selected plant type is included in Section 3.2.1. The safety design bases and compliance with the currently valid safety requirements are discussed in Chapter 4.

Coordinating authority's statement	Processing in the EIA report
Several statements and opinions discussed placement of the residences in the area. In the Ministry's opinion, the EIA report must include an illustrative description of the location of residential areas in the vicinity of the power plant and a description of the protective zone and its impact on the local residents. A general description of evacuation measures, if any, must also be added. Furthermore, a description of the land acquisition procedures for specific land areas and any unfinished land use planning issues must be added.	Locations of the residential areas in the immediate vicinity of the project site are described in Section 7.10.1. Information about the protective zones, their impact on the residents, and potential evacuation measures is available in Sections 4.5.3 and 7.13. A description of the land acquisition procedure is given in Section 1.5. Section 7.2 includes a brief description of the land use planning required by the project.
The EIA program includes a brief description of the zero-option, stating that the increased electricity demand in Finland would have to be covered by increasing import or by other parties implementing separate power plant projects. However, several of the statements propose that the opportunity to save energy, the opportunity to more effectively utilize energy, and other available electricity production methods should be studied. The Ministry notes that the organization responsible for the project is a company that generates power only for its shareholders. Thus, it does not have access to any noteworthy means of saving energy or utilizing it more effectively. The Ministry recommends that the EIA report should briefly describe the energy-saving measures of the applicant's owners and the measures implemented to utilize energy more efficiently.	Energy-efficiency of the planned Fennovoima nuclear power plant is described in Section 3.4.2. The energy-saving measures implemented by Fennovoima's shareholders are described in the EIA of 2008. There is a brief reference to these in Section 7.18.4.
Impacts and assessing them	
The EIA program states that the impacts of cooling water, wastewater, and intake of water on water quality, biology, the fish stock (migratory fish species and fishery, in particular), and other flora and fauna will be assessed. The legislation on marine protection that was revised based on the EU Marine Strategy Framework Directive (2000/56/EC) must be taken into account. Impacts of the project on flora and fauna and protected species on land areas must be described to a sufficient extent.	The impacts on water systems and fishery are described in Section 7.4. The revised marine protection legislation has been taken into account in Table 6-1 and the assessment on impact on water systems in Section 7.4. The impacts on the environment of the land areas are discussed in Section 7.6.
The Ministry is of the opinion that the impact of cooling water is the most significant environmental impact during operation of the nuclear power plant. Thus, the modeling to be implemented when studying the environmental impact from warming of the sea must extensively utilize the available background materials. Calculations regarding cooling water must be conservative. Uncertainties in calculation results must be clearly illustrated. Calculations on spreading must be clearly illustrated and the modeling methods must be described.	The cooling water modeling is based on the situation in the summers of 2009–2013 and the winters of 2010–2011 and 2012–2013. The calculations are conservative, assuming the highest possible thermal load. The starting points for the cooling water modeling system, the spreading of the thermal load, and the impact assessment methods used are described in Section 7.4.2.
Assessment of the impacts of abnormal situations and accidents may not be limited to the protective zone or the emergency planning zone for rescue operations. In the Ministry's opinion, the EIA report must describe various accidents that would cause radioactive releases and describe, with illustrative examples, the extent of the areas of impact and the impacts of the releases on humans and the environment.	The nuclear power plant's abnormal situations and accidents as well as provisions for these situations are described in Section 4.4. Possible impacts of abnormal situations and accidents on people and the environment are described and illustrated in Sections 7.13 and 7.14. The impacts of an accident have been assessed based on a severe reactor accident and the spreading of the release, the fallout, and the radiation dose to the general public have been modeled. The assessment included a study of a variety of accidents. The duration of the release (24–72 hours) and the magnitude of the accident (INES 6 or INES 7) varies. The impacts of abnormal situations and accidents outside the protective zone and the emergency planning zone for rescue operations have also been extensively assessed.

Coordinating authority's statement	Processing in the EIA report
The assessment may use the International Nuclear and Radiological Event Scale (INES) of the International Atomic Energy Agency (IAEA), and the EIA report must include a clear summary of the review bases. A description of the follow-up measures in case of a potential severe accident must also be included in the EIA report. Furthermore, the assessment must discuss the environmental impact of radioactive substances on the countries in the Baltic Sea region, Norway, and Austria. The limit value for a severe accident laid down in the Finnish Government Decree on the Safety of Nuclear Power Plants (733/2008) is 100 TBq for cesium-137. This value was used as the source term, which was used to describe an INES 6 accident in the Finnish EIA. Several statements and opinions proposed including an INES 7 accident in the surveys to be conducted. The Ministry of Employment and the Economy is of the opinion that adding a comparison between the survey method used in Finland and the INES 7 survey method would be appropriate.	The environmental impacts caused by a severe accident are discussed in Section 7.13. This Section also mentions the INES classes of the studied accidents. Furthermore, the Section mentions the starting points and the initial values used in the accident modeling. The Section also includes a description of measures to be implemented after an accident. Section 7.14 describes the impact of an accident on Norway, Austria, and selected Baltic Sea states, and a comparison between a release complying with the Government Decree and an INES 7 accident release.
The abnormal situations to be studied must include any phenomena that could be caused by climate change and preparations for such phenomena (sea level fluctuations, other abnormal weather phenomena). These were studied in several statements. The impact of land-uplift and pack ice in the area must also be taken into account.	Section 3.3.1 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Management of external threats is discussed in Section 4.3.
The socioeconomic assessments included in the EIA procedure must assess the project's impacts on employment that were mentioned in the public event on the EIA program both during the construction and during the operation of the plant, taking into account the special characteristics of all localities and areas. The methods used must be described and their selection justified.	The project's employment impacts during construction and operation are discussed in Sections 7.10.4 and 7.10.5. The assessment methods are described in Section 7.10.2.
According to the EIA program, the organization responsible for the project will study the environmental impacts caused by the production and transport of nuclear fuel, including quarrying of raw uranium, concentration of the ore, conversion, isotope enrichment, and manufacture of nuclear fuel. The environmental impact assessment is based on already existing surveys. The Ministry considers it reasonable that the organization responsible for the project must study the environmental impacts of the entire fuel supply chain in general and, additionally, the company's opportunities to influence this chain. The opportunities to utilize mixed oxide nuclear fuel, if any, must also be described.	The nuclear fuel supply chain is described in Section 3.7.2, and the supply chain's quality and environmental objectives are described in Section 3.7.3. Impacts of the nuclear fuel supply chain in general are discussed in Section 7.15. Fennovoima is not planning to use any mixed oxide nuclear fuel in its nuclear power plant. Section 3.7.1.2 includes a general description of mixed oxide fuel and its manufacture.
Nuclear waste management	
In the opinion of the Ministry of Employment and the Economy, the report must also study nuclear waste management as a whole. Studying management of operating waste to a sufficient detail is also necessary in order to achieve an overall picture. The report must also describe processing of the nuclear power plant's decommissioning waste. The structure of the final disposal facility must be made clear by, for instance, using appropriate illustrations.	Management of operating waste is described in Section 3.12, management of spent nuclear fuel in Section 3.13, and management of decommissioning waste in Section 3.14. The impacts of these types of waste are assessed in Sections 7.11 and 7.12. Figure 3-13 illustrates the structure of the final disposal facility.
The management of spent nuclear fuel must be described in general terms, in the same way as fuel management has been described. The management of spent nuclear fuel on site must be described and the description of interim storage must include illustrations. The description of the management of spent nuclear fuel must also include the arrangements made for its transport from Pyhäjoki, if any.	The management of spent nuclear fuel is described in general terms in Section 3.13 and the structure of the interim storage facility is illustrated by Figures 3-14 and 3-15. There is a description of the transport of spent nuclear fuel to the final disposal facility in Section 3.13.2 and an assessment of the impacts is available in Section 7.11.3.4.

Coordinating authority's statement	Processing in the EIA report
The Ministry notes that, according to the Fennovoima EIA program, the environmental impact assessment of the Fennovoima project does not include an assessment of the final disposal of spent nuclear fuel. Such an EIA is possible according to the Nuclear Energy Act. Thus, an environmental impact assessment on the disposal of spent nuclear fuel from the Fennovoima project must be performed once Fennovoima's plans on arranging nuclear waste management are specified. The EIA report must, however, include a description of the development of Fennovoima's spent nuclear fuel management plans starting in 2008.	A separate EIA procedure will be applied at a later date on the final disposal of spent nuclear fuel. The status of Fennovoima's spent nuclear fuel management plans is described in Sections 1.7.2 and 3.13.3.
Plan for arranging EIA process and associated participation	
The Ministry of Employment and the Economy considers that the arrangements for participation during the EIA procedure can be made according to the plan presented in the EIA program. However, sufficient attention must be paid to communication and interaction with the entire affected area of the project across municipal borders and involving all population groups. The Ministry requests that further consideration be given to how the influence of participation will be presented in the EIA report.	The manner in which the statements and opinions on the EIA program have been taken into account is described in this table. Other issues raised during the participation process are discussed in Chapter 2 and Section 7.10. A resident survey and small group interviews were arranged during the EIA procedure. The comments obtained through these and the public event of October 17, 2013 have been taken into account in this EIA report. The feedback will be taken into account in subsequent communications and interaction of the project (Section 10.4).
The sampling and implementation methods of the resident survey must be described and justified in the EIA report. Measures taken to rectify any defects must also be described.	The sampling methods and implementation methods for the assessment of social impact and their use are described in Section 7.10.

2.8.1 Statements from Finnish authorities requested by the coordinating authority

Table 2-2. Statements requested by the coordinating authority from Finnish authorities according to the statement compiled by the coordinating authority and their processing in the EIA report.

Statements from Finnish authorities requested by the Ministry of Employment and the Economy	Processing in the EIA report
Ministry of Social Affairs and Health	
New requirements to safeguard the emergency preparedness of nuclear power plants must be taken into account in the new EIA report. These requirements are included in a bill that started its circulation for comments in the spring of 2013 (the Government Decree entered into force on October 25, 2013). The new requirements increased the total emission limit of a design basis nuclear power plant accident. Furthermore, the requirements demand that evacuation more than five kilometers from the power plant may not be required even in the case of a severe accident.	Section 4.5.3 discusses the nuclear power plant's emergency preparedness. The new requirements laid down in the Government Decree (VNA 716/2013) have been taken into account in the emergency preparedness arrangements. The requirements have also been taken into account in the assessment of a severe accident in Section 7.13.1.
Ministry of Agriculture and Forestry	
The Ministry of Agriculture and Forestry states that information updated this year on the seawater level rising scenarios is available, and the status in 2013 should be reviewed and the scenario updated, if necessary. Furthermore, the EIA program should include a clear comment on the height of the power plant's buildings that pose a danger when compared to these seawater level rising scenarios. Fennovoima plans to assess the impacts during operation on the fish stock (migratory fish species and fishery, in particular). The Ministry of Agriculture and Forestry is of the opinion that assessing the project's impacts on fishery during construction is even more important.	Section 3.3.1 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Management of external threats is discussed in Section 4.3. There is an assessment on the impact on fishery during construction in Section 7.4, Water systems and fishery.
Ministry of the Environment	
Spreading of noise underwater, underwater noise levels, and their impact on fauna must also be assessed.	Section 7.4.3 describes the impact on water systems and fishery during construction, and an assessment on the impact of underwater noise.
It was observed in the studies that the increased temperature will positively influence the living conditions of invasive species in the normally cold water area. The increased volume of marine traffic and the fact that the cooling water will increase the temperature of the sea will enable the entrance of invasive species into the area. Invasive species have been found to cause clogging of piping, problems with the circulation of water, and other problems at nuclear power plants. A risk assessment is necessary in this respect, and preparation for preventing invasive species in advance or in arrears will also be possible.	The impact of the increased temperature on invasive species and their prevention is discussed in Section 7.4.4.
There were some VELMU (an assessment project for the biodiversity of underwater marine environment) observation points in the area and in its immediate vicinity in 2012 and 2013. The information obtained from these points must be taken into account in the assessment. The VELMU observation points also offered information about benthic fauna.	Biodiversity of underwater habitats and species in the immediate vicinity of the Hanhikivi headland was assessed in the summer of 2009 and 2012 by Fennovoima. These assessment results were used when assessing the impacts. The VELMU project studied aquatic vegetation in the immediate vicinity of the Hanhikivi headland in the summer of 2013. According to information provided by Alleco Oy, the perception of the area's underwater habitats has not changed. Section 7.4.1.6 describes the current status of the underwater habitats and Section 7.4.1.7 the current status of the benthic fauna.

Statements from Finnish authorities requested by the Ministry of Employment and the Economy	Processing in the EIA report
The fact that some fish species are endangered must be taken into account. The sea-spawning whitefish (*Coregonus l. widegreni*) has been classified vulnerable (VU) and the common whitefish has been classified endangered (EN), which means that these species should be taken into account. The same applies to sea trout, which is classified critically endangered (CR) and salmon, which is classified vulnerable (VU).	Section 7.4.1.8 provides information on the fish stock. The fact that some species of fish are endangered has been taken into account.
As for land use planning, the Ministry notes that the information is up to date, but the EIA report should describe any further needs to revise the land use planning due to the project and the impact of such revisions.	The project will not cause the need to further revise the land use plans. Land use planning is discussed in Section 7.2.
As for nuclear fuel, the Ministry wants a more specific description of the measures for nuclear waste management, the alternatives available for the final disposal of nuclear fuel, and the risks arising from the transport of spent nuclear fuel.	Nuclear waste management measures and the alternatives available for the final disposal of nuclear fuel are discussed in Section 3.13. The environmental impacts from transport of new and spent nuclear fuel are assessed in Sections 7.15.4 and 7.11.3.4.
Radiation and Nuclear Safety Authority	
The EIA program must be further specified in terms of the description of the power plant, the limiting of emissions, the environmental impact design bases, and the environmental impact design objectives. Furthermore, an assessment on the opportunity to comply with the currently valid safety requirements must be added.	A description of the nuclear power plant, the design bases, the management of emissions, and the objectives are included in Chapter 3. Information on nuclear power plant safety requirements is available in Chapter 4.
The EIA report must study questions related to applicability of the location for the intended purpose, selecting the location, and available nuclear waste management options. A comprehensive description of the nuclear waste management measures to be implemented onsite, including their environmental impact and radiation effect, must be given.	The selection process of the nuclear power plant site, its safety, and the conditions are discussed in Section 3.3. Management of operating waste and spent nuclear fuel in compliance with Fennovoima's current plans are described in Sections 3.12 and 3.13. Sections 7.11 and 7.13.3 discuss the environmental impact and radiation effect of waste management.
The Radiation and Nuclear Safety Authority (STUK) included in its statement special remarks concerning further specifying the project description in terms of the organization, the nuclear fuel quality and environmental objectives, and the plant alternative. STUK often highlights the importance of taking into account new decrees, guidelines, and requirements in EIA reports. The report must include a reference to the regulations currently in force and describe how amendments will influence the project.	There is a description of the project in Chapter 3. It discusses, for example, the plant alternative and the nuclear fuel quality and environmental objectives. The organization responsible for the project is introduced in Chapter 1. The EIA report includes references to the currently valid regulations and YVL Guides. Their impact on the project are discussed in Chapter 4, Nuclear safety.
STUK also expects Fennovoima to supplement the text on emergency preparedness. Emergency preparedness in compliance with legislation and STUK's guidelines as well as the measures to be implemented must be described and specified in more detail.	The nuclear power plant's emergency preparedness and related measures are described in Section 4.5.3.
Fennovoima must describe in the EIA report in detail how residential areas are located in the immediate vicinity of the plant site and which are the closest vulnerable sites, such as schools, day-care centers, and hospitals.	The latest information about residential areas and vulnerable sites is available in Section 7.10. There are also map images.
The EIA program does not include an estimate of the maximum quantity of nuclear fuel to be loaded into the reactor and its average burnup. Such estimates must be included in the EIA report because they are important in terms of the radioactive releases in case of an accident.	Technical data of the reactor is included in Chapter 1, Chapter 3, and Table 8-1 in Chapter 8. An assessment of the impact of abnormal situations and accidents is given in Section 7.13. This Section (7.13.1.1) also includes the maximum value for fuel assembly specific burnup.

Statements from Finnish authorities requested by the Ministry of Employment and the Economy	Processing in the EIA report
A summary of the starting points of the radioactive emissions during operation and the assessment on the impact of abnormal situations and accidents must be given. The assessment and the report must take into account, particularly in the case of the impact of a severe accident, the fact that a new Government Decree on the safety of nuclear power plants has entered into force since the completion of the previous Fennovoima EIA procedure and STUK's new YVL Guide on limiting the emissions of nuclear power plants has entered into force after this procedure was started.	Radioactive emissions into water systems are discussed in Section 7.4 and emissions into the air in Section 7.3. An assessment of abnormal situations and accidents, including the assessment methods, is given in Section 7.13. The new Government Decree and the new YVL Guide have been taken into account.
The EIA report must include an assessment on whether the current natural conditions and forecasted natural conditions could influence safety of the nuclear power plant, the transfer of radioactive substances in the environment, and the choice of location. The results of the baseline surveys for the Hanhikivi headland must also be discussed in the EIA report.	Section 3.3 illustrates the issues that influenced the decision to choose the specific location for the new power plant. The issues that influenced the decision included current and forecasted conditions of the site and safety requirements. The said Section also includes a description of the site's geological, hydrological, and meteorological conditions as well as their impact on the power plant's safety. Section 4.3 describes management of the nuclear power plant's external threats and how they will be taken into account in plant design.
The EIA report must describe the location of marine and air traffic, and the impact, if any, of the intended plant site on these.	Section 7.8 describes the location of marine and air traffic as well as the project's potential impact on them.
North Ostrobothnia Centre for Economic Development, Transport and the Environment	
The EIA report must separately assess whether the project currently being studied in the EIA procedure will give rise to any need to revise currently valid or pending land use plans. According to the Centre for Economic Development, Transport and the Environment, the latest climate scenarios and their impact on the sea level must be taken into account when assessing flooding heights.	The project's impact on land use and the constructed environment are described in Section 7.2. Section 3.3 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Management of external threats is discussed in Section 4.3.
Jokilaakso Rescue Department	
Safety issues have been taken into account in the EIA program, but risks during construction and management of daily risks have not been studied in sufficient detail. The rescue department requires an all-round analysis of safety risks during construction and requests an analysis of the impact of a severe accident within five and twenty kilometers from the power plant site. Furthermore, the rescue department requests an assessment on the establishment and establishment schedule of the project safety organization.	Management of abnormal situations and accidents during construction is described in Section 3.6.3. Management of the nuclear power plant's external threats and abnormal situations and accidents is described in Chapter 4. An assessment of the impact of a severe accident is given in Section 7.13.

2.8.2 Other Finnish statements requested by the coordinating authority

Table 2-3. Other Finnish statements requested by the coordinating authority according to the statement compiled by the coordinating authority and their processing in the EIA report.

Other statements requested by the Ministry of Employment and the Economy	Processing in the EIA report
Central Organisation of Finnish Trade Unions (SAK)	
The project will have positive impacts on the climate policy and the energy markets, and demand for the plant is as high as it was in 2008. This should be clearly stated in the EIA report. According to SAK, the EIA program focuses on the impacts during operation, and the impacts on employment and society during construction, in particular, should also be discussed in the EIA report to a sufficient extent.	The project's impact on the energy markets is discussed in Section 7.16. The impacts on employment and society during the construction phase are discussed in Section 7.10.4.
Greenpeace	
Greenpeace highlights in its statement the need to take into account changes that have occurred since the previous EIA program in the current EIA procedure. According to Greenpeace, such changes include a more detailed idea of the impacts of a severe nuclear accident, lower electricity consumption growth forecasts, the changed plant type and supplier, the further specified construction site, and negative views of Posiva's current owners on the storage of nuclear waste. Furthermore, the EIA program should include an assessment of an INES 7 accident and its impacts under all possible weather conditions, including the evacuation needs. The need for emergency power and its impact on the power grid in case of an unexpected shutdown as well as the preparations in case of a natural catastrophe should be assessed, taking into account the possible impact of climate change during the plant's service life. Greenpeace would also wish to receive more information on the procurement of fuel, the properties of the fuel, and the final disposal solutions.	Nuclear accidents are described in Section 4 and their impacts are assessed in Section 7.13. Electricity consumption growth forecasts have been taken into account in Section 7.18.3. Information about the plant type and other technical issues, such as the procurement of fuel, is available in Chapter 3. Nuclear waste management is described in Section 3.13 and an impact assessment is available in Section 7.11. Viewpoints on nuclear safety are discussed in Section 4, including the INES 7 class (severe nuclear accident). Results of the modeling of a nuclear accident are given in Sections 7.13 and 7.14.
The Finnish Association for Nature Conservation (FANC)	
FANC does not consider the continuous increase in the demand for electricity in Finland likely, and strongly highlights the opportunities to save energy and improve energy-efficiency. In its statement, FANC requests for improvements in the manner in which future energy trends are taken into account as well as calculations based on the most recent electricity consumption data and forecasts.	The impact on the energy markets are discussed in Section 7.16, and the electricity demand and opportunities to save energy are discussed in Sections 7.18.3 and 7.18.4.
In terms of the environmental impacts, FANC wishes Fennovoima to submit reference figures on the radioactive emissions into the air and water systems from Rosatom's other nuclear power plants. Furthermore, FANC is of the opinion that the cooling water intake system has not been clearly explained and states that no information or surveys on the dredging of the dock basin is available. In the case of other water supply issues, FANC raises the question of uncertainties regarding the supply of potable water. FANC wishes to know how the supply of fresh potable water will be arranged.	The plant's technical description, including emissions into the air and water, cooling water arrangements, and water supply issues, is given in Chapter 3. The impact of dredging is assessed in Section 7.4.
FANC is of the opinion that the plant site is too low-lying for a nuclear power plant and states that the impacts of the new road and its elevation on the landscape or the surrounding environment have not been assessed. FANC requests such an assessment.	The project's landscape impacts are discussed in Section 7.7 and the impact on the natural environment in Section 7.6.

2.8.3 International hearing statements

Table 2-4. A summary of the international hearing statements compiled by the coordinating authority and their processing in the EIA report.

Statements from the international hearing	Processing in the EIA report
Sweden	
The Swedish Meteorological and Hydrological Institute (SMHI) notes in its statement that the radioactive releases of a severe reactor accident will spread over a very wide area. Thus, the fact that the assessments in the EIA program are limited to a distance of 1,000 km from Pyhäjoki is inadequate, and the modeling on geographical spreading of radioactive substances should be expanded. SMHI also highlights the risks caused during normal operation, particularly in terms of seawater, and the risks posed by port activities, if any.	The additional risks caused by a severe accident far away from the plant would be negligent when compared to risks caused by people's lifestyle and the modern society in general. The impacts of a nuclear accident are assessed in Sections 7.13 and 7.14. Section 7.13 describes the starting points of modeling. Radioactive emissions into water systems are assessed in Section 7.4.
The Norrbotten County Administrative Board raises the question of climate change in its statement, and requests from the EIA report a study of the long-term changes in water level and extreme weather conditions. Other Swedish County Administrative Boards that issued a statement included those of Västerbotten, Västernorrland, Gävleborg, and Uppland.	Section 3.3.1 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Section 4.3 discusses preparation for external threats.
Association Kärnkraftsfritt Bottenviken expresses in its statement signed by thirteen civic organizations, five party organizations, and several private persons its deep concern on the project. The association raises the question of the impact of cooling water on the water of the Bay of Bothnia, the impact on vendace spawn (kalixlöjrom), the impact of pack ice, and the accident assessments conducted.	An assessment of the impact of the cooling water is given in Section 7.4. Section 3.3.1 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Abnormal situations and accidents are discussed in Sections 7.13 and 7.14.
Several local and regional environmental protection associations, associations opposing nuclear power, and political parties have gathered a petition of around 1,000 names in Skellefteå. The petition demands that 22 points in the EIA report be further specified. These points include the environment of the Bay of Bothnia, radioactive emissions and thermal emissions, the entire uranium supply chain from mining to final disposal of spent nuclear fuel, and the consequences from an INES 7 accident.	Radioactive emissions into water systems are discussed in Section 7.4 and emissions into the air in Section 7.3. An assessment of the impact of the cooling water is given in Section 7.4. The nuclear fuel supply chain is described in Section 3.7 and its impacts are described in Section 7.15. Waste management of spent nuclear fuel is described in Section 3.13 and its impacts are described in Section 7.11. A separate EIA procedure will be applied at a later date on the final disposal of spent nuclear fuel. Abnormal situations and accidents as well as their assessment methods are discussed in Sections 7.13 and 7.14.
Austria	
Austria requires an assessment of potential impacts of the Fennovoima project on Austria. The assessment should be made using the worst case scenario as the starting point. According to the statement, the source term used by Fennovoima as the starting point in assessing accidents, 100 TBq Cs-137, is insufficient. The statement includes source terms that could influence Austria.	The transboundary impacts are discussed in Section 7.14. Abnormal situations and accidents as well as their assessment methods are discussed in Section 7.13.
Germany	
The state of Schleswig-Holstein posed questions regarding the plant type design bases to prevent and manage accidents and to manage external threats. Furthermore, the state is interested in the transport of new and spent nuclear fuel, and their potential impact on the state.	The plant type's design bases are described in Sections 3.2 and 4.2. The plant site's safety and management of external threats are described in Sections 3.3 and 4.3. Section 4.5 describes the management of abnormal situations and accidents Section 3.7.2.4 describes the transport of nuclear fuel and Section 3.13.2 the transport of spent nuclear fuel to the final disposal facility.

2.8.4 Other statements and opinions

Table 2-5. A summary of other statements and opinions compiled by the coordinating authority and their processing in the EIA report.

Other statements and opinions (Finland)	Processing in the EIA report
Association Pro Hanhikivi ry	
In its statement, Pro Hanhikivi ry states that the Fennovoima nuclear power plant project has been revised to such an extent that the project has practically been restarted from the very beginning. Pro Hanhikivi requires that Fennovoima take into account the following issues when drafting the EIA report: 1) more specific information on Fennovoima's ownership structure, 2) a description of the responsibilities of the Mankala company (a cooperative producing electricity for its owners' needs), 3) a study of the company's nuclear power competence, 4) a study of the project's employment impacts, 5) a study of the impact of any unused compulsory purchase permits, 6) a description of the connection to the external grid, 7) a more specific description of the nuclear waste management solutions, and 8) a study on emergency power and regulating power requirements caused by the Fennovoima project. Pro Hanhikivi also poses demands on the EIA procedure, the project's communications and opportunities to participate in the procedure, the assessed alternatives and the project description, the current status of the environment, and the methods used. Furthermore, the description on the mitigation of adverse impacts should be expanded and the project's impact assessment should include examples on how successful the monitoring of the environmental impact assessment performed in 2008 has been.	The company's current ownership structure is described in Section 1.2. The employment impacts are discussed in Section 7.10. A separate EIA procedure will be applied for the transmission line. Current information about the connection to the external grid is available in Section 13.18.2. Nuclear waste management is described in Section 3.13 and the related impacts are assessed in Section 7.11. The need to increase the emergency power capacity will be studied as planning of the project proceeds. The current status is described in Chapter 7. Issues involving the mitigation of the project's environmental impacts are included in Chapter 9.
Pro Hanhikivi points out that the resident survey did not reach all of the property owners within five kilometers of the plant site, which clearly deteriorated the opportunities of citizens to participate in the project and the project's principle of open processing.	Fonecta was in charge of selecting addresses and processing the address data. Fonecta has access to the data of the Population Register Centre. The sample of residents within five kilometers of the plant site was 142 addresses, which corresponds fairly well with similar data provided by Statistics Finland. The data of Statistics Finland dates back to 2012, while the data used by Fonecta was the latest information from the Population Register. When assessing the sampling performed by Fonecta, one must take into account the fact that people who have a currently valid direct marketing ban or ban on releasing their address data were not included in the sampling. The sampling is judged as having reached a major part of the residents living within five kilometers from the plant site. The sampling was made among those living within five kilometers of the plant site and it did not take into account the Parhalahti village that is included in the protective zone. In addition to the resident survey, the project's social impacts were studied by conducting interviews with stakeholders. These interviews provided information about the opinions of various stakeholders in the area. Furthermore, all stakeholders had the opportunity to voice their opinions about the project to the coordinating authority during the period the EIA program was on public display. The stakeholders will also be able to comment the EIA report.

Other statements and opinions (Finland)	Processing in the EIA report
Private persons	
A statement by a private person raised questions about the disposal of spent nuclear fuel, the procurement of nuclear fuel, and the environmental impacts caused by these activities. The statement also included a demand for further studies on the impacts on the environment, people, and society. The statement requested that Fennovoima study the project's impact on power grids and the Finnish electricity market, taking into account the fact that the electricity consumption forecasts have been lowered since 2008.	Nuclear waste management is described in Section 3.13 and an impact assessment is available in Section 7.11. Impacts on the environment are studied in Chapter 7. Impacts on people and society are discussed in Section 7.10. Impacts on the energy markets are discussed in Section 7.16.
According to a statement by two private persons, the safety risks caused by the fact that the plant site is low-lying must be studied. The statement requests a clear plan on verifying the safety of interim storage and final disposal of nuclear fuel. Furthermore, the statement requests studies on the project's impact on comfort of local residents, business life, safety, and society, as well as the impact of compulsory purchase applications on people's constitutional rights. The statement also notes that a resident survey for the permanent and holiday residents of the Parhalahti village must be arranged.	Section 3.3.1 studies conditions at the plant site and extreme phenomena that will be taken into account in plant design. Nuclear waste management is described in section 3.13. The impacts on people and society are discussed in Section 7.10. A resident survey was arranged during drafting of the EIA report. The results of the survey are given in Section 7.10.3.
Other statements and opinions (international hearing)	**Processing in the EIA report**
MKG, the Swedish NGO Office for Nuclear Waste Review, focuses in its statement on the handling of spent nuclear fuel and the final disposal facility. MKG is of the opinion that long-term sustainable and environmentally acceptable disposal of nuclear fuel must be secured when a new nuclear power plant is built. MKG also states that the EIA program includes very little information about how Fennovoima intends to treat the spent nuclear fuel and other types of nuclear fuel. MKG expresses its concern about uncertainties in the permit procedure for the processing of spent nuclear fuel both in Sweden and in Finland.	Nuclear waste management is described in Section 3.13 and an impact assessment is available in Section 7.11. A separate EIA procedure will be applied at a later date on the final disposal of spent nuclear fuel.
German association Bürgerinitiative Umweltschutz Lüchow-Dannenberg proposes in its statement that a hearing about the EIA program should also be arranged in Germany. The organization refers to the Espoo Convention and the Århus Convention. Furthermore, it gives ten requirements on further surveys, such as studying an INES 7 accident and studying nuclear waste management in more detail. The association opposes the construction of a nuclear power plant in Pyhäjoki.	Safety issues are described in Section 4 and an assessment of the impacts of abnormal situations and accidents is given in Sections 7.13 and 7.14. Nuclear waste management is described in Section 3.13 and an impact assessment is available in Section 7.11.

2.9 Interaction between design phase and the EIA

One of the goals of the EIA procedure is to support the project design process by producing information concerning the project's environmental impacts. The purpose is to produce information as early as possible into the design phase, so as to take environmental impacts into account throughout the design process. The EIA report and the stakeholder interaction during the EIA procedure, as well as the collected data, are important for the more detailed further planning of the project.

The EIA report and the statement on it by the coordinating authority will be appended to any permit applications concerning the project, and the permit authorities will use them as the basis data of their decision-making.

3

Technical project description

3.1 Operating principles of nuclear power plants

Nuclear power plants produce electricity in the same manner as large condensing power plants using fossil fuels – by heating water into steam and letting the steam rotate a turbogenerator. The main difference between nuclear power plants and conventional condensing power plants is the method of production of the energy required for heating the water: in nuclear power plants, the heat is produced in a reactor using the energy released by splitting atom nuclei, whereas in condensing power plants, the water is heated by burning suitable fuel, such as coal, in a boiler.

The plant type considered for this project is the pressurized water reactor. The operation of a pressurized water reactor is discussed in more detail in section 3.2. In a pressurized water reactor (Figure 3-1), the high-pressure water exiting the reactor is led into steam generators. In the steam generators, the water flowing in a separate secondary circuit turns into steam, which is then used to rotate a turbine and an electric generator.

In Finland, the fuel used in nuclear power plants is isotope U-235-enriched uranium dioxide (UO_2). Enriched uranium dioxide contains 3–5 percent of isotope U-235, whereas natural uranium only contains less than one percent of the same isotope. The fuel is introduced into the reactor in the form of ceramic pellets placed in hermetically sealed tubes called fuel rods, which are bundled into fuel bundles (Figure 3-2).

Figure 3-2. Fuel pellets, fuel rods, fuel bundles.

The use of uranium as fuel is based on the heat generated in the splitting, or fission, of atomic nuclei. When neutrons collide with a fissionable atomic nucleus, the latter splits into two lighter nuclei. At the same time, new neutrons, neutrinos, and energy are released. The neutrons released following the splitting of the nucleus can cause new fissions, which enables a chain reaction to start. The fission of U-235 nuclei forms a self-maintaining, controlled chain reaction that enables controlled heat production.

The heat produced in nuclear power plants or other thermal power plants (such as coal, oil, or gas plants) cannot be fully converted into electricity. Due to this, part of the heat produced is removed from the power plant using condensers. In the condensers, the low-pressure steam exiting the steam turbines releases energy and turns back into water.

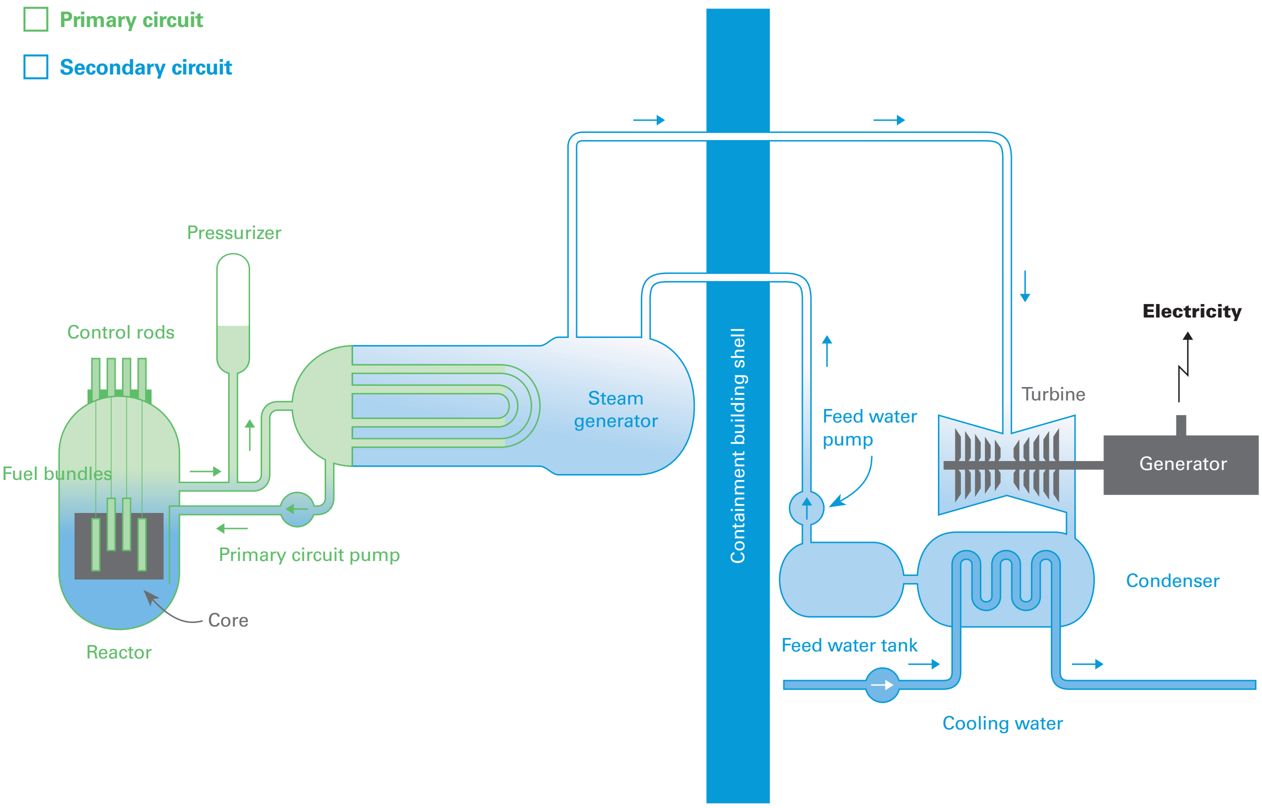


Figure 3-1. The operating principle of a pressurized water reactor.

In Finland, condensers are cooled using cooling water taken directly from a natural water system. The cooling water, the temperature of which rises by 10–12 °C in the process, is then returned back to the water system. In nuclear power plants, more than one-third of the thermal energy generated in the reactor can be converted into electric energy.

Nuclear power plants are best suited as base load plants, which means that they are used continuously at constant power except for a few weeks' maintenance outages at 12–24-month intervals. Plants are designed for an operational lifetime of at least 60 years.

3.2 Description of the plant type

The most widely used reactor type is the light water reactor. The reactors of the nuclear power plants currently in operation in Finland are light water reactors. Light water reactors use regular water to maintain the chain reaction, to cool the reactor, and to transfer heat from the reactor core to the power plant's process systems. The alternative light water reactor subtypes are the boiling water reactor and the pressurized water reactor. The subtype considered for this project is the pressurized water reactor.

In a pressurized water reactor, the fuel heats the water, but the high pressure (approximately 160 bar) prevents the water from boiling. The temperature of the water inside the reactor reaches a maximum temperature of approximately 330 °C. High-pressure water is led from the reactor to separate steam generators. In the steam generators, the water is distributed into small-diameter heat transfer tubes. Heat transfers from the hot water led from the reactor through the walls of the heat transfer tubes to water flowing in a separate circuit (secondary circuit), which is maintained under lower pressure (60–70 bar). The water in the secondary circuit turns into steam which is then led to the turbine rotating the electric generator (Figure 3-1).

As the reactor system and the secondary circuit are completely separated from each other, the water circulating in the secondary circuit is not radioactive.

In Finland, the currently operating reactors at the Loviisa power plant and the reactor of the new power plant unit currently under construction in Olkiluoto are pressurized water reactors.

3.2.1 The Rosatom pressurized water reactor plant

Rosatom's AES-2006 pressurized water reactor plant (Figure 3-3) is a modern third-generation nuclear power plant, which comes in two different versions. The plant version chosen by Fennovoima is AES-2006/V491. Table 1-1 in Chapter 1 contains basic data on the plant.

The AES-2006 plants are based on VVER technology, which has been developed and used for more than 40 years and consequently offers the benefit of long-term operational experience. The plant version considered for Fennovoima's project is the latest development step in the VVER plant series. VVER plants have a history of safe operation spanning over 30 years in locations such as Loviisa.

Contracts have been made to build AES-2006 plants in several countries. Additionally, plants of this type are currently under construction in Russia and Belarus. In total, 13 AES-2006 plants are currently under construction or in contract phase. In Russia, the first plant unit of phase II of the Leningrad plant site in Sosnovy Bor is currently under construction. The construction began in 2008. Additionally, two plant units are under construction in both Kaliningrad and Novovoronez.

The target of the safety design of the plant has from the start been to comply with the requirements of IAEA's safety guidelines and standards, European Utility Requirements (EUR), and Russia's own national regulations and requirements. The designing of Fennovoima's plant will be

Figure 3-3. Rosatom's AES-2006 pressurized water reactor plant.

continued so that it will also fulfill the requirements of the Finnish authorities. Chapter 4 presents safety requirements and principles pertaining to the designing and construction of nuclear power plants.

In terms of safety solutions, AES-2006/V491 equals the Western third-generation nuclear power plants. The safety of the plant is based on both active and passive systems. Active systems are systems that require a separate motive power (for example, electric power) to operate. Among the important safety features of the AES-2006 are additional passive safety systems, driven by natural circulation and gravity. Being independent from the supply of electric power, their operation can be maintained even in the unlikely event of total loss of power supply and unavailability of the back-up power generators.

Four redundant active systems are provided for cooling the reactor after shutdown. One of them is sufficient to perform the safety function. The active safety systems are supplied with motive power from a diesel-backed power supply. The safety systems used to cool the reactor are installed in four separate divisions within the safeguard building. Alternatively, the reactor can be cooled down using passive systems. In this case, heat is extracted from the steam generators to pools located outside the containment building.

In this reactor type, the reactor power is controlled using 121 control rods arranged in 12 rod banks. The high number of control rods (in comparison to other pressurized water plants) improves safety. The control rod system is designed so that in the case of loss of power, gravity causes the control rods to fall into the reactor core. The reactor can be shut down with or without operating the control rods, and the reactor power can also be controlled by injecting boric acid into the reactor.

The plant type features a double-shell containment building. The inner containment shell is made of prestressed reinforced concrete that is capable of withstanding the tensile stresses caused by overpressure under accident conditions. The outer containment shell is a thicker structure made of reinforced concrete that is capable of withstanding external collision loads, including a passenger airplane crash.

The possibility of a severe reactor accident – a partial meltdown of the reactor core – is also considered in the design of the plant. To cope with a severe accident, the containment building is equipped with a core catcher. The core catcher is located below the reactor. It receives the reactor core in the case that the core melts through the reactor pressure vessel. The core catcher cools down the core melt and prevents any adverse effects to the containment structures. The core melt is cooled down by spraying it with water from above. Spraying the core melt with water reduces the dispersion of radioactive substances inside the containment building. The water vapor generated in the core catcher is cooled down using the reactor building's passive cooling system. This allows for maintaining the integrity of the containment building even during severe accidents and, consequently, limiting the dispersion of radioactive releases outside the containment building.

3.3 Safety of the plant site

The Hanhikivi headland in Pyhäjoki was selected as the plant site in 2011. At that time, the remaining alternative site locations were Karsikko in Simo and the Hanhikivi headland in Pyhäjoki. Several different factors were taken into account in selecting the site location. Special emphasis was placed on safety, technical feasibility, environmental and nature-related matters, building costs, and the regional community's willingness and capability to accept the project. Dozens of specific issues falling under these general themes were looked into.

The most important issues in terms of safety were the population of, and activities taking place in, the immediately surrounding area, effective implementation of safety systems and emergency response arrangements, arrangement of the intake and outlet of cooling water in a reliable manner under various conditions, and the soil and bedrock properties.

The assessment revealed no significant differences between the Hanhikivi headland and Karsikko. In the end, the selection of the Hanhikivi headland was supported by, among other things, higher integrity of the bedrock and lower seismic design values, which affect the dimensioning of the nuclear power plant building and the equipment installed inside it.

3.3.1 Conditions at the plant site

Various extreme natural phenomena, accidents, and human activity in the vicinity of the plant site will be comprehensively taken into account in the design of the nuclear power plant. The conditions occurring at the plant site have been examined in numerous different studies and surveys conducted to ensure sufficient consideration of all factors in the design of the nuclear power plant.

A study on the level of sea water, conducted by the Finnish Meteorological Institute, assesses the change in the average sea water level and the probability of occurrence of exceptionally low or high sea water levels in the sea area of Pyhäjoki. The study is based on a comprehensive international literature review on changes in the water level of the oceans during the next hundred years. According to the most likely scenario, the average water level will drop slightly in the course of the current century, because land uplift has a larger effect on the water level of the Bothnian Bay than the global rise in the level of sea water. To ensure that even a significant rise in the level of sea water during the current century will not affect the safety of the plant, sufficient margins are applied in determining the elevation at which the plant will be constructed. *(Johansson et al. 2008, 2010)*

In addition to the level of sea water, other sea-related phenomena that may have an effect on the plant's cooling water intake have been investigated as well. These include pack ice, frazil ice dam (a dam effect caused by formation of ice crystals in subcooled water), migration of sediments, and a severe oil spill accident at sea. The design solutions relating to the plant's sea water intake will be selected on the basis of the results of the investigations such that the possible effects of

Table 3-1. Extreme values of natural phenomena in Pyhäjoki, with average occurence rate of once in a thousand years.

Extreme values of natural phenomena		
Sea level (cm) in the N2000 system in 2075 (and in 2008)	min	-179 (-152)
	max	+201 (+228)
Temperature, momentary (°C)	min	-42.8
	max	33.9
Temperature, 24-hour average (°C)	min	-35.3
	max	22.0
Rainfall (mm)	24 h	84.6
	7 days	126.7
Snow load (kg/m²)		190.5
Wind velocity (m/sec.)	gust, 3 sec.	34.7
	average, 10 min.	31.2

various phenomena are taken comprehensively into account.

Another study conducted by The Finnish Meteorological Institute assesses the probability of extreme phenomena relating to temperature, rainfall, snow load, and wind velocity in Pyhäjoki, as well as the effect of climate change on the occurrence of these phenomena. The study is based on predictions on global climate development, which are used to model the occurrence of local weather conditions. *(Ilmatieteen laitos 2008a)*

Table 3-1 presents the extreme values of selected natural phenomena. The estimated recurrence level of these extreme values in Pyhäjoki is 1,000 years. This means that on an average, each value given in the table occurs once in a thousand years. The weather phenomena considered in the design of the nuclear power plant are significantly more intense than those indicated by the values given in the table.

Soil and bedrock surveys have been conducted to assess the occurrence and probability of earthquakes at the plant site and in its vicinity, to examine the seismic properties of the plant site, and to map any faults occurring at the plant site with the help of various soundings and bedrock analyses. The results of the surveys will be utilized in the design solutions of the plant structures, systems, and equipment.

Several other surveys have been conducted at the plant site as well. These surveys have concerned matters such as the geological and geophysical properties, bedrock, groundwater, and water quality at the plant site.

The effects of human activity in the vicinity of the plant site on the safety of the plant have been assessed. There are no heavy industry sites, gas pipelines, railroads, airports, or harbors in the immediate vicinity of the plant site. Consequently, it has been assessed that the risks relating to the transport, handling, and storage of hazardous substances are very small. The probability of an airplane colliding with the plant has been assessed to be extremely small. Furthermore, the plant will be designed to withstand a large commercial airplane crash.

Fennovoima presented the Radiation and Nuclear Safety Authority (STUK) with the studies and surveys relating to the plant site in conjunction with the submittal of the original application for Decision-in-Principle in 2009. The reports on plant site investigations conducted after this were submitted to STUK in October 2013 together with other reports. These reports will form the basis for STUK's statement concerning the safety of the AES-2006 plant alternative. STUK is currently preparing the statement, which will be given to the Ministry of Employment and the Economy in spring 2014.

3.4 Best available technique and energy efficiency of the plant

3.4.1 Best available technique

The primary criterion applied in the designing and building of the nuclear power plant is safety. The releases of radioactive substances due to the operation of the nuclear power plant and the environmental radiation levels will be kept as low as reasonably achievable (ALARA principle). The limitation of releases and radiation levels will be implemented by applying best available techniques and procedures. This chapter (Chapter 3) discusses treatment methods for liquids and gases containing radioactive substances as well as spent fuel and operating waste. The basic principles for the plant's safety design are discussed in Chapter 4.

As regards the treatment of other discharges and emissions and ordinary waste, the best technically and economically methods will be applied. This section describes techniques possibly applicable to, for example, waste water treatment, waste management, and energy efficiency.

3.4.2 Energy efficiency

The nuclear power plant will be designed for the highest possible energy efficiency. The goal is to maximize the production of electricity and minimize the energy consumption of the power plant operations and the amount of waste heat discharged into the sea with the cooling water. As safety is the starting point of the design, the implementation of solutions improving energy efficiency will be considered on a case-by-case basis.

The dimensioning and technical solutions of the turbine plant will have a significant impact on the energy efficiency of the nuclear power plant. If correctly dimensioned, the efficiency a turbine may be up to a few percentage points higher compared to a plant with a turbine that has not been optimized for the operating conditions. The low temperature of the sea water of the Bothnian Bay will be taken into account in the optimization of the turbine by equipping it with suitably long turbine blades and a sufficient outlet area. This maximizes the expansion ratio of the steam produced at the reactor plant in the turbine and, consequently, the yield of kinetic energy that rotates the turbine and transforms into electricity in the generator.

In the winter, when the cooling water is cold, the efficiency of electricity production is estimated to be approximately 39 %. Part of the produced electricity will be used for the nuclear power plant's processes. These include, in particular, the pumping of cooling and process waters into their points of use and ventilation/air-conditioning. After deducting the plant's auxiliary power requirement from the amount of electricity produced by the plant, the resulting overall net efficiency will be approximately 36 %. The overall net efficiency of Nordic nuclear power plants is typically 30–34 %.

The heat produced in the nuclear power plant cannot be fully converted into electricity. Due to this, part of the heat produced will be removed from the power plant by way of condensation. The condenser will be cooled using water taken directly from the sea. The cooling water, the temperature of which rises by 10–12 °C in the process, will then be returned back to the sea. Another alternative for implementing the condensation process would be to transfer the extra heat directly to the atmosphere via cooling towers. However, direct cooling of the condenser with constantly cold sea water is a better solution from the point of view of electricity production. With direct cooling of the condenser with sea water, the efficiency achieved may be up to two percentage points higher than with cooling towers. In a 1,200-megawatt nuclear power plant, this translates as a 60-megawatt increase in the production of electricity.

The EU Energy Efficiency Directive (2012/27/EU), which entered into force in 2012, obligates electricity production companies to carry out cost-benefit analyses to determine whether their plants should be equipped for combined production of electricity and heat. While the directive exempts nuclear power plants from this obligation, Fennovoima has carried out preliminary technical and financial investigations concerning the combined production of electricity and heat. The investigations have revealed that while the selected turbine technology would make extraction of steam for district heat production technically possible, the small demand for district heat in the Raahe region would make the combined production of electricity and heat financially unfeasible. The decrease in the amount of thermal energy led to the sea would be, at most, approximately 1% in the winter period (*Fennovoima Oy 2009a*). As the demand for district heat would be small, any positive environmental impacts created through the combined production of electricity and heat would remain minor. Transferring district heat to Oulu, approximately 90 kilometers away, has also been found to be financially unreasonable considering the current production structure of district heat in Oulu and the long transfer distance *(Fennovoima Oy 2009a)*. However, part of the steam from the turbine will be used to heat the plant site buildings.

In the case that a demand for the production of district heat arises in the vicinity of Pyhäjoki in the future, heat pumps will enable efficient recovery of waste heat. The heat pumps, which recover heat from the sea water that has passed through the condenser, will produce approximately 3.5 MW of heat energy with an electricity consumption of 1 MW. If required, they can also be used for district cooling purposes.

Significant savings can be made on the electricity consumption of power plant processes by decreasing the friction and pressure losses of the flows, improving process heat recovery, reducing heat losses, and adjusting the operating points of equipment and electric devices to comply with the optimal efficiency range. The issues listed above will be taken into account in the design and use of the power plant.

3.5 Plant area buildings and land use requirements

The nuclear power plant buildings will be located in the middle and northern parts of the Hanhikivi headland, in the energy management block area indicated in the Pyhäjoki local detailed plan for the nuclear power plant. The block area comprises a total of 134.6 hectares. The total permitted building volume of the energy management block area is 300,000 floor square meters. All the central operations of the nuclear power plant will be located in this block area.

The preliminary layout of the plant area is presented in Figure 3-4. The area highlighted in red in the figure is the nuclear island, to the north of which is the turbine island.

In the Pyhäjoki Municipality and the town of Raahe local detailed plans for the nuclear power plant area, block areas are also allocated for buildings required for nuclear power plant auxiliary activities.

The nuclear power plant includes the following buildings and structures:

- Reactor containment building and auxiliary buildings
- Operating waste treatment building
- Fresh fuel storage
- Interim storage for spent nuclear fuel
- Disposal facility of low- and intermediate-level operating waste
- Control room building
- Back-up power generators
- Turbine building
- Electrical building
- Transformer and switchyards
- Sea water pumping station
- Water treatment-related tanks and structures
- Administrative and office buildings (including a health care station, canteen, and other auxiliary facilities)
- Training and visitor center
- Entrance gate building
- Fire station, fire fighting water pumping station, and reservoirs
- Other auxiliary and maintenance buildings (such as mechanical workshops and stores).

The total area required for the buildings and structures located in the energy management block area is approximately 50 hectares, out of which the combined share of the turbine island and nuclear island buildings is some 30 hectares. The area of the reactor building will be approximately 2,400 m², and the area of the turbine building will be approximately 6,500 m². The maximum height of the reactor building will be approximately 70 meters. The highest structure will be the vent stack at 100–120 meters.

The disposal facility of the low and intermediate level operating waste will be located underground. The entrance to the cave leading to the facility will be located within the fenced power plant area. The location of the final disposal facility will be indicated in the construction license application of the nuclear power plant. The planned location of the interim storage for spent nuclear fuel is to the west from the power plant buildings.

Areas will also have to be reserved for work site activities taking place during the construction phase, intermediate storage of soil and rock material, parking, and accommodation. The power plant unit structures will also include tunnels and structures relating to the intake and outlet of cooling water, as well as a dock basin with breakwaters and a wharf for sea transport.

3.6 Construction of the nuclear power plant

3.6.1 Description of the construction site

The construction of a nuclear power plant is an extensive project. The first phase of construction, which lasts approximately three years, will feature the construction of the infrastructure required for the plant and performance of civil engineering work. A connecting road, approximately four kilometers in length, will be built between main road 8 and the power plant area. Preparations for joining the municipal water supply and sewage networks will be carried out in conjunction with the building of the connecting road, and the work site will be connected to the 20 kilovolt power grid.

The earthworks will start with the felling of the trees growing in the plant area and removal of the topsoil, followed by the building of required access roads in the area. The earthworks carried out on land areas will include bedrock blasting and rock excavation work performed for the purpose of constructing the cooling water tunnels and the power plant building pit, as well as the filling, raising, and leveling of the plant area and the supporting areas. Hydraulic engineering works, including soil and rock excavation work performed for the purpose of building the navigation channel, the harbor area, and the cooling water intake and discharge structures, will be carried out simultaneously with the earthworks. The civil engineering work is estimated to commence in 2015 and last approximately two years.

To supply for the construction-phase needs, temporary buildings, such as office and storage buildings, canteen and amenity facilities, and a concrete batching plant, will be built at the plant area. Furthermore, this phase will see the construction of some permanent buildings and structures, such as the entrance gate post and the fence surrounding the plant area.

The actual power plant construction work will begin after the completion of the infrastructure and the civil engineering works. The construction of the power plant will take 5–6 years, including installation work carried out at the plant. The commissioning of the plant will take 1–2 years. The objective is to put the plant into operation by 2024.

During the busiest construction phase up to some 3,500 people will be working at the site. A parking area and accommodation facilities for some of the construction site workers will be built in the vicinity of the plant area.

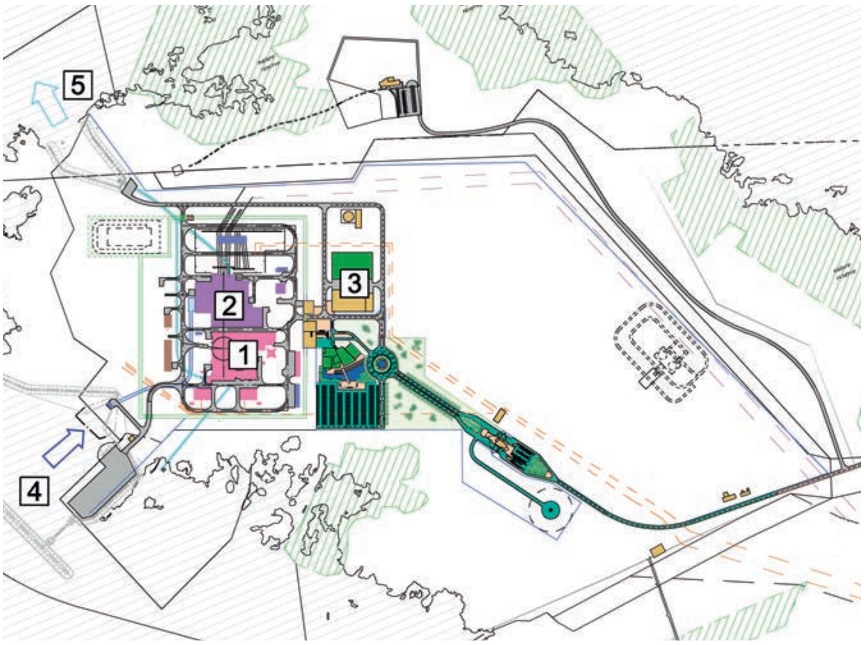


Figure 3-4. Preliminary layout of the nuclear power plant area.
1) Nuclear island
2) Turbine island
3) Office and auxiliary buildings
4) Harbor area and cooling water intake (indicated by the arrow)
5) Cooling water discharge

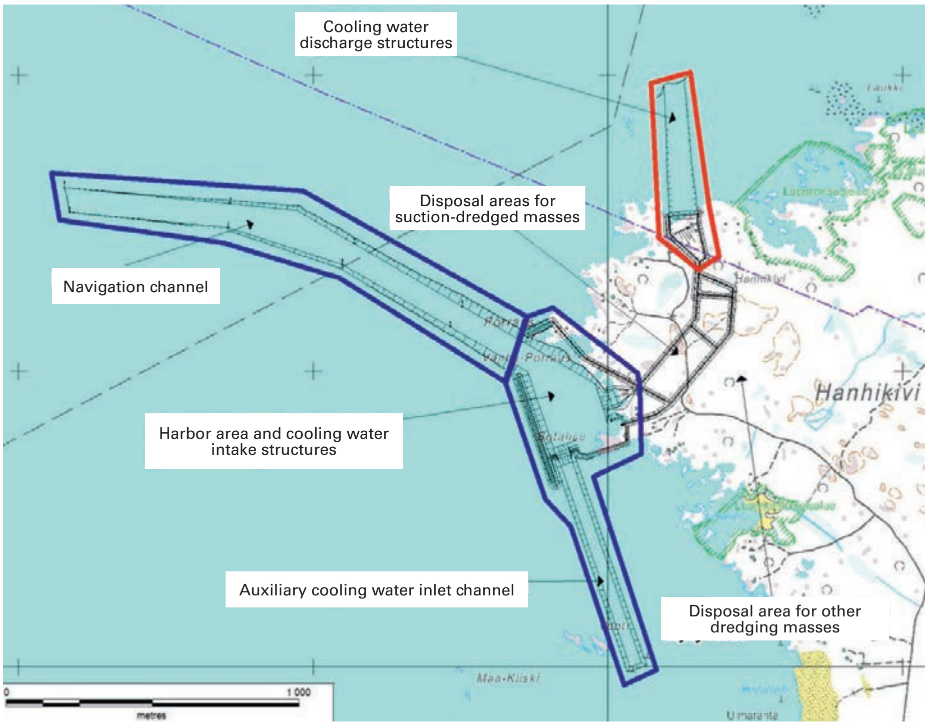


Figure 3-5. The planned locations of the navigation channel, harbor area, cooling water intake structures, auxiliary cooling water intake channel, and cooling water discharge structures in the Hanhikivi headland. The discharge structure area is outlined in red, and other structures are outlined blue.

3.6.2 Civil engineering work

3.6.2.1 Water structures

Figure 3-5 shows the planned locations of the water structures required for the power plant. The dock basin, the navigation channel, the auxiliary cooling water inlet channel, and the cooling water intake structures will be located in the western and north-western parts of the Hanhikivi headland. The cooling water discharge structures will be located on the northern shoreline.

The building of the navigation channel and dock basin on the western shoreline of the Hanhikivi headland is required to enable sea traffic serving the nuclear power plant. The sea link will be needed for transporting machinery and equipment during the construction of the power plant and annual maintenance outages and, later in the future, for operations such as possible transporting spent nuclear fuel. Furthermore, the navigation channel and the dock basin will function as part of the plant's cooling water intake structures.

The water depth of the planned dock basin is 10 meters, and the length of the turning basin will be 200 meters. A wharf with an approximate length of 120 meters will be located in the southern part of the dock basin. According to preliminary plans, the tops of the breakwaters delimiting the dock basin will be at the height of 4 meters from the sea surface, and the combined total length of the breakwaters will be some 650 meters. The auxiliary cooling water inlet channel starting at the southern end of the breakwater will be 700 meters long, with a bed width of 40 meters and a depth of six meters. The navigation channel will be 2.4 kilometers long, with a safe clearance depth of 8.1 meters and a bed width of 80 meters.

The power plant cooling water will be taken in at the eastern edge of the dock basin and led to the power plant through an approximately 200-meter long rock tunnel. The cross-sectional area of the tunnel will be approximately 40–45 m^2. Phenomena impeding the intake of cooling water, such as the impact of algae, sand, subcooled water, and potential pack ice, have been taken into account in the determination and positioning of the cooling water intake location. The intake structure will be dimensioned so that the flow at the mouth of the intake opening remains low (at approximately 0.2–0.3 m/sec.). This will minimize the amount of solids carried along by the cooling water.

The mouth of the cooling water tunnel will be protected with a 15–17-meter-wide concrete structure which will be equipped with a coarse screen in order to remove coarse solids from the cooling water. The building of the concrete structure will take place in conjunction with the performance of the hydraulic engineering works. The building site will be protected by a cofferdam. During the operation of the power plant, the concrete structure will remain mostly submerged. A wharf-like concrete structure will be visible above the water.

The warmed-up cooling water will be led from the power plant through an approximately 300-meter-long tunnel to the northern shore of the Hanhikivi headland for discharge in the sea area. Cooling water discharge structures, including a concrete discharge structure, a discharge channel, and banks protecting the upstream part of the channel, will be built in conjunction with the performance of the hydraulic engineering works. The length of the discharge channel to be dredged will be 600 meters, with a depth of –3 meters and an approximate bed width of 70 meters. The western and eastern banks protecting the upstream part of the discharge channel and the discharge structure will be 200 meters and 150 meters long, respectively.

3.6.2.2 Earth-moving work

Earth-moving work produces large amounts of soil and rock excavation and dredging masses. The main contributors to the total mass amount will be the dock basin and navigation channel dredging masses and the plant area soil and rock excavation masses. The rock material generated during the earth-moving work will be utilized, as far as possible, in the various filling and leveling operations performed in the plant area, as well as in the building of breakwaters in the harbor and cooling water discharge areas. As the ground elevation in the Hanhikivi headland is low, the ground will be raised to 4.5 meters above the sea level in the nuclear power plant building area. It may also be necessary to transport additional rock material onto the site for plant area filling operations.

The loose soil dredged up in the course of the hydraulic engineering work will also be utilized, as far as possible, in the plant area filling operations. The masses that are unsuitable for filling operations, such as masses containing clay, would be dumped at a separate marine spoil area. The planned marine spoil area is located approximately 9.5 to the west from the Hanhikivi headland, and its area is some 190 hectares.

The estimated 100,000–150,000 m^3 (bulk volume) of topsoil removed from the headland area generally cannot be utilized in the plant area, and it will be transported to separately agreed spoil areas on land. Table 3-2 shows an estimate of the quantities of the generated masses and their utilization.

3.6.3 Construction site safety and security, workforce management and environmental management

The management of construction site safety and environmental matters will be planned, and instructions drawn up, before the start of the construction work, and the process will be continued as the construction work progresses. The planning will be based on the safety and environmental risks identified for the operations and each work phase, and it will aim to eliminate the risks in advance. Fennovoima and the plant supplier will appoint separate organizations for the management of safety and environmental risks and the controlling of day-to-day activities. These organizations will also be assigned with the responsibility for cooperating with the various authorities and the representatives of the regional rescue department.

Induction training will be organized to introduce the workers to the safety, security and environmental requirements pertaining to the nuclear power plant project and the worksite, as well as the special characteristics of the worksite, before they begin work at the site. Additional training will be implemented during the various work phases as needed. Care will be taken to ensure that the workers receive the necessary training and instructions in a language that they understand.

3.6.3.1 Occupational safety

In accordance with the Government Decree on the Safety of Construction Work (205/2009), Fennovoima will ensure that the construction work is planned and implemented safely and without causing harm to the health of the workers. The "zero accidents" principle is implemented at the worksite. According to the principle, occupational injuries and accidents can be prevented by careful planning and implementation of work and work phases. The planning will be based on the safety risks identified for each work phase, and it will aim to eliminate the risks in advance.

Fennovoima will be responsible for preparing the safety document for the planning and preparation of the construction operations. The document should present the potential hazards arising from the characteristics, circumstances, and nature of the project, as well as occupational safety-related information associated with the implementation of the project. Furthermore, Fennovoima will prepare the general safety rules and instructions for the worksite, which are to be observed by everyone working at the site.

The worksite will be assigned a main contractor whose responsibility is to prepare the actual safety and worksite plans and safety instructions, organize the associated training, and introduce the plans and instructions into use. The safety plan will show the way in which the construction work is going to be implemented safely, either through elimination of the potential hazards and detriments or through management of the associated health and safety risks. The safety plan will introduce the general occupa-

Table 3-2. Estimated quantities of masses generated during the nuclear power plant construction work.

Masses generated during construction	Quality (bulk volume in m^3)
Removed topsoil	110,000
Plant area soil and rock excavation masses	300,000
Cooling water tunnel rock excavation masses	60,000
Navigation channel dredging and rock excavation masses	380,000
Dock basin and cooling water intake structure dredging and soil/rock excavation masses	750,000
Auxiliary cooling water intake channel dredging and rock excavation masses	110,000
Cooling water discharge structure dredging and soil/rock excavation masses	140,000

tional safety requirements pertaining to the worksite, as well as the safety requirements and information presented by Fennovoima. The worksite plan will include a plan on the use of the worksite area specifying, for example, the construction material loading and unloading locations, the locations of machinery and land masses, the worksite cleanliness and orderliness requirements, and the construction-phase traffic arrangements.

In conjunction with the preparation of the safety and worksite plans, an associated risk assessment will be carried out. Included in the assessment are the hazardous work and work phases performed at the worksite, accident risks, occupational hygiene, worksite management, and the integration of the various contractors and activities.

The main contractor will prepare and introduce into use an occupational safety management system for the worksite. The results of the risk assessments and legal requirements will be taken into account in the preparation of occupational safety-related instructions.

3.6.3.2 Workforce management

According to the Act on the Contractor's Liability (Act on the Contractor's Obligations and Liability when Work is Contracted Out, 1233/2006), the contractor must establish that the enterprises entering into contracts concerning subcontracting or hired labor with the contractor fulfill their legal obligations as employers to fight the gray economy. To manage and control the use of workforce at the construction site, and to fight the gray economy, practices for cooperation with the trade and employer unions, the plant supplier, and the various authorities will be prepared in advance. Fennovoima has assembled a work group consisting of the representatives of major Finnish labor market organizations to discuss advance solutions for the labor market-related challenges arising at the worksite.

Fennovoima is preparing a comprehensive information system enabling real-time control of compliance with the Act on the Contractor's Liability and the labor legislation. Additionally, preparations are underway for the establishment of an authority service point in the vicinity of the worksite. The service point will provide workers and enterprises with, for example, counseling services.

3.6.3.3 Security

During the construction phase, security measures will be taken to prevent illegal activity from taking place at the construction site. The security measures will comprise guarding and monitoring operations, structural protection of the worksite, and administrative procedures.

The worksite will be surrounded by a sturdy metal mesh fence. The fence line will be monitored with the help of a recording camera surveillance system installed as an integral part of the fence line. The worksite area and the fence line will be equipped with lighting. In addition to the fence line, the area monitored with cameras will include the worksite area and the roads, taking into account any legal requirements.

The objective of the construction-phase guarding operations is to maintain a good level of basic security and to prevent any security-threatening situations in advance. In addition to maintaining the level of basic security on a day-to-day basis, the guarding personnel will intervene in any situations threatening the worksite operations. All persons entering the worksite will be subjected to a security check. Their access rights will be verified using a biometric access control system. The biometric identification can be based on, for example, fingerprint recognition. Access control will be used to control and restrict access to and within the area.

Vehicle traffic and parking will be planned taking into account traffic safety and other safety-related matters. A speed limit will be set for the area, and vehicle speeds will be monitored. The access of emergency vehicles to the worksite area and the successful performance of an evacuation will be ensured in all circumstances.

An application for an access and occupation restriction in accordance with the Police Act (872/2011) will be made even for the construction phase.

3.6.3.4 Rescue services

The persons responsible for the safety and security of the construction site will plan, and agree with the regional rescue and police departments upon, the practical measures to be taken in the event of any emergency and accident situations. Such emergency situations include severe occupational accidents, fires, and oil and chemical leaks and spills. The construction site will be equipped with the required manual extinguishing, leak control, and first aid equipment. The workers will be trained for operation in various emergency and accident situations. Furthermore, teams specialized in fire fighting and first aid operations will be established for the site.

3.6.3.5 Environmental management

Fennovoima will also prepare environmental guidelines for the construction project. The guidelines will include the general requirements concerning the management of environmental matters at the construction site. These requirements include the principles relating to the sorting and handling of construction waste, as well as the restrictions relating to outdoor noise and recreational use of outdoor areas. The main contractor will be responsible for preparing and introducing into use an environmental management system and environmental guidelines of its own. This will ensure that the parties operating at the site will manage environmental matters in accordance with the regulations, permit requirements, and best practices.

3.7 Procurement of nuclear fuel

The annual fuel consumption of a nuclear power plant with an electrical output of about 1,200 megawatts is in the range of 20–30 tons of enriched uranium. The production of this amount of fuel requires 200–350 tons of natural uranium. Instead of natural uranium, uranium from secondary sources can be used to produce fuel.

Nuclear power plants usually stock enough fuel for one year's operation. If required for reasons of security of supply, nuclear fuel can easily be stocked for longer periods of operation.

When natural uranium is used, the phases of production of nuclear fuel will be as follows: mining and enrichment of raw uranium, conversion, (isotopic) enrichment, and manufacturing of fuel rod bundles. In addition to natural uranium, Fennovoima is planning to use fuel produced from uranium from secondary sources, such as reprocessed uranium. In this case, the mining and enrichment of raw uranium will be eliminated from the production chain.

Section 3.7.2 contains a general description of the nuclear fuel production chain using natural uranium.

3.7.1 Availability of fuel

Uranium is purchased from global markets. In 2012, the total demand of uranium in the world's nuclear power plants was approximately 65,000 tons, and the world's total nuclear power capacity was 372 gigawatts. According to the basic scenario presented by WNA (World Nuclear Association), the nuclear power generation capacity will increase to approximately 520 gigawatts by 2030, and consequently, the annual demand for uranium will increase to 90,000 tons. *(WNA 2013)*

The production of natural uranium currently accounts for some 85 percent of the demand of uranium. The rest of the uranium on the market originates from the re-enrichment of depleted uranium generated in the uranium fuel enrichment process, reprocessing of spent fuel, and uranium stockpiles.

3.7.1.1 Production of uranium

Uranium is a relatively common element occurring in varying concentrations almost everywhere on earth. Granite, for example, typically contains 0.0004 percent of uranium, and sea water contains one thousandth of that amount. The highest uranium concentrations, up to in excess of 20 percent, can be found in certain Canadian mining regions. Currently, deposits containing at least 0.1 percent of uranium can be feasibly utilized.

The amount of uranium produced in 2012 was slightly under 70,000 tons. The top uranium-producing countries in 2012 were Kazakhstan (accounting for 36.5 percent of the total production of uranium), Canada (15 percent), and Australia (12 percent). Other major producers over recent years include Nigeria, Namibia, and Russia (Figure 3-6). *(WNA 2013)*

The largest natural uranium production companies are KazAtomProm, AREVA, and Cameco, which accounted for some 45 percent of the total production in 2012.

Even though the currently known resources are sufficient to cover the increase in demand due to the expected increase in the nuclear power generation capacity, exploration for new uranium resources is continuously underway around the world. The opening of new mines depends on the demand and global market price of uranium.

3.7.1.2 Secondary sources of uranium

Currently, uranium from secondary sources accounts for approximately 15 percent of the demand of uranium. In addition to natural uranium, sources of uranium include the process of mixing of high-enriched uranium (with a U-235 content of over 20 percent) gained from military sources, mainly nuclear weapons and submarines, with

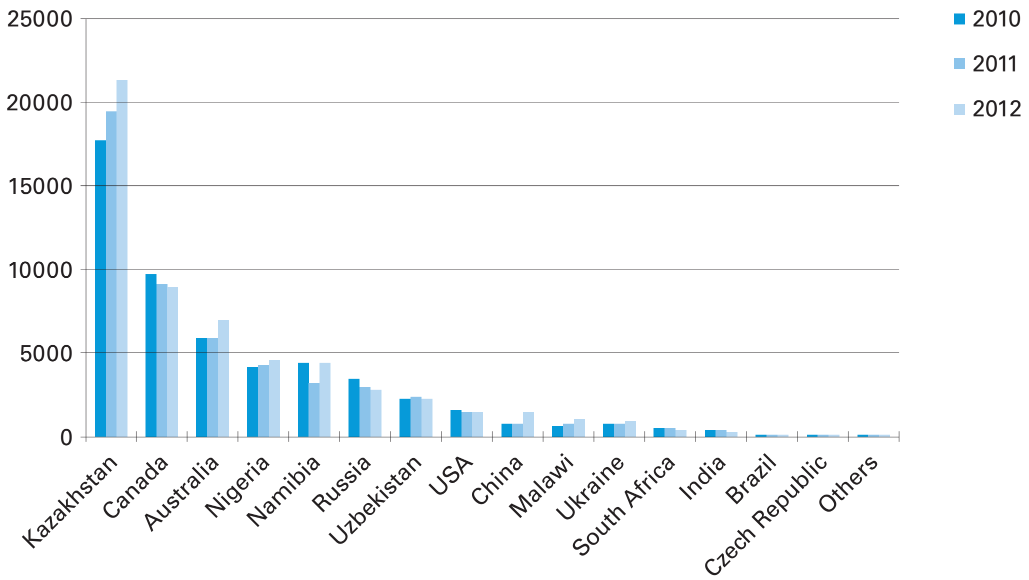


Figure 3-6. Natural uranium production volumes (tons) in 2010-2012 by country *(WNA 2013)*.

depleted uranium, re-enrichment of depleted uranium generated in the uranium fuel enrichment process, and reprocessing of spent fuel. In addition, there are some uranium stockpiles accumulated by investors operating on the raw material markets around the world. The amount of uranium fuel produced through reprocessing is estimated to increase up to twofold in the future.

Some depleted uranium generated in the uranium enrichment process is stored in Russia for re-enrichment because it can be utilized in the production of nuclear fuel in the future. Depleted uranium is also used for the production of mixed oxide fuel, a mixture of uranium oxide and plutonium oxide.

The plutonium separated during the reprocessing of spent nuclear fuel can be recycled into mixed oxide fuel, and the depleted uranium can be recycled to be re-used as nuclear fuel. While the plutonium can be immediately utilized in the production of mixed oxide fuel, the uranium has to be re-enriched in order to be recycled into nuclear fuel. There are reprocessing plants in France, Great Britain, Russia, and Japan. Mixed oxide fuel is produced in locations such as France and Great Britain.

The use of mixed oxide fuel is permitted in several European countries and Japan. Fennovoima is planning to use reprocessed uranium as fuel. However, there are no plans to use mixed oxide fuel.

3.7.1.3 The future outlook of the uranium market

Following the Fukushima accident, the price of uranium has been in steady decline, and it is estimated to reach a low point at the time of the preparation of this report. From this point on, the price is estimated to rise moderately, without major price spiking in sight.

Unlike in the case of energy generated using fossil fuels, in nuclear power production fuel accounts for only a minor part of the overall production costs. The price of uranium constitutes less than one-third of the cost of uranium fuel. Therefore, even a significant increase in the price of uranium will have little effect on the production costs of nuclear power.

In the future, the current producer countries will remain the main sources of uranium.

3.7.1.4 Availability of suppliers relating to the various production phases of uranium fuel

There are six conversion companies in the world, with plants in locations such as France, Great Britain, Russia, and the USA. The plants are currently operating at less than full capacity. *(WNA 2013)*

The enrichment market is dominated by four providers: AREVA (France), Urenco (Great Britain, Germany, the Netherlands), Tenex (Russia), and USEC (the USA). There are major enrichment plants in France, Germany, Great Britain, and Russia, to name some locations. Additionally, there are numerous smaller plants, with countries such as Japan and China having enrichment capacity. Furthermore, it is possible to increase the total enrichment capacity.

Zirconium, the material used in fuel rod cladding, is readily available. About five percent of the world's total zirconium consumption is currently used for the production of uranium fuel.

There are five suppliers of fuel rod bundles. Production plants for fuel rod bundles suitable for light water reactors are located in countries such as Sweden, Germany, Spain, France, the USA, and Russia. While fuel for the 1,200 MW plant planned by Fennovoima is currently only produced in Russia, it is feasible that in the future, the fuel will be produced in other locations as well.

3.7.2 The fuel production chain

When natural uranium is used, the phases of production of nuclear fuel will be as follows: mining and concentration of uranium ore, conversion into uranium hexafluoride (UF_6), enrichment for the U-235 isotope, the production of fuel pellets and fuel rods, and the manufacture of fuel rod bundles.

3.7.2.1 Mining and purification of uranium

Mining of uranium and concentration of ore belong to the scope of normal mining operations. Natural uranium is produced in underground mines and opencast quarries and through underground in-situ leaching. In 2012, underground mining accounted for 35 percent, opencast quarrying 20 percent, and in situ leaching 45 percent of the total production of natural uranium *(WNA 2013)*. The selection of the mining method depends on factors such as the uranium content of the deposit and the geological properties and ground water conditions prevailing at the area.

In conventional mines, the ore is broken loose from the rock, crushed, and milled. In the case of uranium deposits located deep inside the rock, uranium is mined from underground tunnels. Mining waste, tailings and gangue, and waste water are generated in the course of mining operations.

The fine ore is taken to a concentration plant, where the uranium is separated from the ore, typically using sulfuric acid. Usually, 75–90 percent of the uranium contained in the ore can be recovered. The uranium contained in the acid solution is concentrated through extraction using a variety of solvents, after which the uranium is precipitated into U_3O_8 (triuranium octaoxide) using ammonia. The final product of the extraction process is called uranium concentrate (yellowcake, Figure 3-7).

In the in situ leaching method, holes are drilled in the ground for the purpose of circulating an acidic or alkaline solution in the soil (Figure 3-8). The uranium mineral is dissolved into the circulating solution, which is circulated to a plant located on the surface and treated using either the solvent extraction or ion exchange method, depending on the acidity of the groundwater. The mixture recovered from the precipitation phase (U_3O_8) is dried at a high temperature. The in situ leaching method has been utilized for a long period of time in countries such as the USA and Kazakhstan, and the method is gaining wider use in the production of uranium.

3.7.2.2 Conversion and enrichment

For enrichment, the uranium concentrate (yellowcake) is converted into a gaseous form, uranium hexafluoride (UF_6) through chemical processes at a conversion plant. The processes make use of a variety of chemicals and thermal energy.

Natural uranium contains 0.7 percent of the isotope U-235. The uranium used in light water reactors must contain approximately 3-5 percent of U-235. Enrichment is performed using either gaseous diffusion or, increasingly, the centrifuge method, which requires a substantially lower amount of energy. In centrifugal separation, the uranium isotopes, which have different atomic masses, are separated from each other by centrifugal force.

The enrichment process yields 10-15 percent of the original amount of uranium as enriched uranium and 80-90 percent as so-called depleted uranium. Depleted uranium can be mainly utilized in the dilution of uranium derived from military use for use in civilian reactors.

At the conversion plant, gaseous and liquid impurities are generated in the process of production of fluorine and the fluorination of the uranium compound, as well as the solution purification processes. The most significant gaseous impurities monitored at conversion plants are hydrogen fluoride (HF), fluorine (F_2), and uranium isotopes (U).

The operation and maintenance of a centrifuge plant results in some gaseous radioactive emissions. For example, the wastewater from the gas scrubbers of the centrifuge plant is slightly radioactive.

3.7.2.3 The manufacture of fuel rod bundles

The production phases taking place at the fuel production plant are as follows: conversion of uranium hexafluoride into uranium dioxide, production of pellets, manufacture of fuel rods, and manufacture of fuel rod bundles (Figure 3-9).

The uranium dioxide is stored in drums at the fuel production plant. The uranium dioxide powder is compressed into pellets with a diameter of approximately 1 centimeter and a length of approximately 2 centimeters. The cylindrical pellets are loaded into cladding tubes made of zirconium alloy and with a length of 3-4 meters. The fuel rod thus formed is then filled with helium and sealed tightly. During assembly, the fuel rods are composed into fuel rod bundles with an approximate diameter of 30 centimeters. The fuel rod bundles used in pressurized water reactors typically contain around 300 fuel rods.

Enriched uranium contains only minor amounts of the uranium decay products which are more harmful in terms of radiation, such as radium, radon, or polonium.

Exhaust air and wastewater led outside the production plant are decontaminated as necessary before they are released into the environment. The air exhausted from the plant is led through a filter.

Figure 3-7. Uranium concentrate (yellow cake).

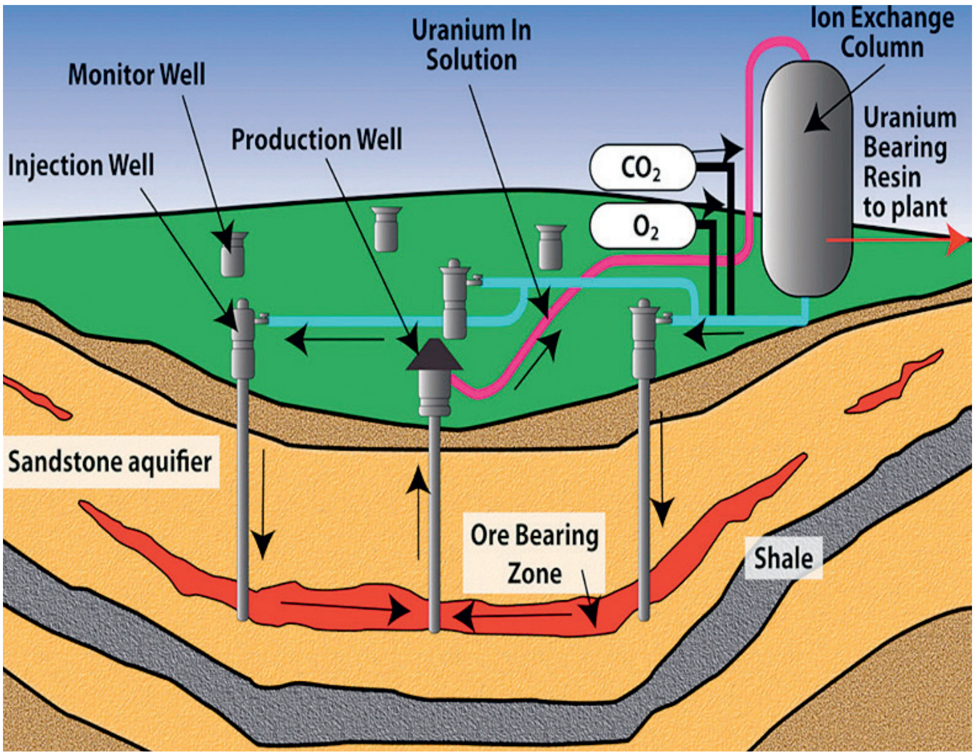


Figure 3-8. The underground in situ leaching method.

3.7.2.4 Transport and storage in the nuclear fuel production chain

At the concentration plant, the natural uranium concentrate is packed into 200-liter drums, which are loaded into containers and transported by ship or by train to intermediate storage and the conversion plant. The uranium concentrate is only slightly radioactive, and the steel transport containers provide adequate radiation protection. The transport only requires equipment suitable for transporting hazardous materials.

After the conversion, the uranium hexafluoride is stored in a solid form in pressurized 8.45-ton containers, in which it is transported to the enrichment plant using a train or trucks. As uranium hexafluoride is chemically highly toxic, appropriate precautionary measures are applied in the transport operations.

For transportation, the enriched uranium is packed, in solid form, into containers similar to the ones used to transport it to the enrichment plant. The transport container has a double structure, and it is thermally protected to withstand, for example, a fire occurring during an accident (Figure 3-10).

The fresh nuclear fuel elements are transported from the fuel production plant to the nuclear power plant in special containers which protect the fuel elements during transport (Figure 3-11). Due to low radioactivity, no special radiation protection is required.

3.7.3 Quality and environmental objectives set for the supply chain of nuclear fuel

The quality requirements set for nuclear fuel are associated with the functionality and reliability of the fuel. Included in the scope of functionality are the flexibility of use, high energy yield, and long service life in the reactor. Reliability means that the fuel rods remain in good condition under all operating conditions as well as exceptional conditions.

The design and manufacture of fuel rod bundles is governed by strict quality standards. Fuel manufacturers and buyers have comprehensive quality control programs and procedures in place in order to ensure that the fuel rod bundles comply with the set requirements. Quality control includes the performance of specific tests and inspections on the fuel materials, assemblies, and their components, as well as the equipment used to manufacture them. Quality assurance is based on inspections performed by external auditors as well as control of the test and inspection results, the purpose of which is to ensure that the work processes in different manufacturing phases and the associated inspections are carried out in compliance with requirements and that the end result meets the requirements set for it. The programs must comply with the requirements set by the national nuclear power authorities of the home countries of both the producer and the purchaser. In addition, all major nuclear fuel suppliers apply in their operations the international quality management standards, as the ISO 9000 standard.

As required by the Nuclear Energy Decree, the Radiation and Nuclear Safety Authority (STUK), supervises the compliance of the design, manufacture, transport, storage, handling, and use of nuclear fuel with the relevant rules and regulations. The requirements pertaining to the phases listed above are presented in the STUK regulatory guides on nuclear safety dealing with nuclear materials.

In addition to quality parameters, the buyers also pay attention to the environmental aspects of the fuel production process. Issues relating to environmental impacts are assessed according to criteria set by the buyer's own environmental policy. The fuel suppliers may be expected to have in place an environmental management system or otherwise prove that environmental matters are managed in an

Figure 3-9. Fuel pellets and manufacture of fuel rod bundles.

Figure 3-10. Enriched uranium transport containers. *(E.ON 2008)*

Figure 3-11. Transport containers of fuel rod bundles. *(E.ON 2008)*

acceptable manner. The minimum requirement is that the operations of the producer comply with national legislation and regulations.

WNA, WANO (World Association of Nuclear Operators), and IAEA (International Atomic Energy Agency) have produced international instructions and guidelines concerning the best practices to be observed in the different phases of nuclear fuel production with regard to both safety and the environment. In particular, the principles of the WNA guidelines are intended for countries where legislation has not yet reached a standard where sufficient consideration of issues such as environmental matters would be ensured. *(WNA 2008)*

The buyers of nuclear fuel carry out audits in the companies and production plants operating at the different stages of the uranium production chain. One purpose of the audits is to form an idea of the standard of environmental protection management in the companies comprising the fuel production chain, the degree to which environmental regulations and standards are observed, and the management of industrial safety matters.

During the audits, attention is paid to matters such as emissions caused by the operations and the monitoring thereof, transportation, subcontracting, contribution to services for the local population, safety and security, risk analyses, handling of exceptional situations, and radiation protection. In the audits, attention is also paid to possible areas of improvement, which are discussed with the production company.

3.8 Use of chemicals

According to the legislation governing the use of chemicals, the chemicals to be used should, if possible, be selected among the least harmful ones. Approximately 200 tons of various chemicals will be used at the nuclear power plant every year. The majority of the chemicals will be various acids and bases used in the production of power plant process water and the control of chemical reactions in the plant's water circulation systems. Chemicals will also be used for cleaning the closed steam cycle equipment and pipelines and preventing corrosion. The most frequently used bases and acids, such as sodium hydroxide, sulfuric acid, and boric acid, will be stored in tanks with volumes of 20–50 m^3. Other chemicals will be stored in various containers or vessels located in facilities specifically designed as chemical stores, or in small tanks.

The power plant's process water will be produced in a water treatment plant, where the raw water supplied from the municipal water utility is led through ion exchangers in order to remove various salts contained in it. This process, which is called demineralization, will utilize sulfuric acid and sodium hydroxide. The process water will be deoxygenated using an oxygen scavenger. Hydrazine is usually used as oxygen scavenger. However, due to its haxardous impacts to human health, an effort will be made to use other chemicals, that prove suitable for the selected components of the power plant.

Water treatment chemicals will also be needed for the control of the acidity of, and chemical reactions in, the plant's water circulation systems. The chemicals used for these purposes include ammonia water and sodium phosphate. Boric acid will be used to control the power (reactivity) of the pressurized water reactor.

Nuclear power plant processes will also utilize flammable liquids and gases. For example, hydrogen will be used for the cooling of the generator located in the turbine plant. Nitrogen gas will be used to provide motive power for certain equipment, and it can also be used to pressurize the emergency cooling water tanks. Other flammable liquids and gases, such as gaseous oxygen, acetone, and acetylene will be stored as necessary.

The emergency diesel generators used to provide back-up power will be fueled with light fuel oil. According to current design, the plant will be equipped with three 10-megawatt auxiliary steam boilers, the purpose of which is to generate steam for the plant process during operational transients as well as for plant heating. The auxiliary steam boilers will also be fueled with light fuel oil.

The amount of light fuel oil stored for the back-up power generators (emergency diesel generators) will be 1,000–2,000 tons per year. A minimum of some 400 tons of light fuel oil, enough for seven days' operation, will be stored for the auxiliary steam boilers.

Furthermore, a gas turbine plant may be built at the power plant site. The plant would only be used during power grid disturbances. The amount of light fuel oil stored will be approximately 4,000 m^3, which will be enough for five days' operation.

Lubricating oils will be used to lubricate rotating machines (including the turbine and generator bearings and pumps). Additionally, the transformer will contain a large amount of oil for cooling purposes.

The prevention of various leakage and accident situations will be taken into account in the design of the chemical and fuel systems. Risk analyses will be carried out to support the design. The chemical offloading locations, storage tanks and stores, and the chemical dosing systems will be constructed in accordance with the legislation governing the safe storage and handling of hazardous chemicals and the pursuant Finnish Safety and Chemicals Agency (TUKES) guidelines as well as the SFS standards. In preparation for leaks, all premises housing chemical tanks or storage facilities will be drained to guard basins, slurry and oil separation wells, and neutralizing tanks. The chemical offloading locations will also be equipped with basins.

The chemical user's duties and responsibilities specified in the REACH regulation, as well as the safe handling instructions presented in the material safety data sheet specific to each chemical, will be taken into account in the storage and use of chemicals. Instructions will be prepared for the handling of chemicals. These instructions will also cover the actions to be taken in the case of eventual chemical leakages and accident situations. Furthermore, the plant personnel will be trained in the safe use of chemicals.

TUKES will monitor the handling and storage of hazardous chemicals and fuels. By virtue of the amount of hazardous chemicals stored at the nuclear power plant, the related operations are considered extensive. Consequently, a corresponding permit must be applied for from TUKES.

The relevant safety instructions and regulations will be observed when transporting chemicals. The transportation of hazardous chemicals is governed by the Act on the Transport of Dangerous Goods (719/1994) and other regulations of lower degree issued pursuant to it.

3.9 Water consumption and supply

3.9.1 Cooling water supply and discharge of cooling water into the sea

The cooling water use will vary in proportion to the amount of energy produced. The 1,200-megawatt plant will use sea water at an approximate rate of 40–45 m^3/s for the cooling of the condensers. According to the plan, the cooling water will be taken from the dock basin located at the western shore of the Hanhikivi headland using an on-shore intake system and discharged at the northern part of the headland.

Before the cooling water is led into the condensers, major impurities or foreign objects are removed by leading the water through a coarse bar screen with bar spacing of approximately 10 centimeters, located at the mouth of the cooling water structure. After this, the cooling water will be led through a finer screen and, finally, through traveling band screens or equivalent filter equipment. The traveling band screens have a mesh size of about 1 mm^2. They are used to remove the remaining particles that could cause erosion when passing through the condenser pipes or other parts of the cooling water system. After the cooling water has passed through the condenser, it will be discharged back into the sea through the cooling water discharge channel. The temperature of the water will rise by 10–12 °C in the process.

The dispersion of the cooling water discharge and its impacts on the water system and the nature are discussed in Section 7.4.

3.9.2 Service water consumption

Fresh water will be usedat the power plant both for tap water and for preparing the plant's process waters. An estimate of the fresh water use of the power plant during the construction and operating phases (by fraction) is shown in the table below (Table 3-3). The power plant will require a service water supply capacity of about 600 m³/day.

3.9.3 Supply and treatment of service water

The primary alternative for the supply of service water is a centralized water supply from the municipal water utility. In this case, the water utility will be responsible for the water quality. Other alternatives include the supply of water from groundwater sources, from fresh surface water sources (such as the Pyhäjoki river) through purification, or from sea water sources through demineralization.

The quality of the groundwater is usually high enough to require little treatment. However, there are no sufficiently abundant groundwater deposits in the Pyhäjoki region. The purification of surface water for use as tap water requires thorough treatment, and, consequently, the construction of a separate treatment plant. Furthermore, the quality and availability of surface water varies significantly from one season to another. The quality and flow rate of the water of the Pyhäjoki river do not allow the use of the river water for the water supply needs of the power plant. Tap water can also be produced by demineralizing sea water through reverse osmosis. The advantage of this alternative is the secure supply of raw water. However, the application of this method would require a separate water production plant.

The process water required for the plant will be produced from tap water through demineralization using ion exchangers. The planned capacity of the demineralization plant is about 50 m³/h.

At the power plant, the service water will be stored in raw water, fire fighting water, and clean water tanks. Water will be pumped from the tanks for use as required. According to the plan, fire fighting water will be stored in two tanks, each with an approximate volume of 1,200 m³. The volume of the raw water tank will be large enough to accommodate preparation for a seven-day disruption in the service water supply. Demineralized water will be stored in two tanks. The capacity of one tank will be sufficient to enable one week's operation in a plant emergency. The volume of this tank will be approximately 1,000–2,000 m³. The water stored in this tank will not be used during normal operating conditions. The clean water stored in the other tank will enable normal power plant operation for three days. The volume of this tank will be approximately 2,000–3,000 m³.

3.10 Waste waters

At the power plant, waste water will be generated as a result of both the use of tap water and plant operations. Sanitary waste water includes waste water from sanitary facilities and shower rooms. Waste water generated in power plant operations includes various washing waters, as well as waste water resulting from the production and use of process water.

The volumes and treatment of the waste waters generated at the power plant are discussed separately for each waste water fraction in the following sections.

3.10.1 Flushing water from cooling water treatment equipment

Algae, fish, and other solids will be carried along with the cooling water to the plant. They will be removed using screens and various filters, and treated as biowaste. The matter accumulating in the cooling water treatment equipment will be flushed loose with sea water, and the flushing water will be led back to the sea. The amount of the flushing water generated from the cooling water treatment equipment will be approximately 50 m³ per hour, or 1,200 m³/day.

3.10.2 Sanitary waste water

The sanitary waste water generated at the power plant will be treated in a municipal water treatment plant.

During the construction phase, the sanitary waste water load will be higher than during the operating phase, because more people are working in the area. It is estimated that during the construction phase, sanitary waste water will be produced at an approximate rate of 300–450 m³/day. The volume of sanitary waste water generated during the operating phase is estimated to be about 150 m³/day during normal operation and about 250 m³/day during annual maintenance. Table 3-4 shows an estimate of the load on water systems caused by sanitary waste waters generated during the construction phase and the operating phase. The annual load caused by sanitary waste water during the construction phase will be equal to the load on water systems caused by some 1,500–2,300 people utilizing the services of municipal waste water treatment. During the operating phase, the annual load will be equal to the load caused by approximately 750 people (1,200 during maintenance outages).

Service water consumption		m³/day
During construction	Tap water	300–450
	Concrete batching plant	100
During plant operation	Tap water	150
	Process water	400–500
During annual maintenance	Tap water	250

Table 3-3. An estimate of service water use during the construction and operation of the plant.

3.10.3 Laundry waste water

A dedicated laundry will be built for the purpose of washing protective clothing worn in the controlled area of the power plant. In order to decrease the amount of radioactivity, the laundry waste water will be treated in the power plant's liquid waste treatment plant by means of filtration using a dirt trap. If measurable concentrations of radioactivity remain in the water, it will be submitted to further treatment using ion-selective filtering. After radiation measurement, the treated laundry waste water will be drained to the cooling water discharge channel. The estimated generation rate of laundry waste water is approximately 20 m^3/day. The phosphorus load caused by laundry waste water will be approximately 10 kg/year.

3.10.4 Other waste water

Process water refers to water circulating in the power plant's closed-cycle steam process system. The demineralization process used to produce process water requires the regeneration of the ion exchange resins. The regeneration will be carried out at the demineralization plant using water with sodium hydroxide or sulfuric acid added. The acidic and basic waters generated in the regeneration process will be drained to the neutralizing tank. The reject water from the reverse osmosis equipment of the demineralization plant will also be drained to the neutralizing tank. The waters will be neutralized to a pH range of 5–9 before they are drained to the cooling water discharge channel. The waste water generated at the demineralization plant is not radioactive, and it mostly contains salts generated in the neutralization process. The total volume of waste water generated at the demineralization plant is estimated to be about 100 m^3/day.

Further waste water mainly consists of filter rinsing and decanting water, floor washing water, laboratory drain water, and neutralized waste water generated in the decontamination process (cleaning of radioactive components). As it contains radioactive materials, it will be treated in the power plant's liquid waste processing plant. The water is treated by means of evaporation and filtration through an ion-selective filter mass. After radiation measurement, the treated water will be drained to the sea with the cooling water.

The estimated volume of this type of waste water is approximately 400 m^3/day. The subsequent annual phosphorus load is estimated to be approximately 10–40 kg, and the annual nitrogen load is estimated not to exceed 4,500 kg. The borium load on the water system caused by the pressurized water reactor will be approximately 6,000–9,000 kg/year.

3.10.5 Rain and foundation water

Rain water and foundation water (water drained to keep the building foundations dry) will be led to the sea via the necessary sedimentation wells and oil separators.

Rock blasting, rock excavation, and crushing operations will take place in the area during the construction phase. The foundation water and rain water drained from the construction site will contain more solids and eventual oil and nitrogen compounds than water drained from the yard areas during the operation of the plant. It will be led to the sea via the necessary clarification basins and oil separators. The quality and volume of water drained to the sea will be monitored.

3.11 Conventional waste management

3.11.1 Construction phase waste management

Waste management during the construction phase is regulated by the Waste Act (646/2011) and the Government Decree on Waste (179/2012). In addition to these, the municipal regulations concerning waste management must be applied. At least the following types of waste will be separated and sorted already at the construction site: metal waste, non-impregnated wood waste, concrete, brick, mineral tile, and ceramic waste, gypsum waste, glass waste, plastic waste, paper and cardboard waste, and soil and rock material. The handling, storage, and transportation of hazardous waste will be arranged in accordance with the regulations.

The waste management plan of the construction site will contain detailed instructions concerning the arrangement of overall waste management in accordance with the order of priority. The primary purpose of the order of priority is to minimize the amount of waste generated, with a secondary purpose of re-using the waste generated and a tertiary purpose of recycling the waste materials. The fourth alternative is to utilize the waste in other ways, including utilization for production of energy. The final alternative is the final disposal of the waste, that is, the appropriate disposal of the waste in a landfill site.

Table 3-4. An estimate of the emission load on water systems caused by treated sanitary waste water during the construction phase (300–450 m^3/day) and during the operating phase (150 m^3/day).

	Concentration, mg/l	Construction phase, kg/year	Operating phase, kg/year
Total phosphorus (P)	0.5	55–85	30
Total nitrogen (N)	15–30	1,600–5,000	800–1,600
Biological oxygen demand (BOD_7)	15	1,600–2,500	800
Solids (SS)	5	550–850	300

The contractors operating at the work site will be obligated to sort the waste at the location where it is generated. The sorted construction waste will be utilized or recycled as far as possible, and an effort will be made to utilize suitable waste material directly at the work site. An effort will also be made to minimize the amount of construction waste disposed of in landfill sites. From the construction site, the sorted waste will be delivered to companies entered in the waste management register and entitled to receive the waste fraction in question.

3.11.2 Operating phase waste management

As at any other energy production or industrial plant, conventional waste (including household, packing, and metal waste) and hazardous waste (including batteries, fluorescent tubes, and oil-contaminated filters) will be generated at the nuclear power plant.

Compliance with the principles of the Waste Act (646/2011) concerning the minimization of the amount of waste generated will be taken into account in the operation of the nuclear power plant. In practice, relevant instructions will be provided as part of the implementation of the plant's environmental management system. The system will contain the procedures and regulations for matters such as the management of environmental emissions. Conventional waste will be utilized as far as possible. All waste transported outside the plant will be delivered to waste management companies holding the appropriate permits for further treatment.

The annual waste quantities will vary depending on factors such as the extent of maintenance carried out. Included in conventional waste is iron and metal sheet scrap, wood, paper, and cardboard waste, biowaste, and energy waste (combustible waste). Hazardous waste consists of, for example, waste oil and other oil-contaminated waste, fluorescent tubes, solvent and chemical waste, as well as waste electric and electronic equipment.

The estimated annual amounts of conventional waste and hazardous waste are approximately 400 tons and approximately 50 tons, respectively.

Most of the waste generated can be utilized through recycling or use in energy production. Sorted waste will be delivered for treatment and appropriate disposal. All conventional and hazardous waste will be treated by companies holding all the required permits.

3.12 Operating waste management

Nuclear power plants differ from other power plants in that radioactive waste is generated in the course of their operation. This waste is divided into two main categories:

- very low, low, and intermediate level waste, i.e. operating waste
- high level waste, i.e. spent fuel.

The starting point for the management of radioactive waste generated in the nuclear power plant is the permanent isolation of the waste from the environment. The party under the nuclear waste management obligation (in practice, the owner of the nuclear power plant) will be responsible for the implementation of nuclear waste management and liable for covering the related expenses. According to the Nuclear Energy Act, nuclear waste must be treated, stored, and permanently disposed of in Finland. The Nuclear Energy Decree further specifies that the nuclear waste must be disposed of in the Finnish soil or bedrock. The final disposal of nuclear waste will be planned so that long-term safety can be secured without supervision at the disposal site. In Finland, the Ministry of Employment and the Economy and the Radiation and Nuclear Safety Authority (STUK) are responsible for controlling the adherence to the principles of nuclear waste management and the related safety requirements and regulations.

3.12.1 Classification of operating waste

"Operating waste" refers to solid and liquid, very low, low, or intermediate level waste generated in the course of processing of radioactive liquids and gases and the performance of maintenance and repair work in the controlled area. Most of the operating waste contains radioactive substances in such quantities that the special requirements specified in the Nuclear Energy Act (990/1987) must be observed during its handling, treatment, storage, and final disposal.

Operating waste is divided into low and intermediate level waste on the basis of its radioactivity content as follows:

- Low level waste, i.e. waste with a level of activity low enough to be handled without implementing any special radiation protection arrangements. The activity concentration of such waste does not exceed 1 MBq/kg.
- Intermediate level waste, i.e. waste with such level of activity that efficient radiation protection arrangements are required during its handling. The activity concentration of such waste is between 1 MBq/kg and 10,000 MBq/kg.

According to the IAEA recommendations and the Nuclear Energy Decree (736/2008), the classification presented above, which is currently in use in Finland, may be expanded to allow for the separation of very low level waste. Very low level waste is waste with a level of activity low enough to be handled without any radiation protection. The activity concentration of such waste does not exceed 100 kBq/kg.

Fennovoima is considering the adoption of a three-tier waste management system similar to the one described above, since this would allow for the final disposal of the very low level waste in a separate surface repository to be constructed in the ground. The main reason for the consideration of the construction of a surface repository is that its construction could significantly decrease the required volume of the repository to be constructed in the bedrock. The final decision on the construction of the surface repository will be made after the estimates on the amount of the waste presented by the plant supplier have been confirmed. Currently, the amount of very low level waste appears to remain so little that the construction of a separate surface repository may not be feasible.

Waste for which handling, storage, and disposal of as radioactive waste is not expedient (taking into account the radiation safety principles) can be cleared on the basis of activity limits set by the authorities. The basic radiation safety requirement observed in the clearance procedure is that the annual dose from cleared materials from one nuclear power plant to the general population or the personnel working at the waste processing site does not exceed 10 µSv. Cleared waste will no longer be considered operating waste, and it can be disposed of or re-used like ordinary waste. The Hanhikivi power plant's solid waste treatment facilities will have a separate area for the processing of waste to be cleared and the related activity measurements.

In the operating waste processing phase, the most important radionuclide in terms of the health effects of radioactive radiation is the cobalt isotope Co-60, which, as a powerful gamma emitter, causes most of the radiation exposure of the personnel involved in the processing of waste. However, as Co-60 is a relatively short-lived radionuclide, it is not relevant in terms of final disposal of operating waste. Relevant in terms of final disposal are the longer-lived radionuclides Sr-90 and Cs-137, which decay to an insignificant level in about 500 years. When considering the even longer term, extremely long-lived radionuclides, such as Tc-99, I-129, Cs-135, and plutonium isotopes, can be deemed the most relevant. However, their concentration in the operating waste will be very low.

3.12.2 Volume, origin, and quality of operating waste

Most of the operating waste will be dry waste, mainly consisting of contaminated waste generated in conjunction with maintenance and repair work, such as protective clothing, plastic, paper, insulation material, small metal objects, ventilation filters, electric cables, and cleaning utensils. This waste is usually low level waste.

In addition to the waste listed above, operating waste will include metal waste, wet waste, hazardous waste, and power plant decommissioning waste (Section 3.14).

Metal waste will include decommissioned tools, equipment, and machine parts, the surfaces of which have been contaminated with radioactive substances. This waste is mainly low level waste. Metal waste will also include components and equipment removed from inside the reactor pressure vessel that have been activated by neutron radiation. This waste is intermediate level waste.

Wet waste will mainly consist of radioactive concentrates and masses accumulated as a result of the plant's water treatment operations, such as spent ion exchange resins, filter support media, evaporation residue, corrosion sludge, active carbon sludge, and sludge accumulated as a result of cleaning activities.

Bringing unnecessary materials to the controlled area will be avoided in order to minimize the amount of waste generated there. The generation of waste can also be prevented by careful planning and implementation of maintenance operations, by choosing the right work methods, by efficient sorting of waste, and by favoring re-usable materials as far as possible.

Table 3-5 shows an estimate of the volumes of low and intermediate level waste generated at a plant with a power of about 1,200 MW (*Platom 2013a*). The estimated volume of waste requiring final disposal generated over the entire service life of the plant is approximately 5,000 m^3.

3.12.3 Processing of operating waste

According to the regulatory guides on nuclear safety (YVL Guide D.4) issued by the Nuclear Safety Authority (STUK), nuclear power plants must have sufficient facilities for processing and storing low and medium level waste. Systems must be designed for the facilities that allow the safe handling and transfer of waste, as well as measuring the amount and type of radioactive substances that it contains.

Whenever possible, the solid radioactive waste will be sorted at the site where the waste is generated. Sorted waste will be removed from the plant premises without delay. For storage or final disposal, maintenance waste will be packed in vessels (typically, 200-liter drums) which facilitate the transfer of the waste, prevent the spreading of radioactive contamination, and reduce the risk of fire. Before waste is packed in the storage or disposal vessels, its volume will be decreased using various methods (for example, compression or mechanical or thermal cutting). Compression typically

Table 3-5. An estimate of the volumes of low and intermediate level waste generated at the power plant annually and over the service life of 60 years (after treatment and packing).

	Waste volume	
	[m³/v]	[m³/60 v]
Dry waste		
Compressible		
Very low level	-	-
Low level	12.1	726
Intermediate level	4	240
Non-compressible		
Very low level	-	-
Low level	22.5	1,350
Intermediate level	3.6	216
Totals for dry waste	**42.2**	**2532**
Wet waste		
Ion exchange masses		
Very low level	-	-
Low level	16.8	1,008
Intermediate level	18.3	1,098
Other miscellaneous masses	-	-
Totals for wet waste	**35.1**	**2,106**
Grand total	**77.3**	**4638**

reduces the volume of the waste to half, sometimes even one-tenth, of the original volume. The spreading of contamination will be prevented by equipping the processing equipment with suction or filtering for exhaust air, or by using a processing method that does not generate dust.

Wet and liquid radioactive waste, ion exchange resins, sludge materials, and concentrates will be processed by drying. Wet waste will be solidified in cement order to facilitate safe handling and final disposal. Dried and solidified wet waste will be typically packed in 200-liter drums for storage and final disposal.

For further treatment and final disposal of the waste, it will be characterized, i.e. its properties will be determined. This means that the physical, chemical, and radiological properties of the waste or waste packages will be established through different measurements. Details of each lot of waste will be collected in a bookkeeping and monitoring system. Because of this, the characterization details of a certain lot of waste will accompany it all the way to final disposal.

Packed and characterized waste will be stored under supervision in a storage building located in the immediate vicinity of the solid waste treatment facilities in the plant area. According to the plan, enough storage capacity for 10 years will be built for very low, low, and intermediate level waste.

3.12.4 Final disposal of operating waste

Table 3-5 shows an estimate of the annual volume of operating waste (after treatment) requiring final disposal.

For final disposal, very low level waste to be placed in the surface repository can be baled or packed into flexible intermediate bulk containers or drums. In the case that a surface repository will not be built, very low level waste will be compressed and packed into 200-liter drums in the same way as other low and intermediate level waste. For final disposal, the intermediate level waste packed into drums will be further placed into concrete crates. The concrete crates will function as radiation shields and technical release barriers.

The principle of final disposal is to isolate the radioactive substances contained in the waste from living nature so that the safety of the environment is not endangered at any stage.

The final disposal methods of very low, low, and intermediate level waste can be roughly divided into two categories on the basis of the disposal location:

- Disposal in a repository located on, or immediately below, the ground surface (Section 3.12.4.1)
- Disposal in a repository located below the ground surface, excavated at the minimum depth of several dozens of meters, inside the geological layers (Section 3.12.4.2).

3.12.4.1 Surface repository

In Finland, only very low level waste, with an average activity concentration not exceeding 100 kBq/kg, may be disposed of in ground repositories, or surface repositories. Fennovoima is considering the construction of a surface repository for very low level waste. As mentioned above, the disposal of very low level waste in a surface repository would have substantially decreased the required volume of the repository to be constructed in the bedrock, particularly in the case of a boiling water plant. Should Fennovoima decide to build a surface repository, it is estimated to reach operational status approximately two years after the of the first startup of the power plant. Should Fennovoima decide not to build a surface repository, very low level waste will be disposed of in underground repositories in the same way as other, higher level operating waste.

A surface repository is an overground structure (Figure 3-12) in which the waste is loaded on a concrete slab. Any leakage water is recovered from the slab surface. Alternatively, the surface repository can be constructed on a well-insulated base which admits the flow of leakage water, while the release barrier retains any contaminants. In either case, the surface repository will be completely or nearly completely insulated by means of waterproof surface layers (clay or geotextile layers). This will keep the waste dry, making the water permeability of the ground significant only in postulated failure situations, such as the failure of the isolating surface layer of the waste and the concrete slab. The small amounts of leakage water, if any, will be admitted out of the repository. The packing of waste and the filling of the space left between the waste packages with a water-permeable filling will ensure that as little leakage water as possible is filtered through the waste. Releases are thus prevented by the concrete slab or a release barrier installed beneath the base.

The repository will be ready for operation when the base layer is ready and the construction of transportation accessways and systems (e.g. the ground water measuring system) is completed. The first deposit campaign may be carried out when enough waste requiring final disposal has been packed for a campaign. Furthermore, sufficient amounts of filling and covering materials shall be stored, in an appropriate manner, in the vicinity of the repository. Following the final sealing of the repository, it will be actively monitored until the radioactivity of the disposed waste has been reduced to an insignificant level. Accord-

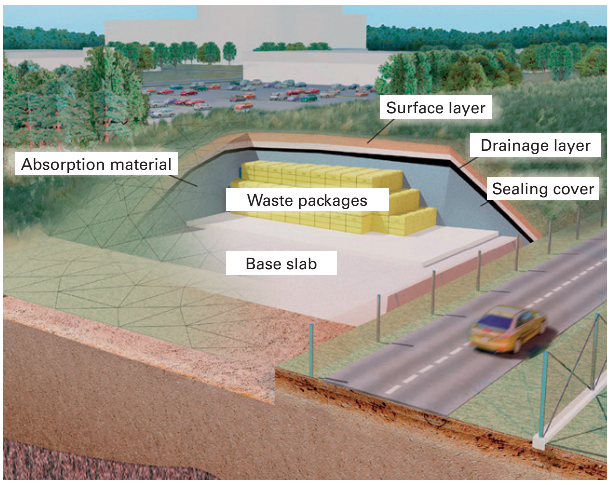


Figure 3-12. The principle of a surface repository.

ing to a preliminary estimate, this will take some 50–60 years. *(Platom 2013b)*
The monitoring activities include:

- monitoring of the ground water conditions and annual reporting of the results to the authorities,
- monitoring of the leaktightness of the base slab (if used) by checking the leakage water drain located at the lowest point of the slab,
- ambient radiation monitoring, and
- checking the condition of the repository, particularly the surface layers, for any damage.

After the end of the active monitoring period, the monitoring of the area can be continued to ensure the preservation of the information concerning the repository, the guard fences, and outdoor identification signs (passive monitoring). *(Platom 2013b)*

3.12.4.2 Operating waste repository

For the final disposal of low and intermediate level waste, Fennovoima will construct an operating waste repository (VLJ repository) in the bedrock of the plant area, at the depth of approximately 100 meters. According to the current plans, the VLJ repository would be taken into operation no earlier than 10 years after the first startup of the plant.

The low and intermediate waste repository may be of either the rock silo or the tunnel type. Of these, the latter solution is more probable. In the case of a tunnel-type repository, the waste would be transported in via a vehicle access tunnel (Figure 3-13). Bedrock will function as the primary release barrier. If necessary, the waste canister and the cement used as binding agent in the solidification process will also function as release barriers. Additionally, various concrete structures may be used, particularly in the intermediate level waste repository.

3.13 Spent nuclear fuel

Approximately 20–30 tons of uranium will be removed as spent fuel from the reactor of the nuclear power plant each year. An approximate total of 1,200–1,800 tons of spent nuclear fuel will be generated over the course of the 60 years of operation of the nuclear power plant.

Ninety-five percent of the spent nuclear fuel is uranium isotope U-238 and one percent of uranium isotope U-235. Spent nuclear fuel contains new elements generated through the uranium decay process and neutron capture. Most of the new elements are fission products. The rest are elements heavier than uranium, or transuranic elements. Fission products and transuranic elements are radioactive. The higher the burnup of the fuel (the amount of energy produced by the nuclear fuel per unit of mass), the higher the concentration of radionuclides (radiation-emitting atomic nuclei) and the higher the temperature it produces.

According to the Nuclear Energy Act, the producer of nuclear waste shall be responsible for the management of the spent nuclear fuel it has produced until the sealing of the repository, and shall make financial provision for the costs arising from the management of nuclear waste. In order to cover the costs, the producer of nuclear electricity shall make an annual payment to the National Nuclear Waste Management Fund, administered by the Ministry of Employment and the Economy. The payments shall be made such that fund contains sufficient funds for the organization of waste management.

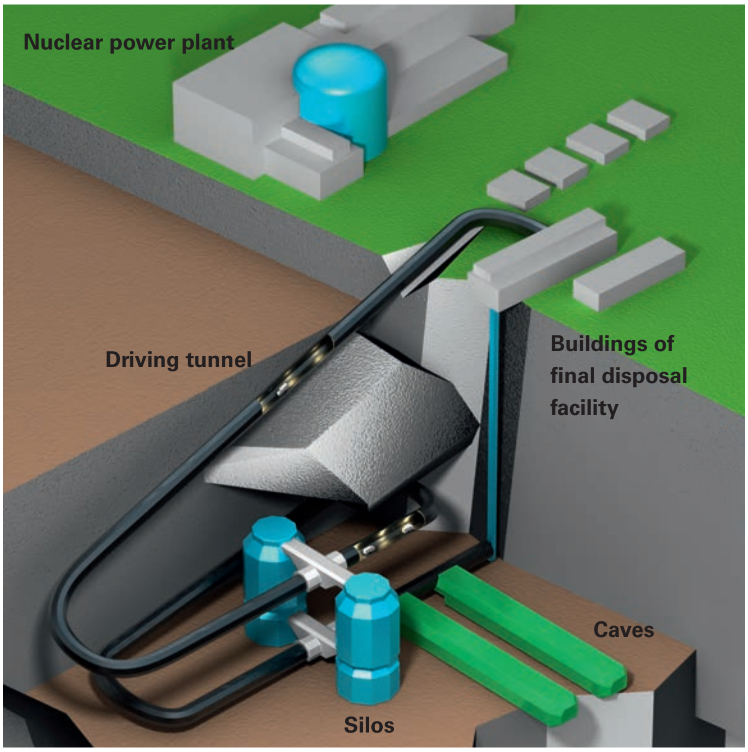


Figure 3-13. An example of a low and intermediate level waste repository of the tunnel type.

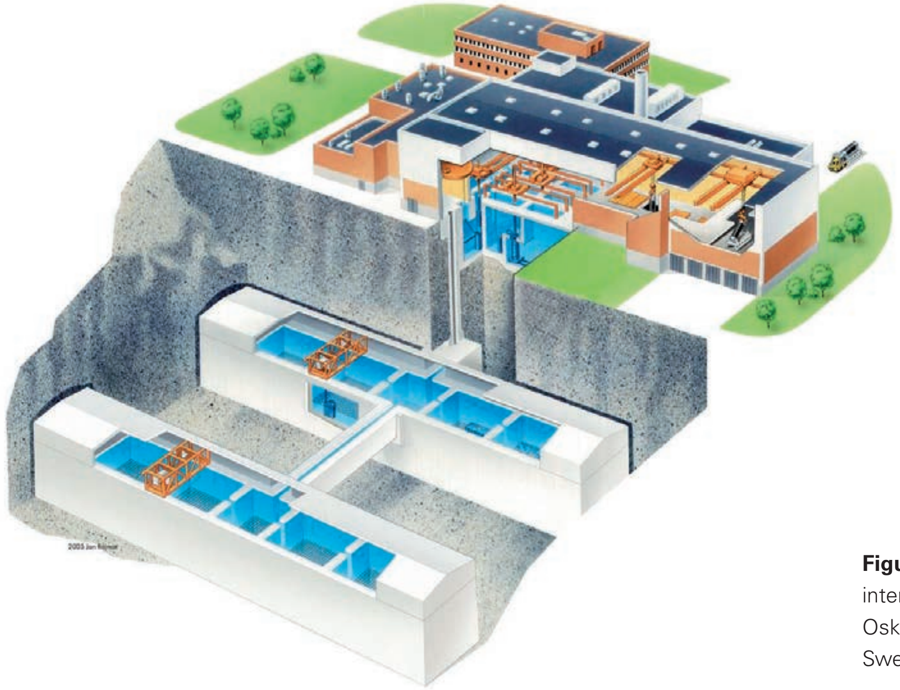


Figure 3-14. A water-pool-type spent fuel interim storage facility located at the Oskarshamn nuclear power plant in Sweden (CLAB).

3.13.1 Interim storage at the plant area

Following removal from the reactor, the spent fuel rod bundles will be transferred to the reactor hall water pools, where they are allowed to cool down for 3–10 years.

The activity and, simultaneously, heat production of the fuel will decrease rapidly during the first year after removal from the reactor. From the reactor hall, the spent fuel will be taken in transport containers to interim storage, where it will remain for a minimum of 40 years prior to final disposal. During interim storage, the activity and heat generation of the spent fuel will further decrease significantly.

Water pools (Figure 3-14) or dry storage (Figure 3-15) will be used for storing the spent nuclear fuel. The water pools are typically located in buildings made of steel-reinforced concrete or equivalent structures. Water functions as a radiation shield and cools the spent fuel.

In dry storage, the spent fuel is packed in special containers designed for the purpose. The heat released by the spent fuel is conducted into the atmosphere via the container material. Dry storage methods have been developed in several countries. They are mainly based on the use of metallic (steel or cast iron) containers, concrete containers, or concrete modules. When concrete containers are used, the spent fuel is additionally packed inside a gas-tight thin metallic jacket. The containers can also be used to transport spent fuel. The container functions as a radiation shield and prevents the spreading of radioactivity contained both in gas and in particles. As the thermal conductivity of air is inferior to that of water, the temperature of the fuel decreases at a slower rate in dry storage than in pool storage. The containers are stored in dedicated storage buildings. The storage facilities are cooled as required to reduce the temperature.

The spent fuel interim storage facility will be constructed in the power plant area similarly to the currently existing power plants in Loviisa and Olkiluoto, where interim storage takes place in water pools. The interim storage concept will be presented in the power plant construction license application, and the facility will be constructed within approximately ten years of the commissioning of the plant.

Figure 3-15. A spent fuel dry storage facility *(E.ON 2008).*

3.13.2 Transportation to final disposal

After intermediate storage, the spent fuel will be transported to the final disposal facility. For transportation, the fuel will be transferred into a transport container.

Transport containers are commercially available. Dry interim storage containers of the same type as those described above may be used as transport containers. The purpose of the container is to protect the fuel from damage during transportation and to protect the surroundings from the fuel. The transport containers are designed to withstand an airplane crash as well as a kerosene fire. The containers must pass several different drop tests in order to be approved for use in transportation of spent fuel. Furthermore, the transport containers must also remain leaktight under pressure. The thick walls of the transport container, which are made of dense material, effectively attenuate the gamma radiation emitted by the nuclear fuel and completely stop the alpha and beta radiation. In normal transportation situations, the dose rate of the radiation shall not exceed 0.1 mSv/h measured at the distance of 1 meter from the outer surface of the transport container or 2 mSv/h measured at the outer surface of the transport container. The container and its contents shall withstand the stresses caused by the transportation without damage, and leakage from the container shall remain very small.

Transport containers manufactured in accordance with the guidance values of the International Atomic Energy Agency (IAEA) shall not break even in the case of a high-velocity collision with a point-like object, e.g. a reinforced steel column. In such a case, the container may bend and lose its leaktightness. However, as the container would not break, only gaseous or otherwise easily released radioactive substances could escape from the nuclear fuel rods into the environment. As the transportation is carried out at low speeds, the swerving off the road of the transportation vehicle and its collision into a concrete structure or a rock cutting alone cannot generate forces of this magnitude.

Spent fuel can be transported from the nuclear power plant to the repository by road, by rail, or by sea. In road transportation, a special carriage hauled by a truck is utilized. Road transportation will take place under supervision, and each transport will be escorted by supervision and security personnel. In urban areas, police patrols will close off the crossing streets as the transportation convoy passes the area. Taking into account the required stops, the average speed of the transportation convoy will be approximately 35 km/h. In rail transportation, the train carrying nuclear fuel must not meet train carriages carrying hazardous substances, the grade crossings must be guarded, and the speed of the train must not exceed 40 km/h. Sea transportation of spent nuclear fuel requires a vessel specifically designed for the transportation of high level nuclear material (an example of such vessel being the Swedish “Sigyn”). The dock basin and wharf planned at the western shore of the Hanhikivi headland are dimensioned so that spent nuclear fuel can be transferred into a vessel in that location for sea transport.

In all transportation alternatives, the transportation of spent nuclear fuel from the Pyhäjoki power plant located in the Hanhikivi headland begins as road transportation. An exception to this is the alternative in which sea transportation begins right at the plant’s harbor. In the road transportation alternative, the transportation convoy starts at the nuclear power plant and progress to main road 8 via the planned new road. From the crossing of the new road leading to the Hanhikivi headland and main road 8, the spent nuclear fuel transport convoy progresses towards the final disposal facility.

In the rail transportation alternative, the spent nuclear fuel is first transported by road from the nuclear power plant to the Raahe harbor via the following route: the nuclear power plant - the planned road from the Hanhikivi headland to main road 8 - main road 8 northwards - Koksaamontie - the Raahe harbor railroad stop. The transportation distance is approximately 27 kilometers. At the Raahe railroad stop, the transport container is transferred to a low loader wagon designed for heavy special transport. From the Raahe railroad stop, the rail transportation convoy progresses towards the repository site, where the transport container is transferred by road from the nearest rail transport offloading location to the repository site.

In the sea transportation alternative, the spent nuclear fuel is transported to the Raahe harbor via the same route as in rail transportation. In the harbor, the transport container is transferred into a vessel designed for the transportation of nuclear materials. From the Raahe harbor, the vessel progresses towards the repository site, where the transport container is transferred by road to the repository site. Alternatively, the harbor planned to be constructed at the Hanhikivi headland can be used.

As the estimated amount of spent uranium nuclear fuel generated over the 60-year service life of the power plant is 1,200–1,800 tons, a total of 120–180 spent fuel transportation operations will be required during the final disposal activities (assuming that one transport container holds approximately 10 tons of spent fuel).

Fennovoima will present the detailed spent fuel transportation alternatives and the associated risk estimates in conjunction with the final disposal facility licensing procedures.

The transportation of spent fuel is subject to license. The licensee must prepare a transportation plan, on the basis of which the Radiation and Nuclear Safety Authority (STUK) will decide on the granting of the transportation license. STUK will assess matters such as the transportation plan, the structure of the transport container, the qualifications of the transportation personnel, and the accident and malicious damage preparedness plans.

The radiation and environmental impacts caused by the transportation operations are described in Chapter 7.

3.13.3 Final disposal solutions

According to the Finnish Nuclear Energy Act, all nuclear fuel spent in Finland must be processed in Finland. As there are no spent nuclear fuel reprocessing plants in Finland, the reprocessing of spent nuclear fuel is not possible.

According to the Nuclear Energy Agency (NEA), an OECD organization, geological final disposal is the most recommendable nuclear waste management strategy. In Finland, the development of geological final disposal has continued without interruption for some 30 years. As a consequence of this long-term development work, Posiva applied for a construction license for a final disposal facility in 2012.

The current understanding is that the spent fuel generated in Fennovoima's nuclear power plant will be disposed of in the Finnish bedrock. The disposal would utilize the KBS-3 (Kärn Bränsle Säkerhet) technology developed in Sweden (SKB Svensk Kärnbränslehantering AB) and Finland (Posiva). As the disposal of spent fuel will not begin until the 2070s, the technological developments in the field can be taken into account in the planning of Fennovoima's final disposal operations.

In the final disposal solution following the KBS-3 concept, the spent fuel is encapsulated in copper canisters, surrounded with bentonite clay, and deposited in deposit holes drilled deep in the bedrock (Figure 3-16). Bentonite is capable of absorbing large quantities of water and consequently expand up to ten-fold in favorable circumstances. The expanded bentonite fills tightly the space surrounding the copper canister. Following the end of the disposal operations, the deposit tunnels will be filled with a mixture of bentonite and crushed rock.

The location depth of the repository will be determined by the geological properties of the selected final disposal site. In any case, the final disposal will take place at the depth of several hundreds of meters. While the selection of the final disposal site depends on several different factors, the most significant ones in terms of the safety of the disposal are related to the geological properties of the bedrock. Guaranteeing the functionality of the copper canister and the buffer material requires that the bedrock is geologically stable, the groundwater flow is low, and the chemical properties of the groundwater are favorable.

In addition to the deposit tunnels, the final disposal facility will comprise an encapsulation plant and the associated auxiliary facilities.

Fennovoima is currently preparing an overall plan on the final disposal of spent nuclear fuel. The matters discussed in the plan include the preliminary schedule for the disposal of the spent nuclear fuel generated in Fennovoima's nuclear power plant and interests in common with the current operators regarding their final disposal project. One of the main goals of the overall plan is to determine an optimal final disposal solution which can, for its part, promote cooperation between Fennovoima and the other parties under the nuclear waste management obligation.

A condition attached to Fennovoima's Decision-in-Principle states that Fennovoima shall produce an agreement on nuclear waste management cooperation with the parties currently under the nuclear waste management obligation or start its own EIA procedure for the final disposal project by summer 2016. The final disposal of Fennovoima's spent fuel will require the completion of EIA and Decision-in-Principle procedures as well as construction and operating licenses regardless of the location of the final disposal facility.

3.14 Decommissioning of the power plant

The minimum estimated operational lifetime of the nuclear power plant is 60 years. Following the end of its lifetime, the plant will be closed down and dismantled (decommissioned). Decommissioning ensures the safety of the plant's surroundings after it is closed down.

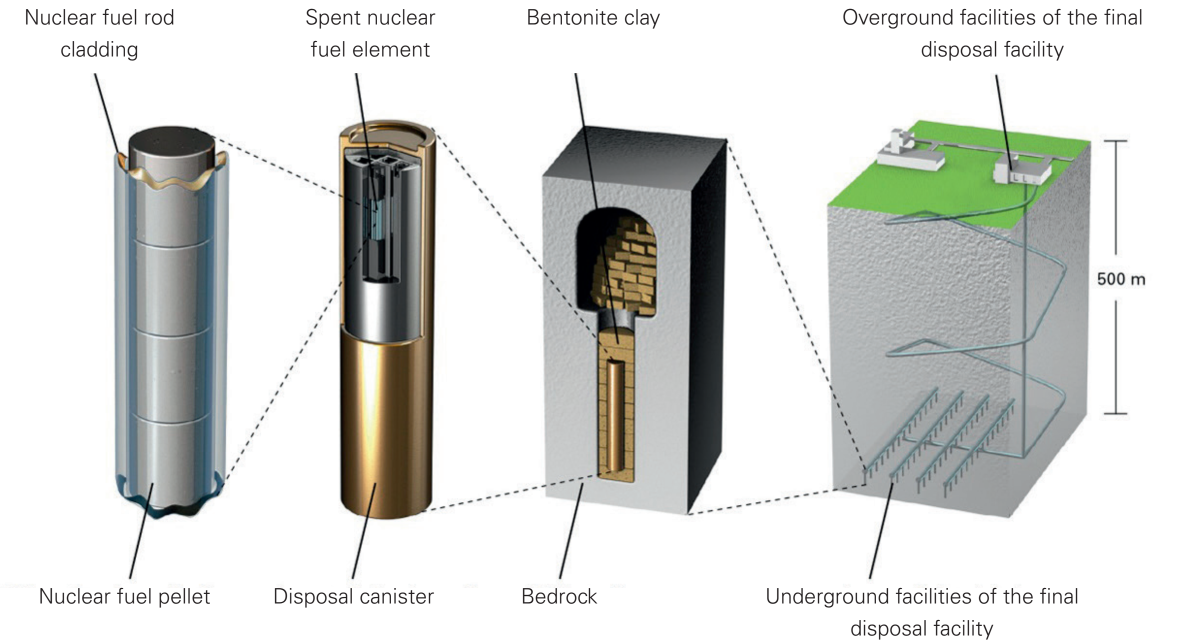


Figure 3-16. Radioactive substance release barriers used in the KBS-3 method.

Decommissioning waste is waste generated in conjunction with the closing down and dismantling of the nuclear power plant. When the operation of the nuclear power plant is discontinued, radioactive substances originating from the migration of radioactive contamination or the activation of the materials of components located in the immediate vicinity of the nuclear reactor will remain in the plant's structures, systems, and equipment.

The goal of the decommissioning of the plant is to dismantle the radioactive systems, completely decontaminate the nuclear power plant of radioactivity, and free the buildings and areas from authority supervision. However, some of the buildings can be left undismantled and, after decontamination, recommissioned for use as part of a new power plant or entirely other purposes.

The waste generated in conjunction with decommissioning could be processed using current technology. As the decommissioning of the power plant and the processing of the decommissioning waste will take place several dozens of years in the future, the process will be eventually implemented utilizing the best technology available at that time.

According to the Nuclear Energy Act, the nuclear power plant licensee shall be responsible for the planning and implementation of the decommissioning of the plant. The plant decommissioning plan and the associated costs shall be first established in the power plant construction license application. The decommissioning plan and the cost estimate will be further specified for the power plant operating license application. After this, the plan shall be updated every six years. The Radiation and Nuclear Safety Authority (STUK) shall approve the plan and any revisions. No other field of industry is using a similar statutory procedure to ensure that no adverse effects or liabilities will be caused to outside parties after the end of the operations.

The plan will discuss the decommissioning methods and schedule, the storage of decommissioning-related radioactive waste before disposal, and the final disposal. The purpose of the plan is to ensure that the radioactive parts of the plant to be dismantled will not present any danger to the environment.

The funds required for the decommissioning of the nuclear power plant will be deposited in advance to the National Nuclear Waste Management Fund in the form of annual nuclear waste management fees as prescribed in the Nuclear Energy Act. While the environmental impacts of the decommissioning of the new nuclear power plant will be assessed later in a separate EIA procedure, this section describes the decommissioning process in order to provide a general view of the nuclear power plant project's lifespan.

3.14.1 Decommissioning strategy

According to Fennovoima's preliminary plan, the delayed dismantling strategy will applied in the decommissioning of the nuclear power plant. Delayed dismantling takes advantage of the decay of the radionuclides over time, which facilitates dismantling work as the radiation levels decrease. The method can be divided into four phases:

1. The spent nuclear fuel is removed from the reactor and the fuel pools and transferred to safe storage, where it awaits final disposal.
2. The nuclear power plant is brought into the state of monitored conservation, or a state in which the risks affecting the environment and the people working at the plant are within acceptable limits and which can be safely maintained until the final dismantling of the nuclear power plant.
3. For the duration of the monitored conservation, continuous monitoring and guarding of the nuclear power plant is arranged to ensure that the plant remains in a safe state.
4. The dismantling is implemented.

Since the dismantling of the nuclear power plant will commence only after a long period of conservation, particular attention must be paid to maintaining familiarity with the plant until the time of dismantling even in the eventual case that the persons responsible for the design and operation of the nuclear power plant are not be available at the time of dismantling. This can be ensured by starting the dismantling work with the dismantling of non-radioactive and slightly radioactive systems already during the monitored conservation period.

3.14.2 Waste and the processing thereof

During the monitored conservation period, low and intermediate level waste will still be generated from the cleaning of buildings and the servicing and maintenance of the systems required during the conservation. As the properties of this waste correspond to those of waste generated during operation, the principles applied to the classification and packing of low and intermediate operating waste may be applied to it as well.

However, large amounts of waste with less common properties of operating waste will also be generated in the course of the decommissioning process. The total amount of this waste will be 10,000–15,000 m^3 , and it can be classified as follows:

- activated steel
- activated concrete
- contaminated ferritic steel
- other contaminated steel
- contaminated concrete
- contaminated insulation.

As much of the decommissioning waste as possible will be decontaminated (cleansed of radioactive substances) in order to enable its clearance and processing in the same manner as ordinary waste. A part of the waste will be low and intermediate level waste. It will be processed, packed, and disposed of in the operating waste repository in the same manner as operating waste generated during the operation of the plant.

Once the decommissioning of the plant has been completed, the plant area has been cleaned in accordance with the radiation safety requirements, and all waste has been appropriately disposed of or transported out of the area, an application concerning the future purpose of the former plant area will be submitted to the Radiation and Nuclear Safety Authority (STUK) for approval. In accordance with the Nuclear Energy Act, the Ministry of Employment and the Economy will make a decision on the termination of the management obligation concerning nuclear waste and the decommissioning of the nuclear power plant on the basis of the application prepared by the party under the waste management obligation.

3.15 Transportation and commuter traffic

3.15.1 Construction phase traffic

During the construction phase, the amount of commuter traffic to and from the plant will be considerably higher in comparison with the present situation. The number of workers will be at its highest in the fourth year of the construction of the power plant, with a total of some 3,500 workers.

A temporary accommodation area for the workers, with access to the work site by foot or by bus, will be built in the vicinity of the plant area. About one-third of the workforce employed during the construction phase will be accommodated in these quarters. As regards the calculation of traffic volumes, these workers are assumed to travel to the nearest city or municipal center two and a half times a week on private business. It is further assumed that two-thirds of them will be using a car.

About two-thirds of the workforce employed during the construction phase will live near the plant, and they are assumed to commute from home. Of these workers, two-thirds are assumed to use a car, and they are assumed to drive to and from the plant once per working day.

In addition to commuter traffic, a maximum of 50 heavy transport vehicles will visit the plant every day. Items transported by road will include construction materials, equipment, and components.

In all, during the construction phase, the volume of passenger traffic from Monday to Friday will be approximately 4,000 private vehicles per day, and the volume of heavy traffic will be approximately 100 heavy vehicles per day.

Table 3-6 shows a summary of the traffic volumes.

3.15.2 Operation phase traffic

Approximately 400 people will be working at the plant during the operation phase. It is assumed that three-fourths of the workers will commute by car. The volume of commuter traffic will therefore be approximately 600 vehicles per day. If required, regular bus transportation will be arranged between the surrounding municipalities with plant worker populations and the plant site. In addition, there will be maintenance and goods transports to the plant, resulting in a traffic volume of about 30 vehicles per day.

The amount of transportation of goods and passenger traffic within the plant area is usually small.

During annual maintenance, the number of workers visiting the plant increases by about 500, of whom three-fourths are assumed to be staying in the accommodation area built during the construction phase. Of these workers, two-thirds are assumed to be using a car, arrive at the area at the beginning of the week, and travel back for the weekend. These workers are assumed to travel to the city or municipal center two and a half times a week on private business. The other annual maintenance workers will commute from the surrounding areas.

Table 3-6 shows a summary of the traffic volumes in the construction and operation phases.

3.16 Radioactive emissions and the limitation thereof

During the normal operation of the nuclear power plant, small amounts of radioactive substances, such as noble gases (xenon and krypton), gaseous activation products (carbon-14), halogens (iodine), and active substances in aerosol form, will be released in a controlled manner in the atmosphere and in the sea water.

These radioactive substances are generated in the nuclear reactor during operation. The majority of the radioactive substances will be contained inside the fuel rods. Furthermore, the reaction of neutrons released as the result of the splitting of nuclei with impurities present in the reactor coolant will generate activation products. Therefore, some radioactive substances will also be contained in the primary circuit water and the associated cleaning and waste water systems. Small amounts of gaseous radioactive substances will be generated in the atmosphere immediately surrounding the pressure vessel due to the effect of neutrons.

The waters and gases containing radioactive substances will be decontaminated and delayed for low activity concentration. The decontaminated gases will be led to the plant's vent stack, and the waters will be led to the sea with the cooling water. The emissions will be measured in

Table 3-6. Estimated traffic volumes at the nuclear power plant during the construction and opening phases.

	Number of vehicles per day
Construction phase	
Passenger traffic	4,000
Heavy traffic	100
Operation phase	
Normal operation	
Passenger traffic	600
Heavy traffic	30
Annual maintenance	
Passenger traffic	1,150
Maintenance and goods transport traffic	10

order to ensure that their radioactivity remains below the set limits. (*STUK 2013a*) The environmental impact of the emissions will be very low in comparison with radioactive substances occurring naturally in the environment.

3.16.1 Radioactive emissions into the atmosphere

According to the Government Decree (717/2013), the radiation dose to individual inhabitants of the surrounding area caused by normal operation of a nuclear power plant may not exceed 0.1 millisieverts per year. This limit value functions as the basis for the determination of the limits for emissions of radioactive substances during normal operation. Emission limits will be established for iodine and inert gas releases. The set emission limits are power plant-specific. In addition to iodine and noble gas emissions, tritium, carbon-14, and aerosols are also released from nuclear power plants into the atmosphere. Even at the theoretical maximum level, the annual emissions of these substances remain so low that setting separate emission limits for them is unnecessary. However, these emissions are also measured. All substances with a significant impact on the total dose rate are taken into account in the determination of the annual dose rate to the inhabitants of the surrounding area. In practice, this applies to the iodine and noble gas releases, as well as the tritium, carbon-14, and aerosol releases, mentioned above.

The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Furthermore, Fennovoima will determine its own emission limit targets for the nuclear power plant. These targets will be lower than the set emission limits.

As an example, table 3-7 shows the average emissions from the Loviisa and Olkiluoto nuclear power plants in 2008–2012 (*STUK 2009a, STUK 2010, STUK 2011a, STUK 2012, STUK 2013b*). The reactors of the Olkiluoto nuclear power plant units are of the boiling water type (BWR), with a net electrical power of 880 MW per unit (*TVO 2013*). Fortum's Loviisa units have pressurized water reactors (PWR), each with a net electrical power of 496 MW (*Fortum 2012*). The atmospheric emissions from the nuclear power plants have been less than one percent of the set emission limits.

The radioactive gases generated in the nuclear power plant will be processed using the best available technology. The gaseous radioactive substances will be directed to a cleaning system, where the gases are dried, delayed, and filtered using e.g. active carbon filters. Gaseous emissions can also be filtered using efficient HEPA (High Efficiency Particulate Air) filters. The decontaminated gases will be led into the atmosphere via the vent stack. Atmospheric radioactive emissions will be monitored and measured in the several stages of the gas treatment systems, and finally at the vent stack.

Table 3-8 shows an estimate of annual atmospheric emissions of radioactive substances from the nuclear power plant.

3.16.2 Radioactive emissions into the sea

Radioactive liquids from the controlled area will be led to the liquid waste treatment plant. After treatment, the water, which contains low levels of radioactivity, will be released into the sea. The level of radioactivity of the water released into the sea will be determined using a representative sample and, additionally, by direct measurement at the outlet line before the water is led into the cooling water discharge tunnel.

The aim will be to minimize aquatic emissions, e.g. by recycling process and pool waters and by minimizing the production of waste waters.

Table 3-9 shows the average actual emissions of radioactive substances into water systems from Finnish power

Table 3-7. Annual atmospheric emissions of radioactive substances from the Loviisa and Olkiluoto nuclear power plants, average in 2008–2012. Emission limits are established for iodine and noble gases.

Radioactive emissions, GBq/year	Loviisa 1 and 2 2 x 496 MW (PWR)	The emission limits for Loviisa	Olkiluoto 1 and 2 2 x 880 MW (BWR	The emission limits for Olkiluoto
Tritium	280	-	320	-
Carbon-14	300	-	820	-
Iodines (I-131 equivalent)	0.015	220	0.023	103
Noble gases	6,200	14,000,000	600	9,420,000
Aerosols	0.1	-	0.017	-

Estimated emission amount, GBq/year	
Tritium	3,900
Carbon-14	300
Iodines (I-131 equivalent)	0.49
Noble gases	46,000
Aerosols	0.051

Table 3-8. Estimate of annual atmospheric emissions from the nuclear power plant.

Table 3-9. Annual aquatic emissions of radioactive substances from the Loviisa and Olkiluoto nuclear power plants, average in 2008–2012.

Radioactive emissions, GBq/year	Loviisa 1 and 2 2 x 496 MW (PWR)	The emission limits for Loviisa	Olkiluoto 1 and 2 2 x 880 MW (BWR)	The emission limits for Olkiluoto
Tritium	17,000	150,000	1,700	18,300
Other beta and gamma	0.56	890	0.22	296

plants in 2008–2012 *(STUK 2009a, STUK 2010, STUK 2011a, STUK 2012, STUK 2013b)*. At the Finnish plants, tritium emissions have been about 10 percent, and the other emissions well below one percent, of the set emission limits. The concentration of tritium released from the nuclear power plants in sea water decreases to an insignificant level in the close vicinity of the plants. As in the case of atmospheric emissions, power plant-specific emission limits will be set for radioactive emissions into the water. Furthermore, Fennovoima will determine its own emission limit targets, which will be stricter than the set emission limits.

Pressurized water reactors utilize boric acid, which forms tritium in neutron reactions. For this reason, more tritium is released from pressurized water reactors than from boiling water reactors. Like other radioactive liquids, liquids containing tritium will be cleaned so that their activity level falls well below the limit values set for emissions before they are led into the water system. The radioactive liquid cleaning methods include collection in monitoring tanks and delaying, evaporation, ion exchange, separation of solids using mechanical filtration, slurry centrifuges, or separators.

The treatment of ion exchange resins, sludges, and other wet waste generated in the course of treatment of the nuclear power plant liquid waste is described in Section 3.12.

Table 3-10 shows an estimate of radioactive emissions into the sea from the nuclear power plant.

Table 3-10. Estimate of radioactive emissions led into the sea from the nuclear power plant.

Estimated emission amount, GBq/year	
Tritium	9,100
Other beta and gamma	0.065

3.17 Conventional air emissions

3.17.1 Emissions from generation of emergency power and heat

In the case of disturbances in the offsite grid connection, the nuclear power plant's electricity supply will be secured using diesel generators as sources of back-up power. Furthermore, a gas turbine plant with a power of approximately 100 MW may be built at the plant area to serve as a back-up power source for the power plant and the main grid. The supply of power to other buildings located at the plant area and the outdoor lighting during disturbances may be ensured with diesel generators.

The emergency diesel generators will be fueled with diesel oil, and the emergency heating plant will be fueled with light fuel oil. The sulfur content of the light fuel oil will be as low as possible (not higher than 0.1 percent by mass). The burning of the fuel during the operation of the emergency diesel generators and the emergency heating plant will produce sulfur dioxide, nitrogen oxides, particles, and carbon dioxide. The use of the gas turbine will lead to small nitrogen oxide emissions. Under normal circumstances, the emergency diesel generators, the gas turbine plant, and the emergency heating plant will only be used for test run purposes. The emergency heating plant may also be used for heat generation if annual maintenance is carried out during the winter period.

Under normal circumstances, the annual emissions from the emergency diesel generators, the gas turbine plant, and the emergency heating plant remain very small. Over a period of one year, they produce about 0.3 tons of sulfur dioxide, about 1.4 tons of nitrogen oxides, less than one ton of particles, and about 750 tons of carbon dioxide.

3.17.2 Emissions from transportation

The unit emission factors for road traffic in Finland published by VTT *(VTT 2012)* were used to calculate the emissions from transportation and commuter traffic.

The commuting distance of workers commuting from home was estimated to equal the average distance from the center of the Pyhäjoki municipality to the plant. The workers arriving from abroad or from further away in Finland were not assumed to return home for the weekends. The external workers working at the plant during annual maintenance were instead assumed to usually return home for the weekends. As these workers may live anywhere in Finland, their commuting distances may vary greatly. Therefore, the emissions caused by commuting will also be distributed over a wide area and thus have little impact on individual areas. For this reason, the emissions caused by commuting were in such cases calculated using the same distances that were used to calculate the corresponding values for those commuting from home.

The emissions of road transportation were calculated using the same principles that were used to calculate the commuting emissions of annual maintenance workers.

Table 3-11 shows the air emissions from the transportation and commuter traffic to and from the nuclear power plant during weekdays, both during the construction phase and normal operation.

3.18 Traffic connections and power lines

The construction of the nuclear power plant is linked with projects extending beyond the plant area, such as the construction of traffic connections or upgrade of the existing ones, the construction of the navigation channel, and the construction of power lines.

The location and construction of the navigation channel in the sea area of the Hanhikivi headland is described in Section 3.6.2.

3.18.1 Traffic connections

Main road 8 (E8) runs through the village of Parhalahti at a distance of approximately 5.5 kilometers from the planned plant location (Figure 3-17). A smaller private road (Puustellintie) runs from the main road to the tip of the Hanhikivi headland. As Puustellintie is not suited for the nuclear power plant transportation operations, a new connecting road (Hanhikiventie) will be built from the main road to the plant area. The new road is indicated in the legally valid partial master plan and local detailed plan for the Hanhikivi nuclear power plant area. The length of the road from main road 8 to the boundary of the energy management block area indicated in the local detailed plan will be about four kilometers. The existing road (Puustellintie) will be upgraded, and it will function as a back-up access connection to the plant area.

The new connecting road will be two-lane asphalt-paved public road flanked by a pedestrian and bicycle way. Requirements relating to the construction and operation of the nuclear power plant will be taken into account in the dimensioning and design of the road. As required in the new regulatory guide on nuclear safety (YVL Guide D.4) issued by the Radiation and Nuclear Safety Authority (STUK), the elevation of the road will be dimensioned so that exiting the area will be possible also in times of exceptional natural conditions. According to preliminary plans, the final elevation of the road will vary between +4.6 meters and +4.9 meters (N2000 elevation system).

Water supply and sewer pipe structures required for the power plant and the supporting areas, as well as the related connections to the municipal network, will be constructed in conjunction with the building of the road. The entire road section will be equipped with lighting.

According to preliminary plans, the final section of the road line may be equipped with a bridge structure enabling the flow of water and animal movement across the road line at Hietakarinlahti. The structures and dimensioning of the road and the bridge structure will be specified further during further design.

3.18.2 Power lines

The nuclear power plant will be connected to the Finnish national grid so that the grid connection enables, for its part, the safe and planned operation of the nuclear power plant, as well as the transmission of the electrical energy produced at the power plant to the grid in the planned manner under all grid conditions. Fennovoima will be responsible for the construction of the power plant connection lines, and the national grid operator Fingrid will have the responsibility for the grid reinforcements required in the main grid. The environmental impacts caused during the construction and use of the power lines will be assessed in a separate EIA procedure, which is estimated to start in 2014.

According to the preliminary assessment, the connection between the power plant and the grid will require the construction of a local connection with two 400 kV transmission lines and two 110 kV transmission lines. Furthermore, Fingrid estimates that securing the regional transmission capacity and the operational reliability of the power system would require two 400-kilovolt power line connections from the 400-kilovolt grid connection station between Hanhela and Lumijärvi.

The impacts caused to the nature types and plant and animal species constituting the basis of conservation for the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area during the construction and use of the nuclear power plant and the associated power lines were assessed in the Natura assessment procedure for the Hanhikivi nuclear power plant carried out in 2009 (*Pöyry Environment Oy 2009a*). According to the Natura assessment, the most significant risk was the collision of individual birds representing the species constituting the basis of conservation with the power lines. The assessment concluded in a recommendation to utilize the guyed H frame design in the construction of the power line towers as this enables the arrangement of conductor wires as low as possible,

	Construction phase (t/year)	Operation phase (t/year)
Carbon monoxide (CO)	111	19
Nitrogen oxides (NO_x)	20	4
Small particles (PM)	0.5	0.1
Sulfur dioxide (SO_2)	0.04	0.01
Carbon dioxide (CO_2)	6,730	1,219

Table 3-11. Air emissions from transportation and commuter traffic to and from the nuclear power plant during weekdays, both during the construction phase and normal operation.

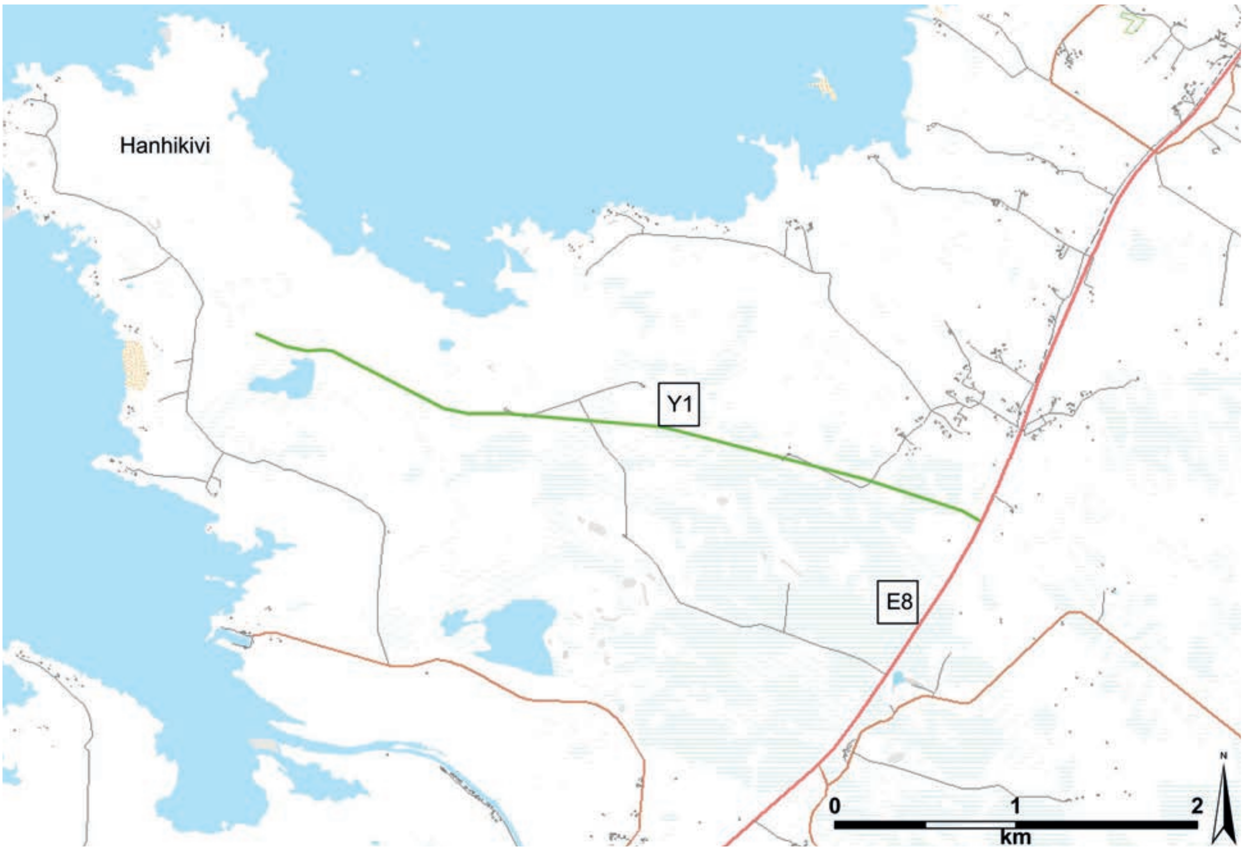


Figure 3-17. The location of the new road (Y1) to be built to the Hanhikivi power plant area. E8 is the existing main road 8.

and at the same level. Figure 3-18 shows a cross-sectional image of the planned power line corridor implemented using guyed H frame towers.

Fingrid carried out a preliminary survey on the location of the power plant connection line routes in 2012. Figure 3-19 shows the power line routes and station locations for the 400 kV and 110 kV local connections. These line routes have been taken into account in the preparation of the regional land use plan guiding the planning of land use in the Northern Ostrobothnian region. All new power lines and station locations would be located within the municipality of Pyhäjoki. The total length of the planned power line sections would be approximately 34 kilometers. The route section located in the Hanhikivi headland, the length of which is approximately 5.6 km, would begin at the nuclear power plant area and end east of main road 8, where the line connection would branch. The 110 kV line connection, indicated in red in Figure 3-19, would run from the branching point of the line route to the planned Valkeus substation. The length of the route section is approximately 13.8 kilometers. The 400 kV line connection would run to the planned Hanhela substation location. The length of the route section is approximately 14.6 kilometers.

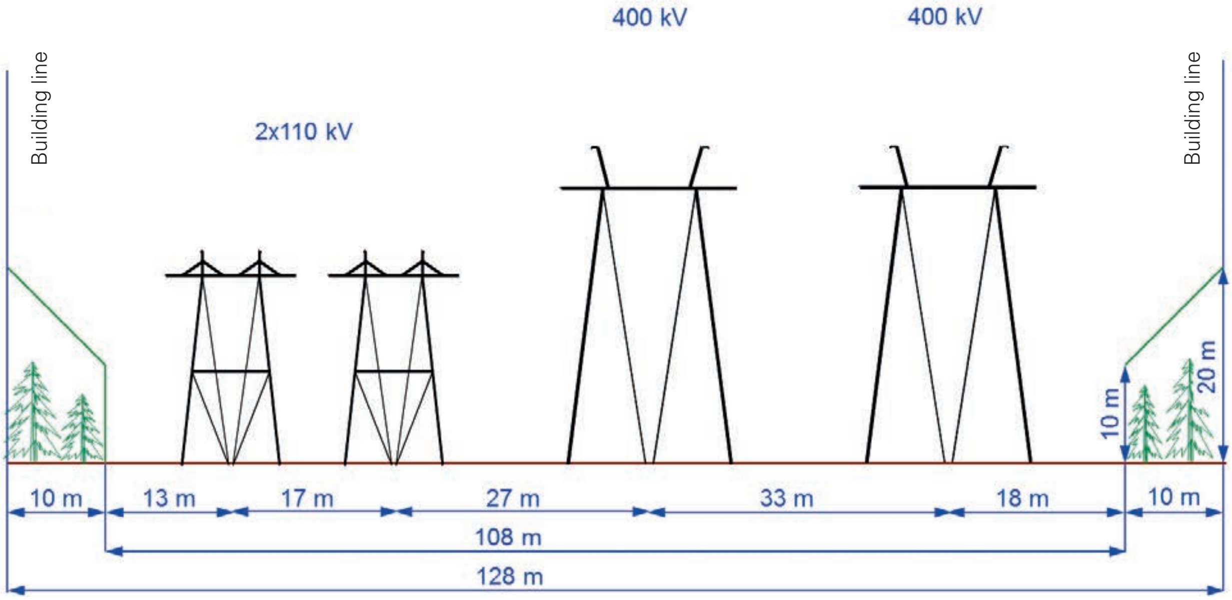


Figure 3-18. Cross-sectional image of the planned power line corridor in the Hanhikivi headland area. The tower type featured is the guyed H frame.

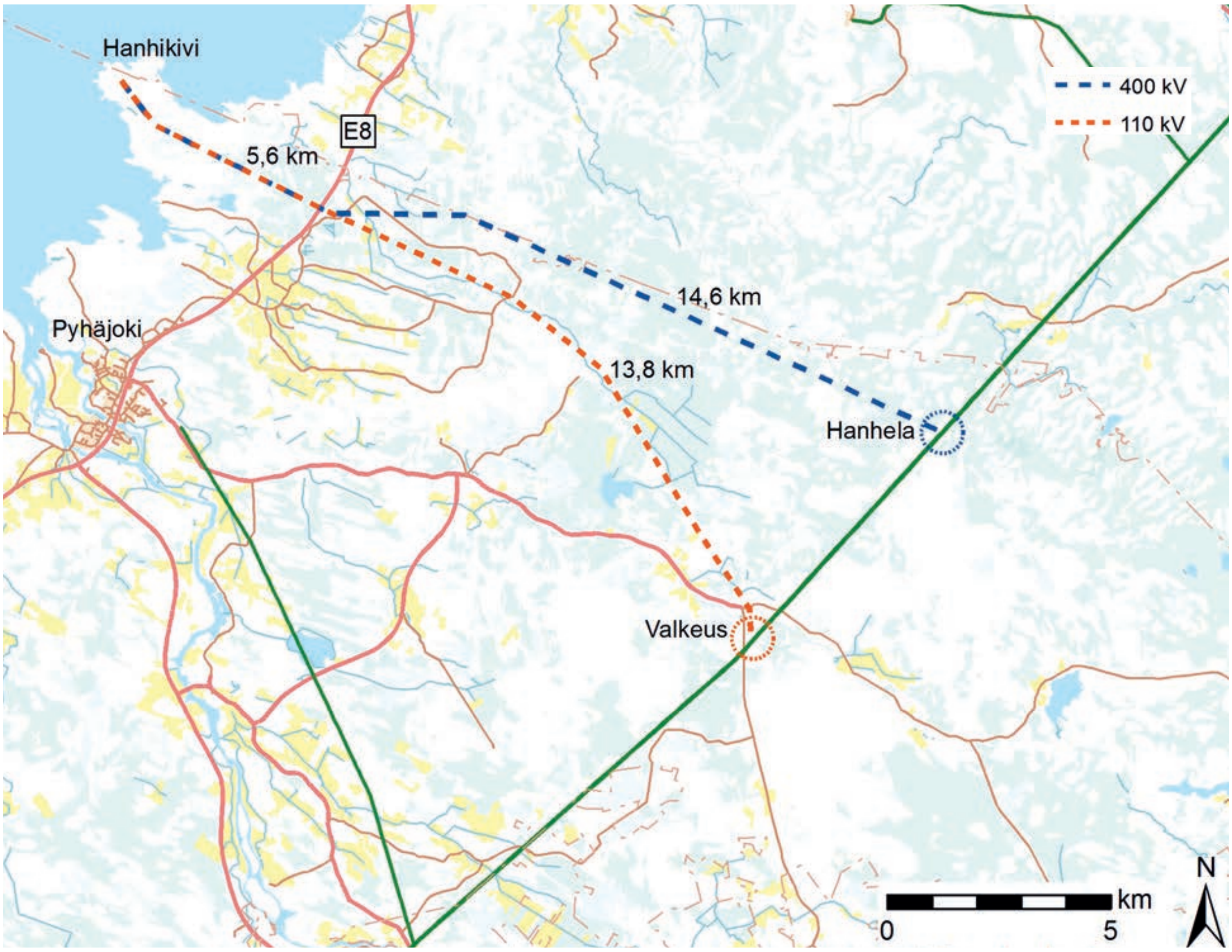
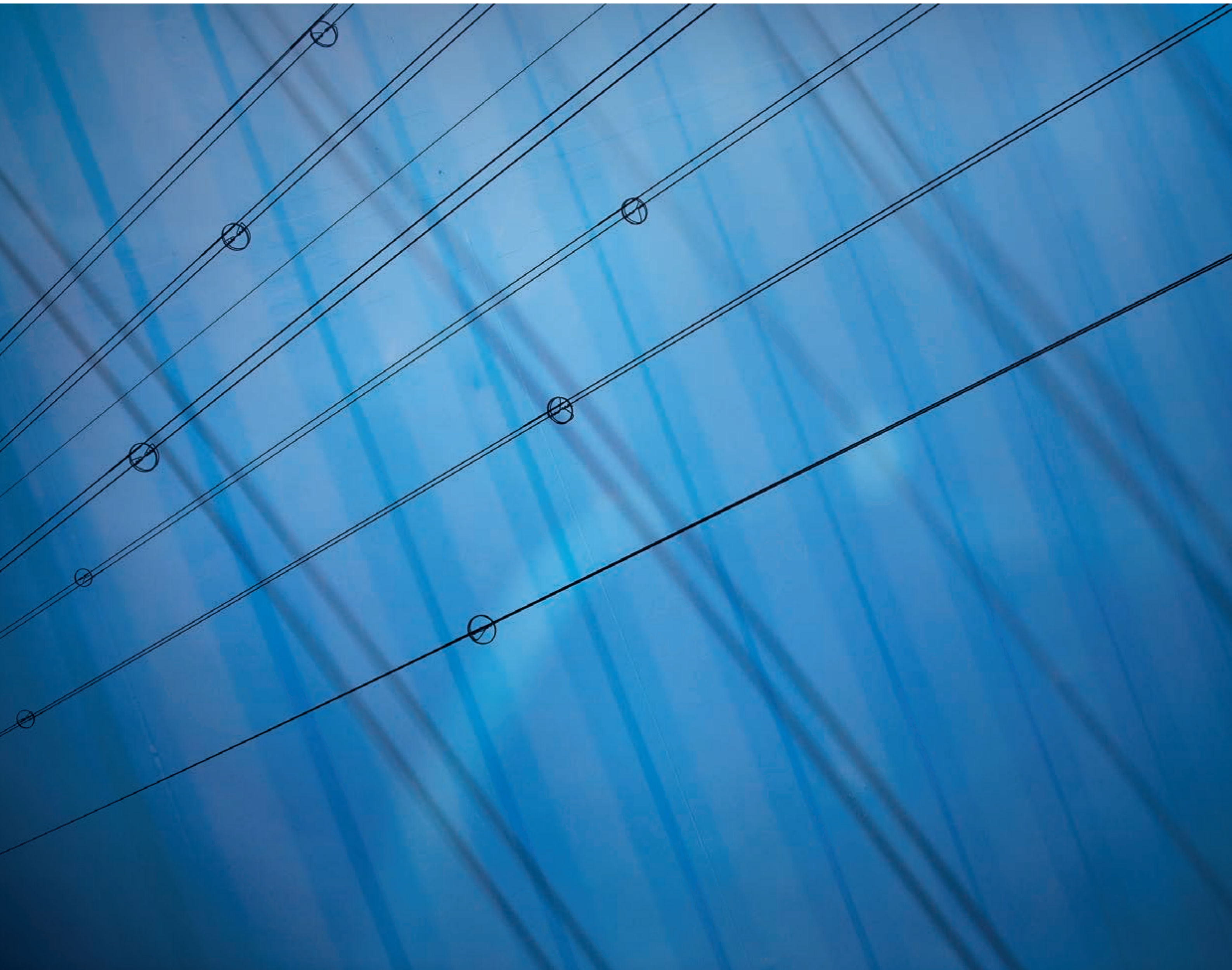


Figure 3-19. Power line routes and station locations for the local connection planned for the Hanhikivi 1 nuclear power plant. The blue dashed line indicates the 400 kV line connection, and the red dashed line indicates the 110 kV power line connection.

4

Nuclear safety



Safety is the first priority in the design, construction, and operation of the Fennovoima nuclear power plant. Nuclear safety covers all the measures utilized to ensure the safety of employees, the people, and the environment with regard to radioactive radiation when using nuclear energy.

The safety and operational reliability of nuclear power plants are under constant improvement. In order to ensure the safe use of nuclear energy, a strict safety culture, special safety principles and regulations, as well as advanced quality assurance methods, will be followed in the design and operation of the nuclear power plant. The use of nuclear energy is subject to a license and is regulated by legislation. Statutory safety requirements shall be taken into account in the design of the plant. The licensee relating to the use of nuclear energy carries the sole responsibility for the safety of the operations.

4.1 Nuclear safety requirements

The safety requirements relating to the use of nuclear energy are based on the Finnish Nuclear Energy Act (990/1987), according to which nuclear power plants shall be safe and shall not cause any danger to people, the environment, or property.

The regulations of the Nuclear Energy Act are specified further in the Nuclear Energy Decree (161/1988). The general principles of the safety requirements set for nuclear power plants are laid down in Government Decrees 734/2008, 736/2008, 716/2013, and 717/2013. Their scope of application covers the different areas of the safety of nuclear energy use. Detailed regulations for the safety of nuclear energy use, safety and emergency preparedness arrangements, and nuclear material safeguards are given in the regulatory guides on nuclear safety (YVL Guides) issued by the Radiation and Nuclear Safety Authority (STUK). Various national and international regulations and standards also control the use of nuclear energy. Figure 4-1 shows the hierarchy of Finnish nuclear safety legislation and the corresponding requirements.

The legislation concerning nuclear energy is currently being revised. Government Decrees 716/2013 and 717/2013 have entered into force on October 2013. At the time of writing, STUK is in the process of revising the YVL Guides. The objective of the revision process is to update the guide's structure and edit the whole guides so that the number of guidelines is reduced. Most of the new YVL Guides entered into force on December 1, 2013.

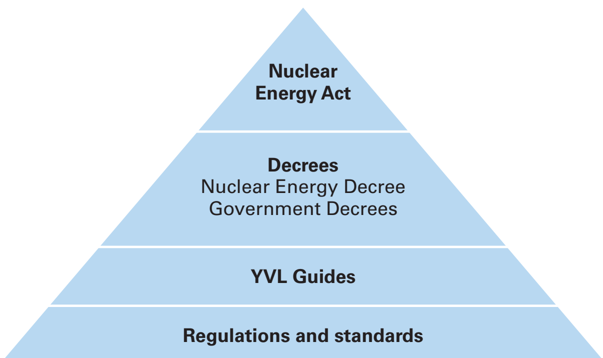


Figure 4-1. The hierarchy of Finnish nuclear safety legislation and the corresponding requirements.

According to the Nuclear Energy Act, the leading principle concerning nuclear safety is to maintain the level of safety of the use of nuclear energy as high as reasonably achievable. Safety shall be developed further on the basis of operation experience and safety studies, taking into account scientific and technological development. According to the defense in depth principle, the safety of nuclear facilities must be ensured using successive and independent protective measures. This safety principle must be extended to include the plant's operational and structural safety. The possibility of operational transients and accidents must also be taken into account in the design of nuclear power plants.

International agreements and other safety requirements, such as the International Atomic Energy Agency's (IAEA) guidelines, have been taken into account in the preparation of the legislation and instructions concerning nuclear safety (*STUK 2013l, IAEA 2013*).

The fulfillment of the safety requirements will be assessed individually for each plant unit. STUK and the licensee may, at their discretion, set design objectives that are more stringent than existing safety requirements. The safety requirements observed in Finland are internationally considered to be stringent.

4.2 Nuclear safety principles and their implementation

The safety of nuclear power plants is based on the defense-in-depth principle, which Fennovoima will implement in the project. Several independent and supplementary levels of protection will be applied in the design and use of the plant (Figure 4-2) (*IAEA 2000*):

- Prevention of operational transients and failures through high-quality design and construction, as well as appropriate maintenance procedures and operation
- Observation of operational transients and failures and returning the situation to normal using protection, control, and safety systems
- Management of design basis accidents using existing and planned safety features
- Observation and management of severe accidents using the accident management system
- Mitigation of the consequences of releasing radioactive substances through emergency and rescue operations.

Nuclear power plants are designed so that the failure of operations at any single level of protection will not endanger people, the environment, or property. In order to ensure reliability, each of the levels is built on several mutually complementary technical systems and based on the limitations and regulations relating to the use of the plant.

Proven technology will be applied in the design of the nuclear power plant, and all processes will be designed for natural stability. For example, light water reactors are designed to be naturally stable with regard to power control. This means that the reactor's inherent feedbacks will automatically limit any uncontrolled power increases. The safety of light water reactors is further improved by the fact that an increase in the temperature of the coolant restrains increases in power, and coolant leakage from the reactor shuts down the chain reaction.

The design of all safety-related equipment and functions will be based on special safety analyses, for which even improbable failures are taken into account and sufficient safety margins are applied. In addition, high-quality requirements will be applied in the production of safety-related equipment. As part of efficient quality management, the nuclear power plant's systems, equipment, and structures will be divided into categories on the basis of their significance to safety. The higher the category, the higher the required quality will be. Despite all this, safety design always starts from the assumption that equipment failures or plant operator errors are possible. Internal incidents, such as equipment failure and mistakes made by the operating personnel, and external factors, including exceptional weather and environmental conditions, risks related to the operation of cooling water routes (such as clogging), and airplane crash will be taken into account in the design of the plant. The nuclear power plant will be equipped with safety systems enabling the prevention, or, at least, limitation, of the progression and impacts of transients and accidents.

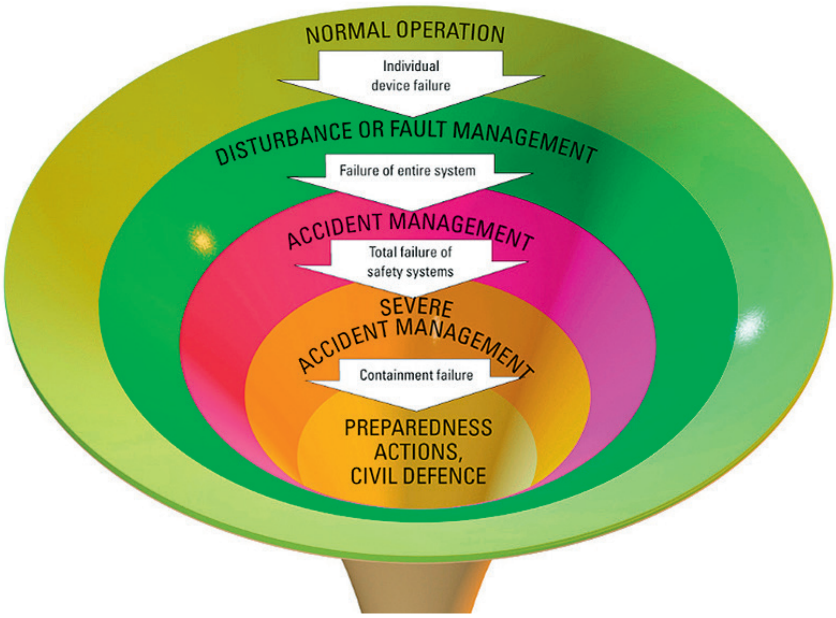
The safety systems will be divided into multiple parallel subsystems, the combined capacity of which will be designed to exceed the requirement several times over (*the redundancy principle*, Figure 4-3). The overall system consisting of multiple redundant subsystems will be able to perform its safety functions even in the case of failure of any single piece of the system equipment and the simultaneous unavailability of any piece of equipment contributing to the safety function due to maintenance or some other reason. Redundancy ensures the operational reliability of the safety systems. Reliability can be further improved by utilizing several pieces of equipment of different types to perform the same function. This eliminates the chance of type-specific defects preventing the performance of the safety function (*the diversity principle*, Figure 4-3). The redundant subsystems will be separated from each other so that a fire or a similar incident cannot prevent the performance of the safety function. One alternative for implementing the separation is to place the subsystems in separate rooms (*the separation principle*, Figure 4-3).

To cope with a severe accident (core meltdown), the plant will be equipped with special protection equipment and structures. Due to the improbability of such accidents, it is sufficient for the systems designed to cope with them to perform their safety function even in the case of inoperability of any single piece of the system equipment *(STUK 2004).*

During the normal operation of the nuclear power plant, radioactive substances will be released in a controlled manner into the environment. The emission amounts will remain very small and below the limits set by the authorities. These emissions will have no significance for the safety of the local population or the environment. Uncontrolled emissions into the environment can be reliably prevented under all conditions. The uncontrolled emissions of radioactivity into the environment will be prevented with several successive technical *barriers* (Figure 4-4). Each of these barriers alone will be sufficient to contain the radioactive substances.

The *first barrier* is the gas-tight and mechanically resistant, metallic protective cladding of the fuel rods. The *second barrier* consists of the reactor's pressure-resistant and leak-tight cooling circuit. The pressure-resistant and gas-tight,

Figure 4-2. Several protection levels will be applied in the design and operation of the nuclear power plant in accordance with the defense in depth principle.



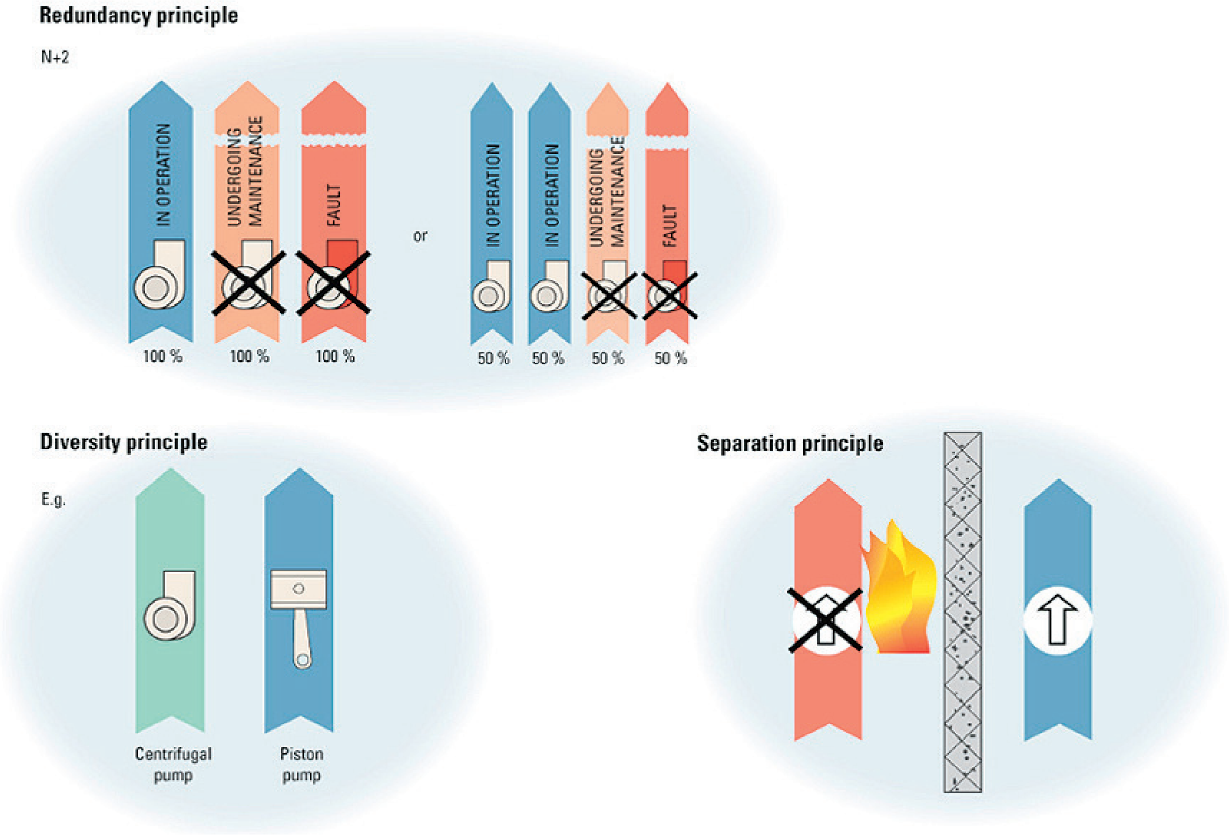


Figure 4-3. The design principles of safety systems.

double-shell containment building surrounding the reactor forms the *outermost barrier.* The inner containment shell will be made of pre-stressed reinforced concrete that is capable of withstanding the tensile stresses caused by overpressure under accident conditions. The carbon steel lining installed at the inner surface of the shell will ensure its leaktightness. The outer containment shell will be a thicker structure made of ordinary reinforced concrete. It will protect the reactor and the inner containment shell from external hazards and the associated collision loads. It will be designed to withstand loads including a large passenger airplane crash. Furthermore, the outer shell will function as an additional barrier against the dispersion of radioactivity and limit the releases into the environment in accident situations.

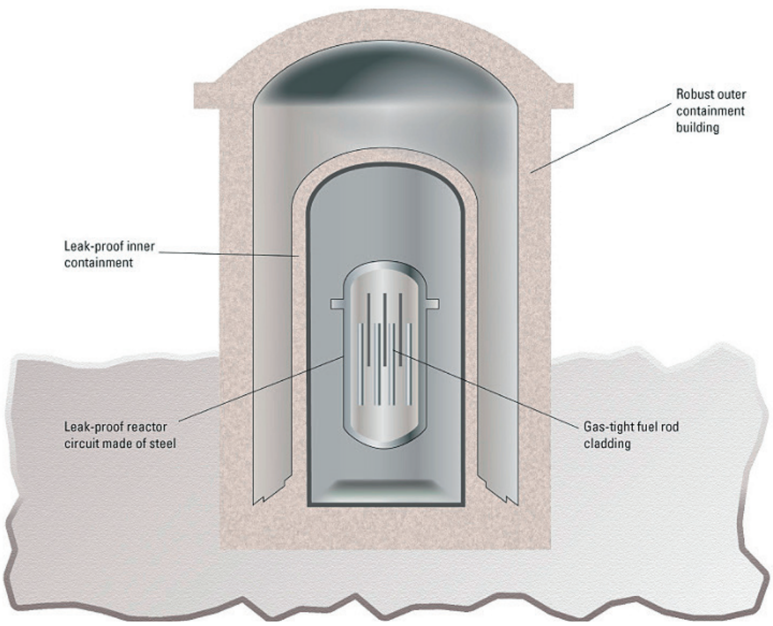


Figure 4-4. The barriers preventing the dispersion of the radioactivity contained in the fuel.

The nuclear power plant will be designed so that the containment building will also withstand a severe core meltdown accident. The containment building will prevent the spreading of the core melt, and the dispersion of the majority of the gaseous radioactive substances contained therein, into the environment. Outside the containment building, the radiation levels will remain low and safety will be maintained even in the case of a release of radioactivity inside.

A high standard of safety culture will be followed, and advanced quality assurance procedures utilized in the operations of the nuclear power plant. Comprehensive instructions will be prepared for the performance of measures required in the various operating conditions of the nuclear power plant, as well as for clearing any transient and accident conditions. Furthermore, these measures will be drilled regularly. During maintenance and repair work, particular attention will be paid to attentiveness and precision. The objective is to protect the plant from disturbances, and the employees from radiation. The Radiation and Nuclear Safety Authority (STUK) will audit personnel training and revise the safety-related instructions. STUK will also audit the whole safety management system of the nuclear power plant.

4.3 Management of external hazards

The nuclear power plant will be designed to withstand the loads resulting from various external hazards. These include extreme weather conditions, sea and ice-related phenomena, earthquakes, various missiles, explosions, flammable and toxic gases, as well as intentional damage. The nuclear power plant will be constructed so that it will withstand a large commercial airplane crash without significant emissions into the environment. Both the collision force caused by the airplane itself and the eventual fire caused by its fuel will be taken into account in the design of the buildings that are important to safety.

Other factors that will be taken into account in the design include the eventual impacts of the climate change, such as the increasing frequency of extreme weather phenomena, the warming of the sea water, and the rising of the average sea water level.

The impacts of the land uplift occurring at the Pyhäjoki area will be assessed in conjunction with the designing of the nuclear power plant. However, the uplift is steady and is not expected to place any particular requirements on the design of the nuclear power plant.

Various weather-related phenomena, such as low and high temperatures, rain and snowfall, snow loads, strong wind, whirlwinds, downbursts, air humidity, and lightning, will be taken into account in the design of the nuclear power plant. As regards extreme natural phenomena, the safety system design values will be determined in accordance with the requirements of the YVL Guide B.7 so that they are expected to be exceeded with a frequency lower than once in 100,000 years. Conditions occurring at an even lower frequency will be prepared for by ensuring that the most important safety functions can be performed even in the case that the design values are exceeded.

The high temperature, as well as low and high levels of sea water will also be taken into account in the design. In accordance with the YVL Guide B.7, the design value for the nuclear power plant with regard to the sea water level (i.e. the construction elevation) shall be determined by adding a wave margin plus an additional two meters to the highest sea water level occurring at the location once in a hundred years. The construction elevation determined for the Fennovoima plant (approximately +4.9 meters according to the N2000 system) fulfills the YVL Guide requirement by a good margin. This means that the plant will not be endangered even under highly exceptional flooding conditions. Flooding has also been taken into account in the design of the roads leading to the plant site; the plant site can be accessed via two separate roads, of which at least one will remain available even when the sea water level is exceptionally high.

Factors with a potential impact on sea water intake, such as oil spills in the surrounding sea, formation of pack ice, frazil ice (formation of ice crystals in subcooled water), and extensive occurrences of algae and fish, will be taken into account in the design of the plant and its cooling systems. The various impurities will be removed from the sea water by successive screens and filters. The sea water intake structures will be located in the harbor area which will be protected with breakwaters. Breakwaters will prevent ice from entering the intake harbor. In addition to the main channel, cooling water can be taken through the auxiliary cooling water intake channel or from the outlet side, if required. Despite these design solutions, provision will also be made for situations in which sea water cooling is totally lost.

As Finland is located in the central part of the Eurasian continental platform, intense earthquakes are very rare and highly improbable. Earthquakes will nevertheless be taken into account in the design of the nuclear power plant. The design basis earthquake was determined, in accordance with the requirement of the YVL Guide B.7, so that greater earthquakes are estimated to occur with a frequency lower than once in 100,000 years. The performance of the most important safety functions will be possible even in the case that the design basis earthquake is exceeded.

Experience gained from the Fukushima accident has also been utilized in the design of nuclear power plants. The reliability of the power supply during various extreme natural phenomena will be taken even more into account than before in the design of new reactors. Passive systems enable reactor cooling even in possible loss-of-power situations. Provision will be made for the loss of sea water cooling by equipping the reactor so that heat can be transferred into the atmosphere. Sufficient cooling must be ensured for both the nuclear fuel contained inside the reactor and the spent fuel placed in separate cooling pools outside the reactor.

The nuclear power plant and the nuclear materials used will be protected from illegal activities, such as vandalism and sabotage. Threats caused by terrorism or other illegal activities will be addressed through continuous implementation of comprehensive security arrangements. They will supplement the protection provided by the sturdy structure and protection of sensitive components required by the plant's basic safety planning.

The backgrounds of the personnel working at the nuclear power plant either permanently or during annual maintenance outages will be checked, and employee access in the plant area will be restricted, with the help of access permits of different levels, to areas necessary for the performance of their work tasks. Preparation for external hazards will also cover situations in which the threat is presented by a person or a group of people who work regularly or temporarily at the plant and have access permits.

4.4 Verification of nuclear safety and authority supervision

The Ministry of Employment and the Economy requires that the Radiation and Nuclear Safety Authority (STUK) assess the safety of the AES-2006 pressurized water reactor plant. The implementation of the safety solutions will be described in detail in conjunction with Fennovoima's submittal of a construction license application for the nuclear power plant in accordance with the Nuclear Energy Act. The licensee and STUK will continue the supervision of the implementation of safety solutions throughout the project's construction period. The solutions implemented, and the results gained from pre-operational testing, will be assessed as a whole when Fennovoima applies for an operating license in accordance with the Nuclear Energy Act.

Supervision of the use and safety of nuclear energy is the responsibility of STUK, and the safety of the nuclear power plant will be controlled by means of various authority inspections. STUK will determine, and record in the plant-specific operational inspection program, the inspections to be periodically performed at the nuclear power plant. Additional inspections performed at the plant will include those required in the YVL Guides. To support the supervision operations, STUK is to be provided with periodic reports as well as reports on any transient situations.

The radiation exposure of the local population caused by the nuclear power plant, the health impacts of radiation, and the emergency and rescue operations relating to the operation of the nuclear power plant are discussed in more detail in Section 4.5.3. Radiation monitoring is discussed in Chapter 10.

4.5 Management of abnormal and accident situations

For nuclear power plant design and safety assessments, potential nuclear power plant conditions are classified as follows:

1. normal operating conditions
2. anticipated operational transients
3. postulated accidents
4. severe accidents.

This chapter deals with the last three categories, i.e. conditions which constitute a deviation from normal operation.

4.5.1 Abnormal situations at nuclear power plants and the related requirements

According to the Nuclear Energy Act, provision shall be made in the design of nuclear power plants for the possibility of operational transients and accidents. A nuclear power plant accident does not necessarily constitute a situation in which the operating personnel of a nuclear power plant or the residents of the surrounding area are exposed to significant levels of radiation. The more severe the possible consequences of an accident are, the smaller its probability shall be. While the primary objective in the design of nuclear power plants is the prevention of accidents, practical measures necessary for the management of accidents and the mitigation of their consequences must also be implemented. Nuclear safety is discussed in more detail above in this chapter.

The Government Decree on the Safety of Nuclear Power Plants (717/2013) sets limits for the radiation exposure of the general public and radioactive emissions due to events constituting a deviation from the normal operating conditions of the nuclear power plant. This Decree superseded the previous Government Decree (733/2008).

4.5.1.1 Anticipated operational transients

Anticipated operational transients are deviations from normal operating conditions that can be expected to occur once or more often than once during hundred years of operation.

The annual radiation dose limit for individuals of the local population due to anticipated operational transients is 0.1 millisieverts. The nuclear power plant shall withstand all anticipated operational transients without fuel damage. Possible causes for operational transients include individual equipment failure, mistakes made by the plant operating personnel, and external events, such as disturbances in the electric power transmission network and exceptional weather phenomena *(Sandberg 2004)*.

4.5.1.2 Postulated accidents

Postulated accidents are events used as design bases for the safety systems of nuclear power plants. The nuclear power plant shall withstand postulated accidents without severe fuel damage and without such radioactive emissions that would require extensive measures in the vicinity of the plant in order to restrict the exposure of the local population.

The Government Decree (717/2013) classifies postulated accidents into two categories as follows:

1. Accidents with an expected frequency of occurrence lower than once in a hundred reactor operating years

but equal to or higher than once in a thousand operating years. In this case, the annual radiation dose limit for the most exposed individual of the local population is 1 millisievert.
2. Accidents with an expected frequency of occurrence lower than once in a thousand reactor operating years. In this case, the annual radiation dose limit for the most exposed individual of the local population is 5 millisieverts.

The nuclear power plant will be equipped with safety systems that retain their capability of performing their tasks during transients and accidents even in the case of system failures or unfinished maintenance operations.

Government Decree 717/2013 defines the design extension conditions, which cover the following:

a. An accident involving a combination of an anticipated operational transients or a Class 1 postulated accident and the occurrence of a common-cause failure in the safety system required for the performance of the safety function
b. An accident caused by a combination of failures identified as significant on the basis of a probabilistic risk analysis
c. An accident caused by a rare external event.

The plant will be required to withstand design extension conditions without severe fuel damage. The maximum annual radiation dose for the most exposed individual of the local population is 20 millisieverts.

4.5.1.3 Severe accident

In accordance with the defense in depth principle (see Section 4.2), the nuclear power plant will make an effort to prepare for situations in which the management of an anticipated operational transient or a postulated accident fails to function as planned, potentially leading to a severe accident. In a severe accident, a considerable portion of the fuel contained in the reactor is damaged.

A severe accident shall not cause a need for extensive civil protection measures or long-term restrictions on the use of large land or water areas. According to the Government Decree (717/2013), in a severe accident, the limit for the release of cesium-137 into the environment is 100 terabecquerels. The matter is specified further in the Radiation and Nuclear Safety Authority guidelines (YVL Guide C.3 and VAL Guide 1), according to which a severe accident shall not cause a need to evacuate the local population outside the protective zone (extending to the distance of some 5 kilometers from the plant) or a need to take shelter indoors outside the emergency planning zone (extending to the distance of approximately 20 kilometers from the plant). The evacuation will be implemented if the radiation dose is estimated to exceed 20 millisieverts during the first week. Taking shelter indoors is justified in the case that an unprotected person is estimated to be exposed to a dose of over 2 millisieverts over a period of two days. The possibility of exceeding the emission limits shall be very small. Additionally, the possibility of a release occurring in the early stages of an accident and causing a need for civil defense measures shall be very small.

According to YVL Guide A.7 issued by STUK, the expected core damage frequency shall be less than once in a hundred thousand years. Since not all damage to the reactor core will cause large radioactive releases, the probability for such is even smaller. According to the same YVL Guide, the expected frequency of occurrence of a release exceeding the 100-terabecquerel limit set for a Cs-137 release shall be less than once in two million years.

4.5.2 The International Nuclear Event Scale (INES)

The International Nuclear Event Scale (INES) is used to rate nuclear facility events and nuclear accidents. The scale was developed in international cooperation between the International Atomic Energy Agency (IAEA), the Organization for Economic Cooperation and Development (OECD), and experts from several countries. The scale has been in official use for nuclear power plant events since 1992, and it is currently used in approximately 70 countries (*STUK 2013d*).

The INES scale has promoted communication on nuclear power plant events by standardizing the related terminology. It allows for less ambiguous specification of an event's significance for nuclear safety. On the INES scale, nuclear power plant events are rated into eight categories, ranging from INES 0 to INES 7 (Figure 4-5).

The rating criteria are presented in the IAEA INES Manual (IAEA 2008), according to which the consequences of an accident are divided into three areas: off-site impact (environmental impact), on-site impact (radiation within the plant area), and impact on defense in depth (deterioration of safety). Each of these areas is considered separately when determining the INES rating. If the rating can be determined on the basis of more than one area and different starting points result in different ratings, the highest rating shall always be chosen.

The INES scale has seven actual ratings, with levels 1–3 representing incidents (events that compromised safety). The lowest levels (1 and 2) are mostly applicable to technical failures that have compromised plant safety. Levels 4–7 represent accidents of varying severity. An accident is rated at least at level 4 if any civil defense measures must be implemented outside the plant. In accident situations, the severity level of the accident is determined as soon as possible, and it can be reviewed later. Level 0 events are below the actual scale due to their minor safety significance.

The different nuclear power plant events used for the design of, and safety assessment relating to, the nuclear power plant can be roughly divided according to the levels of the INES scale as follows: anticipated operational transients are rated at levels 1 to 3, postulated accidents and design extension conditions at level 4, and severe accidents at levels 5–7.

INES 0: A deviation that has no significance for nuclear or radiation safety, and thus cannot be rated on the actual scale. An example of an event rated at this level is a reactor scram, provided that all the plant systems operate as designed during the event.

INES 1: An anomaly with an impact to safety resulting from equipment failure, operational error, or procedural inadequacies. Events rated at this level do not endanger safety, but the operating condition, or operation, of the plant deviates substantially from normal. Level 1events may include, for example, the failure of several redundant components of a safety system, even if the safety system was not required in the situation in question.

Events of this level occur relatively often, and they are usually only reported nationally. In Finland, for example, there were a total of 36 events of this level between 2000 and 2012 (*STUK 2013d*).

INES 2: A significant event with an impact on safety involving a significant failure of safety factors, but with sufficient guarantee for safety remaining. Events rated at this level also include events that cause radiation doses exceeding the dose limit to employees, or events that result in substantial releases of radioactive substances into areas within the plant not designed to receive them.

The International Atomic Energy Agency (IAEA), which maintains a network of communication between countries that use the scale, shall be informed of events rated at level 2 and above. While no events of this level have occurred in Finland in the 21st century, a total of 7 such events occurred between 1977 and 1999 (*STUK 2013d*).

An example of an event rated at this level was the 1991 Olkiluoto 2 switchgear building fire, as a result of which the plant unit lost its connection to the off-site power grid. As the event revealed deficiencies in the securing of off-site power supply, it belongs in level 2.

INES 3: A serious incident with an impact on safety that causes a release of radioactive substances into the environment exceeding the release limits approved by the authorities for normal operation. The most exposed individual resident of the vicinity of the nuclear power plant is exposed to a radiation dose of less than one millisievert. However, no off-site countermeasures are needed. The events rated at this level also include events which expose power plant employees to radiation doses sufficient to cause acute health effects, or events that result in a substantial dispersion of radioactive substances within the plant, however allowing the material to be recovered and stored as waste. Furthermore, this level includes events in which a further single failure of a safety system could lead to an accident, or in which the required safety systems would be inoperable due to a failure and thus unable to prevent an accident.

An example of an event rated at INES level 3 is the fire at the Vandellos nuclear power plant in Spain in 1989. The fire did not lead to any releases of radioactive substances, fuel damage, or on-site contamination. However, the event is rated at level 3 because the fire damaged several systems intended to guarantee the safety of the plant.

INES 4: An accident that results in a release of radioactive substances into the environment causing a radiation dose in the order of more than one millisievert to the most exposed individual resident of the vicinity of the nuclear power plant. The accident is caused by substantial damage to the nuclear power plant, such as a partial reactor core meltdown, and may cause a long-term interruption to plant operation. The release of radioactive substances into the environment may give cause to some civil defense measures, such as controlling the use of local foodstuffs, in the immediate vicinity of the plant. The events rated at this level also include events which expose one or more power plant employees to radiation doses likely to cause short-term lethal effects.

Events of INES level 4 include, for example, the release of radioactive substances inside the plant at the Windscale (now Sellafield) reprocessing plant in 1973. The cause of the accident was an exothermic chemical reaction in a process vessel. The event is rated at level 4 due to the impacts on-site.

INES 5: An accident that causes danger to the environment and results in the release of radioactive substances into the environment (in the order of hundreds to thousands of terabecquerels of iodine-131 equivalents). This type

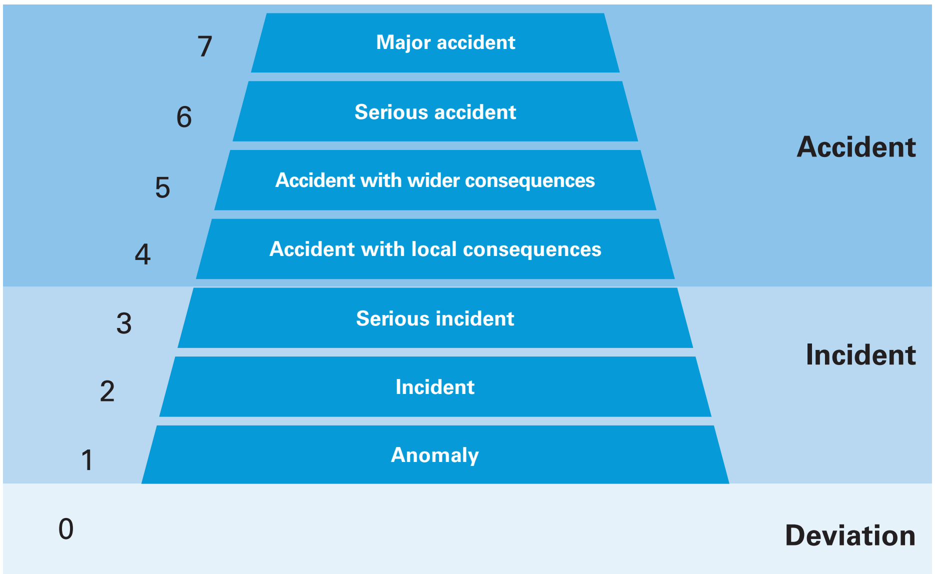


Figure 4-5. Severity levels on the International Nuclear Event Scale (INES).

of release would result in the partial implementation of civil defense measures in order to lessen the likelihood of health impacts. The accident involves severe damage to the nuclear power plant, such as extensive reactor damage, a major uncontrolled power increase, a fire, or an explosion spreading a substantial quantity of radioactive substances inside the plant.

For example, the Three Mile Island accident in the United States in 1979, the third most severe accident in the history of nuclear power plants, is rated at INES level 5. Such a large quantity of cooling water was lost through a stuck-open relief valve that the reactor dried up, overheated, and partially melted. Despite the severe damage to the reactor core, the reactor pressure vessel and containment building remained intact and prevented emissions into the environment as designed. Consequently, off-site impacts of the accident remained minor. However, the event is rated at level 5 due to the impacts on-site.

INES 6: A serious accident resulting in the release of a large quantity of radioactive substances into the environment (in the order of thousands to tens of thousands of terabecquerels of iodine-131 equivalents). Such a release is likely to result in the full implementation of civil defense measures to limit serious health impacts. The various civil defense measures available are discussed in more detail in the next section (4.5.3).

Only one accident has ever been rated at INES level 6. In 1957, a vessel containing high-level liquid waste exploded at the Mayak reprocessing plant near the town of Kyshtym in the Soviet Union, and radioactive substances were released into the environment. Health impacts from the accident were limited by countermeasures including the evacuation of the local population. The accident is rated at level 6 due to its environmental impacts.

This report includes a more detailed analysis of an accident rated at level 6. The dispersion of radioactive releases and the resulting radiation dose have been modeled. The results of the modeling and the impacts of the accident are discussed in more detail in Section 7.14. Consequences of level INES 7 severe accident have also been assessed with these results.

INES 7: A major accident involving a substantial release of radioactive substances from a large nuclear power plant into the environment. The release typically contains both short- and long-lived fission products (in the order of more than tens of thousands of terabecquerels of iodine-131 equivalents). Such a release may result in acute or delayed health damage and long-term environmental impacts. The impacts may extend to a wide area.

Two accidents have been rated at INES level 7: the 1986 explosive destruction of one of the reactors of the Chernobyl nuclear power plant in the Soviet Union (currently, Ukraine), and the 2011 accident at the Fukushima I plant in Japan following a massive earthquake and the resulting tsunami.

The non-compliance of the graphite-moderated RBMK type reactor with the crucial safety principle, according to which any uncontrolled reactor power increase must be prevented on the basis of physical properties, is considered to constitute the most important cause leading to the Chernobyl accident. The complete breakdown of the reactor caused major releases of radioactive substances, and the residents of the surrounding area were evacuated within a 30-kilometer radius of the nuclear power plant. Several people who participated in the rescue operations died from the acute health impacts of radiation. As the exposure of the local population to radiation occurred over a wide area, no acute health impacts were observed. However, exposure increased the statistical risk of cancer. Following the accident, statistics revealed that the occurrence of thyroid tumors in children had increased in Belarus, Ukraine, and the Russian territories located near the border. After the accident, several modifications improving nuclear safety were made to other reactors of the RBMK type, and more detailed instructions for the operation of the reactor were issued.

In the Fukushima accident, an earthquake and the resulting tsunami seriously damaged the systems performing the removal of decay heat in the Fukushima I plant. This resulted in the loss of coolant, fuel meltdown, and releases of radioactive substances from three reactors. The local population was evacuated within a 20-kilometer radius and, additionally, from an area extending up to 40 kilometers from the plant in the north-western direction. The power plant personnel and the local population were not exposed to radiation doses causing acute health impacts. The management of contaminated waters has presented a major challenge during the post-accident management phase, and several smaller radioactive releases into the environment have occurred.

4.5.3 Emergency preparedness operations and civil defense

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. The emergency preparedness arrangements include preparation for civil defense measures and the planning of their implementation. The nuclear energy legislation places requirements on the emergency preparedness, rescue, and civil defense operations. Furthermore, the Radiation and Nuclear Safety Authority issues detailed guidelines in its YVL Guides and separate emergency preparedness guides (VAL Guides).

Fennovoima will cooperate with the Pyhäjoki rescue department, as well as the Jokilaakso rescue department operating in the surrounding municipalities, in order to bring the emergency preparedness arrangements to the required level by the time of commencement of the operation of the plant.

4.5.3.1 Nuclear power plant emergency preparedness arrangements

The licensee will prepare an emergency preparedness plan and the emergency preparedness instructions required by the emergency preparedness organization to carry out their operations. The emergency preparedness plan will present an account of the planning, implementation, and maintenance of the emergency preparedness arrangements and describe the measures to be taken in an emergency response situation. The nuclear power plant emergency preparedness arrangements will be harmonized with the external rescue plan prepared by the authorities for eventual nuclear power plant accidents.

Events representing various accident scenarios will be analyzed in order to facilitate the planning of the emergency preparedness operations and the classification of emergency situations. The possibility of a severe accident shall be considered, and the variation of the plant conditions, duration of events, radioactive releases, discharge pathways, and weather conditions shall be taken into account.

The nuclear power plant will establish an emergency preparedness organization, consisting of persons trained for the tasks, to plan and implement the emergency preparedness arrangements. The emergency preparedness plan will define the duties and responsibilities of the organization personnel in the case of an emergency and determine how the plant operations will be harmonized with the rescue operations carried out by the authorities and the operations of the Radiation and Nuclear Safety Authority (STUK). The emergency preparedness organization will have at its disposal appropriate facilities and equipment, as well as adequate communication and alarm systems. The nuclear power plant will maintain a continuous state of preparedness for immediate emergency response operations when required. The emergency preparedness organization will have sufficient personnel for the management of even long-term emergency response situations.

The emergency preparedness organization will be alerted in emergency response situations, which include emergency situations and emergency standby situations. In emergency standby situations, the organization will assemble as required by the situation. In emergency situations, the organization will assemble in full force. The emergency preparedness plan will classify emergency situations into plant emergencies and general emergencies on the basis of their severity and manageability.

In an *emergency standby situation*, the aim is to ensure the safety level of the plant. STUK and the local emergency response center will be informed of any emergency standby situation. The latter will in turn inform the rescue authorities.

A *plant emergency* is a situation in which the safety of the nuclear power plant is compromised or is in danger of being significantly compromised. In the case of a plant emergency, STUK and the local emergency response center will be alerted immediately. The latter will in turn alert the rescue authorities.

A *general emergency* is a situation involving a risk of a release of radioactive substances potentially requiring the implementation of civil defense measures in the vicinity of the plant. In the case of a general emergency, STUK and the local emergency response center will be alerted immediately. The latter will in turn alert the rescue authorities.

In emergency response situations, the nuclear power plant emergency preparedness manager will be responsible for the management of nuclear safety and radiation protection-related matters at the nuclear power plant. Furthermore, the nuclear power plant emergency preparedness manager will provide the director of the rescue operations with recommendations concerning civil defense measures until STUK assumes the responsibility for the provision of such recommendations. The nuclear power plant emergency preparedness manager will ensure that personnel skilled in nuclear technology and radiation protection is placed to assist the director of the rescue operations. The authorities will, in cooperation with the licensee, prepare detailed rescue plans for emergency situations. These plans will cover the area within a radius of approximately 20 kilometers from the plant (the emergency planning zone).

The implementation of the emergency preparedness plan will be practiced in co-operation with the emergency preparedness and rescue organizations of the relevant authorities even before the fuel is transferred into the reactor. During the operation of the nuclear power plant, emergency preparedness exercises will be organized at least once a year. In addition, joint exercises between the authorities and the nuclear power plant will be organized at least once every three years. The purpose of the emergency preparedness exercises is to verify the appropriateness of the emergency preparedness arrangements in various accident situations. This is done to identify any need for change or improvement.

4.5.3.2 The protective zone and the emergency planning zone

According to the Radiation and Nuclear Safety Authority guideline on the location of the nuclear power plant (YVL Guide A.2), provision shall be made for the eventuality of a severe accident exceeding the plant design bases. This is done by preparing area use and civil defense plans. The Hanhikivi nuclear power plant will be located in a relatively sparsely populated area and at sufficient distance from population centers. The justification for the placement of the plant in a sparsely populated area is that the emergency preparedness measures are easier to implement for a smaller population group.

The nuclear power plant will be surrounded by a protective zone extending to a distance of approximately five kilometers from the plant. According to the YVL Guide A.2, densely populated settlements, hospitals, or facilities inhabited or visited by a considerable number of people are not allowed within the protective zone. The number of permanent residents and holiday residences, as well as recreational activity, within the protective zone will be limited so that a general rescue plan enabling effective evacuation of the local population can be prepared and implemented.

The indicative five-kilometer radius for the protective zone was defined in the 1970s based on the existing Finnish nuclear power plants and their surrounding areas. At the time, the objective was to guide future land use planning around the plants, and no particular consideration was made for possible new nuclear power plant sites when the

Figure 4-6. The nuclear power plant's protective zone and emergency planning zone.

radius distance was defined. No other country has a strictly identical practice concerning protective zones, and, compared to Finland, the number of people living within a similar radius from a nuclear power plant is significantly higher elsewhere in the world. (*STUK 2007*)

The purpose of the protective zone is to simplify emergency preparedness planning and to ensure that, in case of a severe hazard, the population can be rapidly evacuated from the vicinity of the plant. In practice, the efficiency of the rescue operations would be determined by many other factors beside the density of population, including the location of housing, traffic connections and routes, and the scope of the rescue actions.

STUK considers the five-kilometer radius to be an appropriate starting point for land use planning (*STUK 2007*). With regard to the radiation hazard, it is not possible to define a specific radius from the nuclear power plant beyond which the radiation caused by a severe accident would substantially decrease. When planning land use in the vicinity of new nuclear power plant sites, it is essential to highlight the possibility of fast evacuation in the event of an impending accident. Most importantly, the presence of access routes and adequate transport equipment enabling rapid transportation must be ensured.

Figure 4-6 shows the protective zone and emergency planning zone of the nuclear power plant. According to STUK's interpretation, any continuous residential area which extends, even in part, within the five-kilometer radius, will be considered to be located within the protective zone. Thus, the zone covers the continuous residential area of the Parhalahti village in its entirety.

In accordance with the Government Decree (716/2013), the Hanhikivi nuclear power plant will be surrounded by an emergency planning zone extending approximately 20 kilometers from the plant. The authorities will, in cooperation with the licensee, prepare detailed rescue plans for purposes of civil defense for this area and assume responsibility for the implementation of the plans.

The nuclear power plant will maintain in its safety analysis reports a current description of the area surrounding the power plant, its population, and industrial and commercial activities. The number of permanent residents in the vicinity of the Hanhikivi nuclear power plant and the sensitive sites located in the area are given in Section 7.10.

In addition to the sensitive sites listed in Section 7.10, all sites that may be simultaneously occupied by a considerable number of people are important from the point of view of rescue planning. Such sites include significant commercial districts, libraries, hotels, and various meeting facilities. Other sites with special implications for rescue operations include sites with fire and explosion hazards, such as gas stations and certain industrial sites, and large production and storage facilities.

During the normal operation of the nuclear power plant, the protective zone and the emergency planning zone will have no effect on the everyday life of the population living within them. Iodine tablets will be distributed to the population living within the protective zone for use in accident situations.

4.5.3.3 Civil defense measures

In the case of a nuclear accident, the need for civil defense measures is determined by the stages of the accident and the current weather conditions. In an accident situation, the nuclear power plant emergency preparedness organization and the Radiation and Nuclear Safety Authority (STUK) will give recommendations concerning civil defense measures. The authorities will be responsible for the implementation of those measures. In the case of a radiation hazard caused by a severe nuclear accident, the key civil defense measures include taking shelter indoors, ingestion of iodine tablets, evacuation, access restrictions, the protection of domestic animal production, and restrictions on the use of foodstuffs. Measures will be performed according to pre-defined criteria (Table 4-1). The authorities will broadcast information on the performance of the civil defense measures on the radio and television.

Even in the case of most severe nuclear power plant accidents, taking shelter indoors and ingestion of iodine tablets are adequate measures in all areas located farther than 20–30 kilometers from the plant *(STUK 2002)*. The purpose of taking shelter indoors while the radioactive plume passes over is to avoid breathing the radioactive outdoor air and to reduce exposure to the direct radiation from the plume. A milder measure would be to advise people to avoid going outdoors unless necessary. People will be advised to take iodine tablets if the breathing air is expected to contain high levels of radioactive iodine (I-131) due to the accident. Respiration will carry the radioactive iodine to the lungs, and it is finally retained in the thyroid gland. Due to this, the radiation dose for the thyroid gland will be significantly high. As the iodine contained in the iodine tablets is also retained in the thyroid gland, it prevents the accumulation of radioactive iodine.

In Finland, the population living in the protective zone will be evacuated in the case of an impending significant release of radioactive substances into the environment. If there is enough time, the evacuation will be carried out before the radioactive plume reaches the area. If there is not enough time, people will take shelter inside, and the evacuation will be carried out after the plume has passed the area. As the nuclear power plant will be designed so that the probability of a release occurring in the early stages of an accident and causing a need for civil protection measures is very small, there will be enough time for the performance of civil defense measures. In addition, access to areas which are contaminated or under the risk of contamination may be restricted for a specified time.

After the passing of the emission plume, no significant amounts of radioactive substances will remain in the outdoor air. All rooms shall be carefully ventilated and surfaces wiped clean. Radioactive particles from the emission plume will still be present on land, building surfaces, and in water. While the natural elimination of radioactive substances remaining in the environment may take a long time, their concentration decreases significantly during the first year. If necessary, the environment may be cleaned, for example, by washing the walls and roofs of buildings located in the most contaminated areas.

The radiation dose from food products may be decreased by preventing them from being contaminated with radioactive substances. Protective measures are of particular importance in primary production. The effects of a nuclear accident on the food supply chain are determined by the season, crop cycle, the circumstances and practices of local food production, and the production structure. The risk of elevated activity levels in food products is significantly higher during the growth period than during other seasons. Radioactive substances are easily transferred into milk and meat. Therefore, farmers will be advised to move their

Table 4-1. The planning criteria for key civil defense measures used in emergency preparedness planning.

Civil defense measure	Criterion: the measure will be performed when required to avoid the radiation dose to an individual listed below
Taking shelter indoors (for two days)	10 mSv*
Ingestion of iodine tablets	For persons under 18 years of age or pregnant: 10 mGy**, for adults: 100 mGy (thyroid dose)
Evacuation (for one week)	20 mSv

* The unit of radiation dose is the sievert (Sv)

** When referring to the effects of radiation on a single organ, the unit of radiation dose is the gray (Gy) domestic animals indoors and, if possible, to cover their feed even when there is only a threat of an accident. Other possible measures include covering cowsheds, restriction of ventilation or filtering the air, and storage of clean water. Reasonably sized areas of vegetable, berry, and fruit crops may also be covered before the onset of radioactive fallout. Following the accident, tilling of the soil and fertilization will effectively decrease the amount of radioactive substances ending up in farm products (*Rantavaara 2005*). The concentration of radioactive substances in affected food products may be decreased during processing by, for example, conversion of production. An example of this would be making cheese out of the milk so that most of the radioactive substances will be left in the whey.

The use of at least some food products will be restricted in the aftermath of a severe accident. If necessary, the pre-established limit values for food products to be placed in the market in the European Union (Council Regulation 87/3954), shown in table 4-2, may be quickly applied on the radioactivity concentration of food products.

Products sold in grocery shops shall be clean enough to meet the safety requirements set by the authorities. STUK and the pertinent ministries will provide through the media instructions and recommendations for the users of raw materials that are self-produced or harvested from the forests and lakes.

4.5.3.4 Liability in accident situations

Nuclear liability means the liability of the licensee of a nuclear facility for damage to third parties. According to the Nuclear Liability Act (484/1972), the licensees of nuclear facilities are liable for nuclear damage caused by nuclear incidents in their nuclear facility, regardless of whether the licensees are responsible for the cause of the damage. Compensable damage includes personal injuries, damage to property, financial loss, and the costs of environmental restoration measures and counter-measures.

The licensees of nuclear facilities located in Finland have unlimited liability for nuclear damage caused by a single nuclear event in Finland. The liability of the licensees of nuclear power plants located in Finland for nuclear damage caused outside Finland is limited to 600 million Special Drawing Rights of the International Monetary Fund, corresponding to approximately EUR 676 million. The licensee of the nuclear power plant shall have insurance covering this liability.

As per international treaties, the Finnish Radiation and Nuclear Safety Authority shall notify the International Atomic Energy Agency (IAEA) of an accident situation. All events classified INES 2 or higher must be notified to the IAEA, which will then convey the information to other governments. The EU has its own notification and information exchange system for events at nuclear power plants and radiation hazards.

4.6 Radiation and its health impacts

Radiation is either ionizing or non-ionizing depending on how it affects the substance it encounters. Ionizing radiation originates from radioactive substances or equipment generating radiation, such as X-ray equipment.

The health impacts of ionizing radiation can be divided into two categories: direct and long-term effects. Direct impacts are inevitable adverse impacts caused by extensive cellular damage. Long-term impacts are statistically observable adverse impacts caused by genotype changes in a single cell.

The unit of radiation dose is the sievert (Sv), which is used to measure the health impacts of radiation. Since one sievert is a large amount of radiation, sub-units, such as one-thousandth of one sievert (millisievert, mSv) or one-millionth of one sievert (microsievert, μSv), are commonly used. Dose rate indicates the intensity of the radiation, or how large a radiation dose a person receives over a certain time. The unit of dose rate is sieverts per hour (Sv/h).

Table 4-2. The pre-established maximum permitted levels of the concentration of radioactive substances in food products to be placed in the market in the European Union.

Radionuclides	Activity concentration, becquerel/kg*		
	Baby food	Dairy products and liquid food products	Other food products
Isotopes of strontium	75	125	750
Isotopes of iodine	150	500	2000
Isotopes of plutonium and transplutonium elements	1	20	80
Other radionuclides with a half-life longer than 10 days, for example, ^{134}Cs and ^{137}Cs	400	1000	1250

*) Following an accident, the maximum permitted levels, as set out in the table, may be applied for food products to be sold within the European Union market by a Commission Decision (the permitted levels for rarely used food products are ten times higher than the permitted levels for basic food products listed in this table) Situation-specific permitted levels may be applied by Council Decision.

4.6.1 Direct radiation impacts

Direct radiation impacts can occur when people are exposed to very large radiation doses in a very short period of time. The direct radiation injury hazard is only associated with powerful artificial emission sources, not natural radiation. For example, nuclear accident situations or medical radiation treatment may cause direct impacts. *(STUK 2009b)*

Direct imapcts are inevitable adverse impacts caused by exposure to very large radiation doses in a very short period of time. Direct radiation impacts include radiation sickness, radiation burns, radiation pneumonitis (irritation reaction of the lungs), gray cataracts, and fetal abnormalities. The consequences of radiation exposure depend on whether the whole body is exposed to radiation, or whether the exposure is limited to a certain organ, such as the thyroid gland, or a specific skin area. *(STUK 2009b)*

Small radiation doses do not cause direct impacts. Indeed, a threshold value for radiation can be said to exist. If the dose remains smaller than the threshold value, there will be no tissue damage. If the threshold value is exceeded, adverse impacts are inevitable. Above the threshold value, the severity of the impacts increases with the radiation dose received. The threshold value and the severity of the impact depend directly on the dose rate. Even high radiation doses do not necessarily result in adverse health impacts if the dose is accumulated slowly, over a long period of time. *(STUK 2009b)*

For whole body exposure, the threshold value for direct impact is approximately 500 mSv. In this case, the impacts can be seen as changes in the blood count within a few days. However, there will be no symptoms of radiation sickness at that time, and the person cannot feel the impacts. Local exposure can be ten times higher before radiation injury occurs. A whole body dose of more than thousand millisieverts, i.e. one sievert, received in a short period of time, will lead to radiation sickness. A sudden dose of four sieverts may be fatal, and a dose of ten sieverts will cause certain death. *(STUK 2009b)*

Radiation sickness is a life-threatening condition caused by widespread destruction of cells. Radiation sickness has been observed in the victims of atomic bombs in Hiroshima and Nagasaki, as well as the persons who took part in the rescue operations on the night of the accident at the Chernobyl nuclear power plant. Otherwise, radiation sickness has mainly been associated with situations in which people have unknowingly handled powerful radiation sources manufactured for industrial or medical use. *(STUK 2009b)*

4.6.2 Long-term radiation impacts

In practice, any radiation doses received by people will remain well below the threshold values of direct impacts. In the case of small radiation doses, the risk of developing a radiation-related cancer is small, and even large doses of radiation may not necessarily cause cancer. However, each radiation dose will contribute slightly to the overall cancer risk. Small radiation doses may cause genotype changes in cells and thus lead to the development of cancer or occurrence of genetic damage in offspring later on. The main objective of the radiation protection measures related to long-term impacts is to minimize the risk of cancer and, simultaneously, hereditary damage. All radiation-induced health impacts result from damage to the DNA molecule, i.e. the cellular genotype. However, as cells can repair DNA damage, all DNA damage does not result in detrimental health impacts. Radiation can nevertheless cause a permanent change of cellular genotype, i.e. a mutation. Mutations occurring in the cell's essential genes may cause cancerous tumors. Permanent damage only occurs as a result of a long chain of events, which is affected by many factors in addition to radiation. *(STUK 2009b)*

Because of the prevalence of cancer, the cancer risk among the whole population caused by small radiation doses is practically undetectable. In Finland, approximately 20,000 people develop cancer every year. For example, the Chernobyl fallout, which caused an average total dose of 2 mSv to Finnish people, may, according to an estimate, cause some 500 cancer deaths in Finland over 80 years, i.e. 6.25 deaths per year. The figure has no actual significance for the cancer death statistics. *(STUK 2013e)* Cancer caused by radiation cannot be distinguished from cancer caused by other factors *(STUK 2009b)*.

The assessment of the cancer risk caused by radiation exposure is based on population studies focusing on the follow-up of the Japanese atomic bomb survivors, the exposures of radiation workers, the follow-up results of radiation treatment patients, and environmental radiation doses. Scientific animal testing has also been utilized in the research *(UNSCEAR 2010)*.

Exposure to radiation in childhood increases the relative risk of cancer more than exposure in adulthood, when the prevalence of cancer is in any case higher. For example, in the follow-up of the residents of the areas in the vicinity of Chernobyl, only persons who were exposed to radiation to their head and/or neck area while under 20 years of age have been found to suffer from a clearly increased risk of thyroid cancer. *(Paile 2002, IAEA 2009)* This is why it is particularly important that children should take iodine tablets in the event of radiation exposure (see the criteria for civil defense measures in Section 4.5.3.3).

The International Commission on Radiological Protection (ICRP) has estimated that exposure to a radiation dose of 1,000 mSv increases cancer risk by 5.5 percent on small doses and dose rates *(Mustonen et al. 2008)*. This is an absolute risk, i.e. the likelihood of developing radiation-related cancer regardless of other factors that affect the development of cancer. The figure represents the lifetime risk for the whole population. The actual level of risk may be different for each individual. *(Paile 2002)*

Animal testing has shown that radiation can cause hereditary changes. However, the risk of hereditary damage is significantly smaller than the risk of cancer *(STUK 2009b)*. ICRP has estimated that exposure to a radiation dose of 1,000 mSv increases the risk of hereditary damage by 0.2 percent *(Mustonen et al. 2008)*.

The research on the impact of small radiation doses on the development of cancer and cancer mortality in the population, and in particular children, living in the vicinity of nuclear power plants has been carried out over decades. Most studies show no difference between the morbidity of the population living close to nuclear power plants compared to that of the rest of the population. The 2010 Finnish study on the prevalence of leukemia in children living in the vicinity of nuclear power plants in Finland did not indicate an increased risk of developing leukemia. As the study was restricted to a five-kilometer radius of the nuclear power plants, the study sample was not very large. *(Ghirga 2010)*

A publicized German study (*Kaatsch et al. 2007*) suggests that cases of childhood leukemia are statistically more prevalent within a five-kilometer radius of nuclear power plants than elsewhere. According to the researchers, the risk of developing cancer cannot be caused by any radioactive releases from the plants, because the doses caused by natural background radiation are 1,000–100,000 times greater.

4.6.3 Radiation and pregnancy

A developing fetus is sensitive to radiation because the cells of a fetus divide at a rapid rate. However, there is no evidence indicating that random small radiation doses could cause any significant damage to fetuses. The effect of radiation during pregnancy depends of the radiation dose, dose rate, and the stage of pregnancy. (*STUK 2009b*) Pregnant women may be exposed to radiation in the course of regular radiation-related work or during the performance of a lower abdominal X-ray examination. During pregnancy, natural radiation causes to the developing fetus a total radiation dose of approximately one millisievert (*Paile 2002*).

Radiation damage to the fetus occurs only at rather large doses (*Paile 2002*). With the exception of the survivors of the Hiroshima and Nagasaki nuclear explosions, it has not been possible to demonstrate the impacts of radiation on pregnancies (*Auvinen 2004*). A large radiation dose received in the early stages of pregnancy will very likely lead to the death of the embryo, in which case the pregnancy would terminate even before it has been detected. After the first two weeks of pregnancy, only significant cellular damage or other disruption affecting multiple cells may endanger fetal development. This may happen if the radiation level exceeds a certain minimum value, which depends on the fetus's stage of development, type of radiation, and dose rate. The stage of development also determines the type of developmental disorder caused by the exposure. The fetus's central nervous system is most sensitive to damage by radiation during pregnancy weeks 10–17. (*STUK 2009b*)

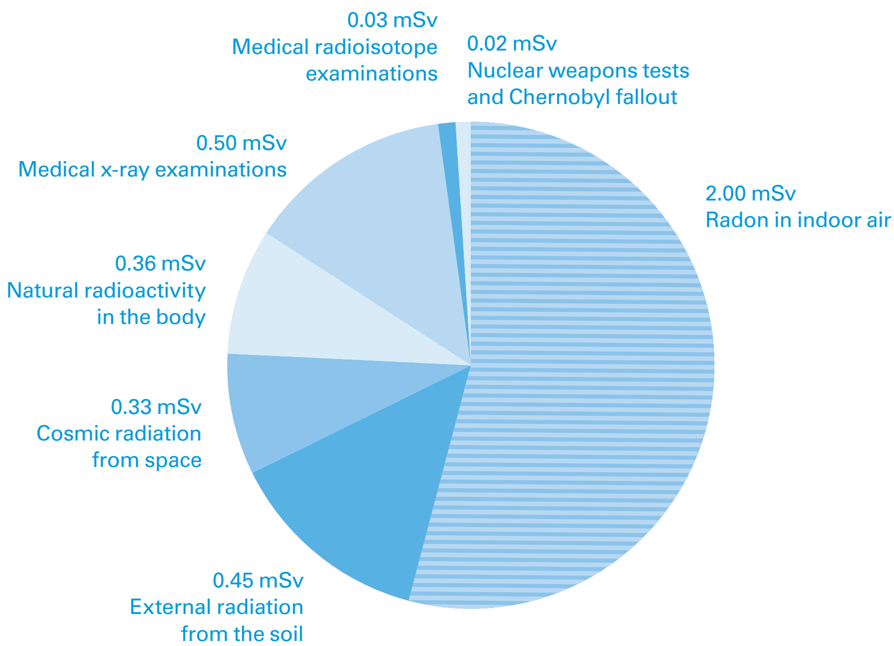
Exposure to radiation exposure during pregnancy can also increase the risk of childhood cancer. If a fetus is exposed to a radiation dose of 10 mSv during pregnancy, the risk of childhood cancer will be 1/1,700. (*STUK 2009b*)

4.6.4 Reference data on radiation sources and doses in Finland

Roughly one in three Finnish people will develop cancer during their lives. Ionizing radiation is estimated to cause 1–3 percent of all cases of cancer *(Pukkila et al. 2011)*. The average annual radiation dose received by Finnish people is approximately 3.7 mSv (Figure 4-7). More than half of this dose comes from radon found in indoor air.

The average radon concentration inside Finnish homes is 120 Bq/m^3, which corresponds to an annual radiation dose of about two millisieverts. Due to the high uranium content of Finnish granitic rock types, the radon concentration of indoor air in Finland is among the highest in Europe. While high indoor air radon concentrations are found throughout Finland, they are most prevalent in the province of Southern Finland and the Pirkanmaa area. With regard to high radon concentrations, the most unfavorable areas

Figure 4-7. The sources of the average annual radiation dose of 3.7 mSv received by Finnish people *(STUK 2013f)*.



include rough gravel ridge formations, through which air containing radon passes with ease. In Finland, some 2,000 cases of lung cancer are diagnosed every year, of which radon is estimated to account for 300. The solid decay products of radon enter the lungs through inhalation and stick to the inner surface of the lungs, emitting alpha radiation which increases the risk of lung cancer. *(STUK 2011b)*

Natural background radiation accounts for some 30 percent of the annual radiation dose received by Finnish people, and an additional 15 percent comes from the use of radiation in healthcare services *(STUK 2009b)*.

Radiation from space, or cosmic radiation, causes Finnish people to receive an annual dose of approximately 0.3 mSv. The impact of cosmic radiation becomes more pronounced with altitude. The maximum annual dose to flight personnel from cosmic radiation is approximately five millisieverts, which is several times more than the dose received by the rest of the population. In practice, there are few or no ways of protecting oneself from cosmic radiation. *(STUK 2013o)*

Part of the annual radiation dose comes from our own bodies. Natural radioactive substances, such as potassium-40, enter our bodies with food, drinking water, and inhaled air. Exposure to internal radiation continues until the radioactive substances have been excreted from the body or depleted due to radioactive decay. The annual dose caused by the decay products of the uranium and thorium series contained in drinking water and other food products is considerably smaller, averaging some 0.3 mSv. *(STUK 2009c)*

With regard to the internal radiation exposure of humans, the most significant artificial radioactive substances are the long-lived isotopes cesium-137 and strontium-90, which are contained in all natural food products, such as mushrooms, lake fish, game, and berries. These isotopes have entered the Finnish territory as the result of atmospheric nuclear testing and the Chernobyl nuclear power plant accident that took place in Ukraine in 1986. The Chernobyl fallout still causes Finnish people to receive an annual radiation dose of approximately 0.02 mSv. *(STUK 2009c)*

Table 4-3 presents a few examples of different radiation doses. According to the Government Decision (395/1991), the normal operation of a nuclear power plant may only cause a maximum annual radiation dose of 0.1 mSv to the people living in the vicinity of the plant. Table shows that the radiation doses caused by nuclear power plants in 2012 were clearly smaller than one-hundredth of this limit value.

Table 4-3. Examples of radiation doses (STUK 2002, STUK 2013k, STUK 2013l, STUK 2013m, STUK 2013n).

Dose	Description
0.00007 mSv	The calculated radiation dose caused by nuclear power plant emissions to the most exposed group among the population living close to the Loviisa and Olkiluoto nuclear power plants in 2012
0.01 mSv	The dose received by a patient during a dental X-ray imaging
0.018 mSv	The dose of cosmic radiation received on a return flight from Helsinki to Rome
0.1 mSv	The dose incurred by a patient during an X-ray imaging of the lungs
0.2 mSv	The dose received by a patient during mammography (X-ray imaging of the breasts)
0.3 mSv	The annual dose received by Finnish people from cosmic radiation
0.8 mSv	The annual dose received by the residents of Mexico City, located at an altitude of over two kilometers, from cosmic radiation
3.7 mSv	The average annual radiation dose of Finnish people
50 mSv	The maximum annual dose allowed for a radiation worker (in 2012, the largest dose received by a Finnish nuclear power plant worker was 14.3 mSv)
100 mSv	The maximum five-year cumulative dose allowed for a radiation worker (in 2008–2012, the largest accumulated dose received by a Finnish nuclear power plant worker was under 54 mSv)
1,000 mSv	A dose that, if received in less than a day, will cause symptoms of radiation sickness
6,000 mSv	A dose that, if received suddenly, may be fatal

5

Licenses, permits, plans, notifications and decisions required for the project

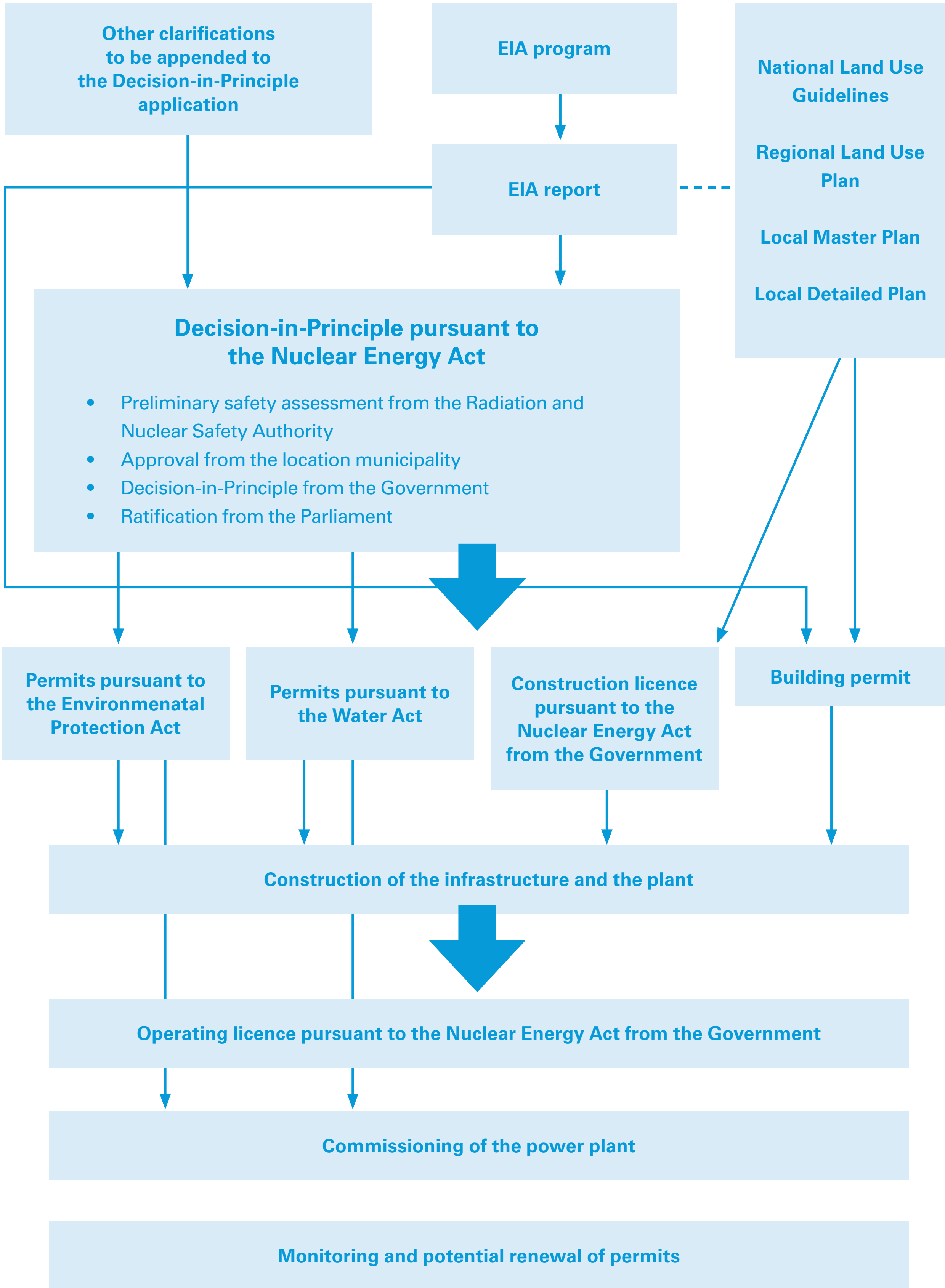


Figure 5-1. Licencing and permitting procedures in the construction and operation of a nuclear power plant.

The licenses, permits, notifications and decisions related to the construction and operation of a nuclear power plant are illustrated in figure 5-1.

5.1 Land use planning

5.1.1 General

Land use and building are regulated by the Land Use and Building Act (132/1999) and Decree (895/1999). The land use planning system consists of the national land use guidelines and three planning levels: the regional land use plan, the local master plan and the local detailed plan.

The national land use guidelines (VAT) were approved by the Finnish Government on November 30, 2000, and they entered into force on June 1, 2001. The content of the guidelines was reviewed on November 13, 2008. Moreover, on December 22, 2009, the Government decided that the national inventory of the built cultural environment of national importance (RKY 2009), prepared by the National Board of Antiquities, replaces the 1993 inventory referred to in the national land use guidelines.

The purpose of the national land use guidelines is to ensure that matters of national importance are taken into consideration in land use and planning all over the country. The national land use guidelines must be taken into account and advanced in the actions of the state's authorities and regional and municipal planning.

The guidelines are mainly implemented in regional land use planning where the objectives are aligned with regional and local conditions and objectives. The guidelines are also to be taken into consideration in the regional plan and programs. The nature of some guidelines requires that they must be taken directly into account in municipal planning. In municipalities, the local master plan is an essential tool for the practical implementation of the national land use guidelines and the regional land use plan.

The regional land use plan is a master plan of land use within a region or parts of it. It presents the principles of land use and the urban structure and indicates areas important for regional development. The purpose of the regional land use plan is to settle national, regional and local issues regarding land use. The regional land use plan can also be prepared in stages, as a plan concerning a certain entity.

The regional land use plan prescribes planning in municipalities and other land use planning by the authorities. The plan is presented on a map using plan symbols and regulations. The regional land use plan also includes a review, presenting the plan's objectives, impacts and other information required for the interpretation and implementation of the plan.

The regional land use plan is prepared by the regional council and approved by the regional assembly. The plan is ratified by the Ministry of the Environment, after which it becomes legally valid. Complaints against the council's decision can be filed with the Ministry of the Environment. Complaints against the Ministry's decisions, in turn, can be filed with the Supreme Administrative Court.

The local master plan is a municipality's general land use plan. Its purpose is to define the locations for various urban functions, such as housing, services, workplaces and recreational areas, and organize connections between them. Master planning defines the principles of targeted development and prescribes the preparation of local detailed plans for the area.

The local master plan can apply to the entire municipality or a certain area, in which case it is called a partial master plan. The plan is presented on a map, including plan symbols and regulations and a review.

The municipality is responsible for preparing the local master plan. The plan is approved by the town or community council. If municipalities have prepared local master plan jointly, it is approved by a joint body of the municipalities and ratified by the Ministry of the Environment. The local master plan will enter into force once its approval is publicly announced.

The local detailed plan defines the future use of an area. The plan defines, for example, the environment to be preserved, and what can be built and how. The plan can also define the location, size, and purpose of buildings. The local detailed plan can apply to an entire residential area, including housing, work, and recreational areas, or a single lot. The local detailed plan is prepared by the municipality.

The local detailed plan includes a map and plan symbols and regulations. The local detailed plan includes a review describing the plan's preparation process and central features.

Building in coastal areas can be prescribed with a shore plan.

5.1.2 Planning required by the project

The implementation of the planned nuclear power plant project at Hanhikivi headland, Pyhäjoki, has required that the necessary areas for the plant have been indicated in the land use plans for the planned site location. Procedures pursuant to the Land Use and Building Act (132/1999) have been followed to prepare the land use plans of all three planning levels for the Hanhikivi headland, as required by the project.

The Council of Oulu Region has been responsible for preparing the regional land use plan. The local master and detailed plans have been prepared by the municipality of Pyhäjoki and the Town of Raahe. The plans of all three levels of planning are legally valid. For a more detailed account of the land use planning concerning the Hanhikivi headland, see Section 7.2.1.2.

5.2 Licenses and permissions pursuant to the Nuclear Energy Act

The Nuclear Energy Act (990/1987) prescribes the general principles of the use of nuclear energy, the implementation of nuclear waste management and the licenses required for using nuclear energy. The purpose of the act is to ensure that the use of nuclear energy is in the overall interest of society and safe for people and the environment.

5.2.1 Decision-in-Principle

According to the Nuclear Energy Act, the construction of a nuclear facility of considerable general significance, such as a nuclear power plant, shall require a Government Decision-in-Principle in that the construction of the nuclear power plant is in line with the overall good of society. The Decision-in-Principle is applied for using an application submitted to the Government.

In addition to basic project information, the Decision-in-Principle application must include reports of the expertise and financial operational conditions available to the applicant and the nuclear facility's general significance for the nation's energy management, the use of other nuclear power plants, and their nuclear waste management. For each nuclear power plant project, the application is to include rough descriptions of the plant's technical operational principles, the safety principles to be followed in the project, a rough plan of nuclear fuel management and the applicant's plans for organizing nuclear waste management. The application is also to include rough descriptions of the ownership and administrative relationships in the planned location and its suitability for its intended purpose as well as a report of the functions and planning arrangements in the nuclear power plant's planned location and its surroundings.

The Ministry of Employment and the Economy must obtain a preliminary safety assessment on the basis of the application from the Radiation and Nuclear Safety Authority and a statement from the Ministry of the Environment, as well as from the municipal council of the selected municipality and the neighboring municipalities.

Before the Decision-in-Principle is made, the applicant shall compile a general public description of the plant project, its safety and the expected environmental effects. The description shall comply with instructions issued by the Ministry of Employment and the Economy, and will be reviewed by the Ministry before being published. The report must be made publicly available. The Ministry of Employment and the Economy shall provide the residents and municipalities in the immediate vicinity of the nuclear facility, as well as the local authorities, with an opportunity to present their opinions towards the project before the Decision-in-Principle is made. Furthermore, the Ministry shall arrange a public event in the municipality where the facility is planned to be located. The public shall have an opportunity to give their opinions at the event. These opinions shall be made known to the Government.

According to the Nuclear Energy Act, the Government can only give a favorable Decision-in-Principle regarding the plant location if the site municipality's statement mentioned above supports the project. The Government must also be able to find that it is possible to build and operate the plant so that it is safe and does not cause any danger to people, the environment or property. The Government must also consider the issue from the perspective of the overall good of society, with special attention paid to the following:

- the need for the nuclear facility project with respect to the country's energy supply
- the suitability of the planned location of the nuclear facility, and its environmental impacts
- arrangements for the nuclear fuel and nuclear waste management.

The Government's Decision-in-Principle shall be forwarded to Parliament for perusal. Parliament may reverse the Decision-in-Principle or decide that it remains in force as such, but it cannot amend its content. The applicant cannot make any significant and financially binding acquisition agreements related to the construction of the plant before the Decision-in-Principle enters into force.

In January 2009, Fennovoima submitted an application to the Government for a Decision-in-Principle concerning the construction of a nuclear power plant. Based on the application, the Government issued a favorable Decision-in-Principle on May 6, 2010. Parliament ratified the Decision-in-Principle on July 1, 2010.

As the project currently subjected to an environmental impact assessment (one pressurized water reactor with the approximate electric power of 1,200 MW) is not mentioned as a plant alternative in Fennovoima's original application for a Decision-in-Principle, the Ministry of Employment and the Economy requires that the following additional measures are carried out:

- Fennovoima updates the project's environmental impact assessments
- the Radiation and Nuclear Safety Authority assesses the safety of the current plant alternative
- the Municipality of Pyhäjoki issues a statement on the matter
- the Ministry of Employment and the Economy organizes a public hearing in accordance with the Nuclear Energy Act.

After these clarifications have been completed, it will be decided whether the currently valid Decision-in-Principle also covers the present plant alternative or whether the Decision-in-Principle ratified by Parliament in July 2010 must be reprocessed.

5.2.2 Construction license

The Government grants the license to construct a nuclear facility. A license to construct a nuclear facility may be granted if the Decision-in-Principle ratified by Parliament has deemed the construction of a nuclear facility to be in line with the overall good of society and the construction of a nuclear facility also meets the preconditions for granting a construction license for a nuclear facility as provided in Section 19 of the Nuclear Energy Act. These preconditions include:

- the plans concerning the nuclear facility meet the safety requirements laid down in the Nuclear Energy Act, and the safety of employees and the population have been

appropriately taken into account when planning the operations;
- the location of the nuclear facility is appropriate with regard to safety and environmental protection has been appropriately taken into account;
- safety arrangements have been taken into account when planning operations;
- the area is reserved in the local detailed plan for the construction of a nuclear facility as referred to in the Land Use and Building Act (132/1999) and the applicant has control over the area as required by the plant operations;
- the methods and plans available to the applicant for arranging nuclear fuel and nuclear waste management, final disposal of nuclear waste and decommissioning of the plant are sufficient and appropriate; and
- the applicant has the necessary expertise available, possesses sufficient financial conditions, and is otherwise considered to have the prerequisites to engage in its operations safely and in accordance with Finland's international contractual obligations.

The Decision-in-Principle includes the condition that Fennovoima shall apply for a construction license referred to in the Nuclear Energy Act within five years of Parliament's decision that the Decision-in-Principle shall remain in force; this period of five years will end on June 30, 2015.

5.2.3 Operating license

The Government grants the license to operate a nuclear facility. The license to operate a nuclear facility can be issued as soon as the license has been granted to construct it, providing the preconditions listed in Section 20 of the Nuclear Energy Act are met. These preconditions include:
- the nuclear facility and its operation meet the statutory safety requirements, and the safety of employees and the population and environmental protection have been appropriately taken into account;
- the methods available to the applicant for arranging nuclear waste management, including the final disposal of nuclear waste and the decommissioning of the facility, are sufficient and appropriate;
- the applicant has sufficient expertise available and, in particular, the competence of the operating staff and the operating organization of the nuclear facility are appropriate; and
- 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 shall not be started on the basis of the license granted until the Radiation and Nuclear Safety Authority has ascertained that the nuclear facility meets the prerequisites prescribed by law, and the Ministry of Employment and the Economy has stated that provision for the cost of nuclear waste management has been arranged in a manner required by law.

5.3 Notifications pursuant to the Euratom Treaty

The European Atomic Energy Community (Euratom) Treaty requires that each Member State provides the Commission with plans relating to the disposal of radioactive waste (Article 37) and that the licensee submits to the Commission an investment notification (Article 41) and declares to the Commission the technical characteristics of the facility for nuclear materials safeguarding purposes (Article 78).

5.4 Building permit

A building permit in accordance with the Land Use and Building Act (132/1999) must be applied for regarding the power plant buildings. For large projects, such as the construction of a power plant, the building permit can be applied for the power plant building and other related structures and buildings in one or more parts.

The building permit is obtained from the building permit authorities of the municipality in which the plant is located, which, when granting the permit, will ensure that the construction plan is in accordance with the ratified local detailed plan and the building codes. Building permit applications in the municipality of Pyhäjoki are currently the responsibility of the Raahe building and environmental control services.

A building permit is required before construction can be started. The issuance of a building permit also requires that the environmental impact assessment procedure has been completed.

Building permits must also be applied to any temporary storage or office buildings and the concrete batching plant used during the construction phase.

Commencement of earth-moving and excavating work requires an action or landscape work permit pursuant to the Land Use and Building Act.

5.5 Flight obstacle permit and no-fly zone

According to the Aviation Act (1194/2009), a flight obstacle permit is required for setting a device, building, structure or sign that extends more than 30 meters above the ground. The permit is required as an enclosure with the building permit application for the nuclear facility. The flight obstacle permit is applied for from the Finnish Civil Aviation Authority. The application must include a statement provided by the appropriate airline service supplier (Finavia Oyj).

A flight obstacle permit will also be required for any large cranes during the construction process.

According to the Aviation Act, a no-fly zone can be prescribed in the vicinity of nuclear power plants through a

Government decree. A no-fly zone refers to airspace with defined limits above a country's land area or territorial waters where aircrafts are forbidden to fly. However, the no-fly zone is not directly a requirement for nuclear power plants and its size is not prescribed by law. The surrounding areas of the Loviisa and Olkiluoto nuclear power plants are prescribed as no-fly zones through a Government decree. A no-fly zone will also be defined for Fennovoima's nuclear power plant.

5.6 Permits pursuant to the Environmental Protection Act and the Water Act

A permit pursuant to the Environmental Protection Act shall be required for activities that pose a threat of environmental pollution. A permit is required for the activities on the basis of the Environmental Protection Act (86/2000) and the Environmental Protection Decree (169/2000) enacted on the basis of the Environmental Protection Act. The permit can only be granted if the activities do not constitute harm to health or cause significant pollution of the environment or a risk of such pollution. The environmental permit authority will be either the Regional State Administrative Agency of Northern Finland or the environmental conservation authority of the municipality of Pyhäjoki, depending on the activities for which the permit is applied.

The Water Act (587/2011) regulates permits for water economy projects. A permit pursuant to the Water Act is required for the hydraulic construction works and structures within water systems. A permit pursuant to the Water Act is also necessary for operations that include leading water out of a water system. The water permit authority is the Regional State Administrative Agency of Northern Finland.

For water economy issues that pose a threat of pollution of water systems, the Environmental Protection Act applies.

5.6.1 Permits required for construction

Fennovoima filed the permit applications pursuant to the Water Act to the Regional State Administrative Agency of Northern Finland on February 12, 2013. Public notices were issued on the permit applications on November 26, 2013, to obtain statements and comments concerning the applications.

There are three applications, the most extensive of which concerns the construction of a pier and the related area, cooling water intake structures, and a navigation channel. The second application concerns the cooling water discharge structures and the third the definition of the marine spoil area in the sea. The cooling water intake is planned to be built on the western shore of the Hanhikivi headland, in connection with the dock basin. The cooling water discharge location would be in the northern part of the Hanhikivi headland.

Furthermore, the construction site has functions that require permits in accordance with the Environmental Protection Act. These include a rock crushing plant and a concrete batching plant. These permit applications will be processed by the environmental conservation authority of the municipality of Pyhäjoki.

5.6.2 Permits required for operation

An environmental permit must be obtained for operating a nuclear power plant. An environmental permit covers all matters relating to the environmental impacts of the facility, such as atmospheric and aquatic emission limit values, waste treatment regulations, and noise limits, as well as other related environmental matters such as emission monitoring and reporting.

The Regional State Administrative Agency of Northern Finland grants the environmental permit if the activities fulfill the requirements prescribed by the Environmental Protection Act and other legislation. In addition, the project must not contradict land use planning for the area. The environmental impact assessment procedure must also be completed before the permit can be granted.

A water permit pursuant to the Water Act is required for the intake of cooling and other water necessary for the power plant.

5.7 Legal impact of protection measures

The project area and its surroundings include areas and objects protected in different ways. If the implementation of the project is considered to have a detrimental effect on the protected area, a permit required by legislation must be obtained for deviating from the protection decisions. The most significant regulations are described below. The project's potential impacts on the protected areas and objects are described in Chapter 7.

5.7.1 Nature Conservation Act

The Nature Conservation Act (1096/1996) includes several alternative means for organizing conservation. This chapter describes the various conservation means and how they are or have been taken into account in the nuclear facility project.

The impacts related to the areas included in the Natura 2000 network must be assessed if the project is considered likely to reduce the area's Natura values significantly. The authorities must not grant a permit for implementing the project if the assessment procedure indicates that it is likely that the project will significantly reduce these values. However, the permit can be granted if the Government decides in a plenary session that the project is to be implemented for the very important overall good of society and there is no alternative solution. If the Natura 2000 area has a habitat type and/or a species primarily to be protected in accordance with the Habitats Directive (92/43/EEC), special requirements exist for granting the special exemption and a statement from the European Commission must be obtained.

Natura assessment of the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area located in the vicinity of the Hanhikivi headland has been carried out in 2009. The assessment was carried out in connection with preparing a regional land use plan. The conclusion of the assessment is that the project, including the construction of power lines, will not, solely or together with other projects, cause any significant adverse impacts on the habitat types and bird species acting as conservation criteria, or the Natura 2000 area as a whole. As the power line route on the Hanhikivi headland will change from that originally planned, update of the Natura assessment will probably be necessary in connection with the environmental impact assessment of the power lines.

According to the Nature Conservation Act, *nature conservation areas* can be established on state-owned or private land. In the latter case, an application or consent of the private landowner is required to make the area a nature conservation area. A private protected area can be terminated or its preservation regulations reduced if the preservation of the area prevents the implementation of a project or a plan that is very important for the overall good of society. The permit for changing the conservation decision is to be applied for from the North Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre).

Based on the Nature Conservation Act, the ELY Centre can make a decision on the boundary-marking of an area belonging to a protected habitat type. The owners and holders of the area shall be notified of the decision. The area must not be changed in a manner that puts the preservation of the characteristics of the habitat type in the area at risk. However, the ELY Centre can grant a special exemption if the conservation objectives of the habitat type in question are not significantly endangered or the conservation of the habitat type prevents the implementation of a project or plan that is very important for the overall good of society. The boundaries of areas belonging to the habitat type seaside meadow have been defined by the ELY Centre's decision chiefly on the north-eastern and eastern shores of the Hanhikivi headland.

The Nature Conservation Act defines the protection measures to be applied to *protected species.* The Nature Conservation Decree (160/1997) lists all the animals and plants protected in the whole of Finland, and some plant species protected in parts of Finland. The ELY Centre may grant a special exemption from the protection measures of a protected species based on preconditions specified by law. Fennovoima has received a special exemption for the purpose of removing a habitat of yellow iris and transferring the plants to a favorable new habitat. The exemption was necessary for the construction of the planned dock basin, cooling water intake structure and navigation channel. The exemption concerning the yellow iris is legally valid.

Species under strict protection are species that have been listed in the Nature Conservation Decree as being at imminent risk of extinction. Important habitats of species under strict protection must not be destroyed or deteriorated. The ELY Centre can issue a decision to mark boundaries of the habitat. The decision also includes the authority's view of the measures that could destroy or deteriorate the habitat. The ELY Centre has issued a boundary-marking decision concerning the territory of a bird of prey in the Hanhikivi headland.

The Nature Conservation Act also defines protection measures for *species in need of strict protection, listed in the EU Habitats Directive, Annex IV, sections a (animals) and b (plants)*. The ELY Centre may grant a special exemption from the protection measures based on preconditions specified in the Habitats Directive. Fennovoima has been granted two such exemptions, one concerning the removal of a breeding place of the moor frog and one concerning the transfer of moor frogs from the area to a breeding place suitable for the species. The exemptions are related to the construction of the planned dock basin, cooling water intake structure and navigation channel. The permits are legally valid based on the decision issued by the Administrative Court of Oulu on October 7, 2013.

5.7.2 Antiquities Act

Fixed antiquities are preserved by virtue of the Antiquities Act (256/1963) without a separate preservation decision. Hanhikivi, a boundary mark originating from historical times, is located in the Hanhikivi headland and protected by the Antiquities Act as a historical monument. Hanhikivi will remain accessible during the construction and operation of the nuclear facility.

According to the Antiquities Act, any complete or partial wreck of a ship or other vessel that is found in the sea or in a water body and that can be assumed to have sunk more than one hundred years ago is protected. No protected wrecks or partial wrecks have been found in the sea surrounding the Hanhikivi headland.

5.8 Permits required for connected projects

The establishment of public and private roads is prescribed by the Highways Act (503/2005). Construction of public highways requires the preparation of a general plan and road plan. The Finnish Transport Agency acts as the authorizing body. Fennovoima is responsible for the construction of a new private road connection, Hanhikiventie. For the construction of a private road, a permit procedure in accordance with the Land Use and Building Act is required. Road proceedings will later be held to make the road a public highway.

The construction of 400 kV and 110 kV transmission lines requires a building permit pursuant to the Electricity Market Act (588/2013). The Energy Market Authority is the authorizing body. The construction of a transmission line of more than 15 kilometers long and of more than 220 kV requires an EIA procedure. Building permit applications for smaller transmission lines must be attached with a report of environmental impacts in accordance with the Electricity Market Act.

The environmental impact assessment for the construction and operation of power transmission lines from the nuclear power plant is planned to begin in 2014.

A route decision for the navigation channel to be constructed will be applied for from the Finnish Transport Agency. The route decision is an administrative decision that confirms the official adoption of the routes and safety devices mentioned in the decision. A permit from the Finnish Transport Agency is required for setting up navigation safety devices as defined in the decree concerning the marking of fairways (846/1979).

5.9 Other permits

Other permits of relevance to this project include permits for the import of nuclear material, possession and transportation of nuclear fuel, a permit or an agreement for wastewater discharge into the sewage system and permits pursuant to the Chemicals Act.

Permits for the import and possession of nuclear material, as well as for the transportation of nuclear fuel shall be applied for from the Radiation and Nuclear Safety Authority.

Fennovoima aims to sign agreements with the municipal sanitary services of Pyhäjoki on the treatment of household and industrial waste water at the municipal wastewater treatment plant. The agreement may contain conditions set for the quality and quantity of the water discharged into the sewage system.

During the operating phase of the plant, the storage and handling of chemicals requires a permit that shall be applied for from the Finnish Safety and Chemicals Agency (TUKES). The application and the permit are based on the Act on the Safe Handling and Storage of Dangerous Chemicals and Explosives (390/2005), Government Decree on the Monitoring of the Handling and Storage of Dangerous Chemicals (855/2012), and the Government Decree on the Safety Requirements for the Industrial Processing and Storage of Dangerous Chemicals (856/2012). A notification concerning the minor amounts of chemicals that will be processed and stored at the construction site shall be issued to the municipal authority in charge of chemicals control in Pyhäjoki.

6

The project's relationship with plans and programs concerning environmental protection and the use of natural resources

The plans and programs with the most significance for the project (Table 6-1) include national target programs and international commitments. These do not generally obligate operators directly, but their objectives can be introduced at the operator level for example through environmental permits.

The following table explains the relationship of the project to existing environmental plans and programs.

Table 6-1. The project's relationship to plans and programs concerning environmental conservation and the use of natural resources.

The project's relationship to plans, programs and agreements			
Name	**Content**	**Relationship with the project**	**Reference**
United Nations Framework Convention on Climate Change, UNFCCC	In the Framework Convention on Climate Change organized in Kyoto in December 1997, the approved EU objective was to reduce the total volume of greenhouse gas emissions by eight percent from the 1990 level. Negotiations over setting a new objective are in progress.	Nuclear energy production does not directly create greenhouse gas emissions. Nuclear power can replace fossil energy production forms based on combustion processes and reduce the average carbon dioxide emissions of electricity production.	The Kyoto Protocol 1997 The most recent UNFCCC conference was held in Warsaw in November 2013.
Energy Policy for Europe	The objective of the EU energy policy is to secure competitive availability of clean energy as a response to climate change, increasing global energy demand and future insecurities in energy supply. In order to achieve the objectives of the energy policy, a ten-point action plan has been defined. The action plan includes the development of the EU's internal energy market, the security of energy supply, commitment to the reduction of greenhouse gases and the future of nuclear power.	The future of nuclear power is one of the ten points of the energy strategy's action plan. According to the action plan, the Commission regards nuclear energy as a noteworthy energy source that would allow the achievement of strict emission targets. According to the Comission, EU should maintain and delevop its technological leading position in nuclear energy. The Commission also proposes that the authorities of the Member States increase the efficiency of nuclear power-related license procedures and remove unnecessary restrictions.	The Energy Policy for Europe was published on January 10, 2007.
EU climate and energy package	The European Commission's climate and energy package is an extensive legislation proposal concerning the Member States. The EU is committed to reducing greenhouse gases by 20% by 2020 from the emission level in 1990 and increasing the share of renewable energy in the total energy use within the EU to one-fifth. The emission reduction objective will increase to 30% if the new global emission reduction agreement can be achieved. In addition to renewable energy, measures towards this objective include improved energy efficiency and investments in clean forms of energy such as the recovery and storage of carbon dioxide.	If nuclear power is used to replace the capacity of power plants that use non-renewable energy sources (such as coal-fired power plants), the average carbon dioxide emissions in electricity production can be reduced.	The EU published the renewable energy and climate change package on January 23, 2008.

Name	Content	Relationship with the project	Reference
The Finnish National Climate and Energy Strategy	The Finnish energy policy framework is defined in the National Climate and Energy Strategy, approved by the Government in March 2013, and the programs that complement the previous strategy approved in 2008. Key objectives of the strategy update include ensuring that the national targets for 2020 are achieved and to make preparations for meeting the long-term energy and climate objectives set by the EU. Parliament's opinion on the 2008 strategy, according to which cost-efficiency, greater energy self-sufficiency and ensuring a sufficient and moderately priced electric power supply must be emphasized in the fulfillment of energy and climate commitments, has been taken into account in the strategy update.	The construction of the new nuclear power plant unit is in line with the climate and energy strategy. The National Climate and Energy Strategy aims to maintain a diverse domestic energy production capacity of maximum self-sufficiency; the construction of a new nuclear power plant supports this objective.	A report of measures to be carried out in the energy and climate policy in the near future, approved by the Government on November 6, 2008. Government's report to the Parliament on March 20, 2013.
Government foresight report on climate and energy policy	On October 15, 2009, the Government approved a foresight report on climate and energy policy to define a Finnish climate and energy policy over the long term. The report sets the objective of reducing Finland's greenhouse gas emissions by at least 80% from the 1990 level by 2050 as part of an international effort. The Government's climate and energy strategy aims to increase the share of renewable energy sources to 38% by 2020 and further to 60% by 2050.	The use of nuclear power for energy production supports Finland's long-term climate and energy policy objectives of limiting greenhouse gas emissions.	The foresight report to outline long-term climate and energy policy, approved by the Government on October 15, 2009.
Air Pollution Control Program 2010	The Government approved the national Air Pollution Control Program in 2002. The program defined measures that allowed Finland to gradually reduce emissions and, in 2010, to achieve the level set out in the EU National Emission Ceilings Directive that came into force in 2001. The Air Pollution Control Program 2010 defines the maximum annual emissions of sulfur dioxide, nitrogen oxides, volatile organic compounds and ammonia starting from 2010. The program includes the measures to reduce the emissions of energy production, traffic, agriculture and industry.	Nuclear power production does not create emissions that are limited by the National Emission Ceilings Directive. The replacement of combustion-based energy production with nuclear power supports the achievement of the objectives set in the directive for Finland.	Program approved by the Government on September 26, 2002, National Emission Ceiling Directive 2001/81/EC.

Name	Content	Relationship with the project	Reference
Convention on Long-range Transboundary Air Pollution (CLRTAP) and the Gothenburg Protocol	The UN Convention on Long-range Transboundary Air Pollution was adopted in 1979 to control the migration of air pollution between countries. The convention does not set out actual emission reduction obligations, but creates the framework for cooperation and detailed protocols to be separately approved. These protocols define acceptable levels for emissions of substances such as sulfur, nitrogen oxides and volatile organic compounds (VOC). In 1999, the European parties to the CLRTAP agreed on the national limits for sulfur, nitrogen oxides, volatile organic compounds and ammonia in the Gothenburg Protocol.	The protocol binds Finland as a state; it does not bind individual operators. The commitments are to be fulfilled using control methods aimed at operators as deemed appropriate by the state. Nuclear power production does not directly create emissions that are limited in the record. Nuclear power can replace combustion-based energy production forms and thus reduce the total emissions in Finland.	Decree 15/1983 on enforcing the convention on long-range transboundary air pollution. The Gothenburg Protocol has been enforced by Presidential Decree 273/2005.
Guidelines for water protection until 2015	The guidelines for water protection define the national needs and objectives for water protection until 2015. The decision presents measures to be taken for reaching a good status in water systems and preventing any deterioration. The guidelines for water protection also support the preparation and execution of the EU sea protection strategy and the action plan between the Baltic countries for protecting the Baltic Sea. The central objectives of the plan include the reduction of eutrophication and heavy loads caused by detrimental substances, the protection of groundwater and water habitat, the reduction of damage caused by hydraulic construction and the regulation and repair of water systems.	The emission limits defined in the environmental permit will be followed in the purification of the nuclear power plant's wastewater. The heat load transferred to the water system along with the cooling water constitutes the most significant impact of the nuclear power plant on the water system. Cooling waters do not contain any nutrients or detrimental substances. The heating effect from the cooling water adds the primary production of the sea area.	Government's decision-in-principle (November 23, 2006) concerning the water protection objectives until 2015
Finland's marine resources management plan	The Government issued a decision on the first part of the marine resources management plan in 2012. The first stage of the plan involves assessing the current condition of the sea, laying down goals for achieving good sea condition and defining indicators for monitoring the condition. The marine management plan covers Finnish territorial waters and the exclusive economic zone.	This EIA report includes an assessment of impacts on the sea area. According to the assessment, the discharge of cooling water into the sea leads to local deterioration of the condition of the sea through eutrophication. The monitoring carried out within the project also serves the needs of marine management.	Government's decision issued in 2012

Name	Content	Relationship with the project	Reference
River Basin planning in the Oulujoki-Iijoki River Basin District	The river basin plan includes information of the district's river basins, their loads and other impacts of human activities, the ecological state of the river basin, the targets of river basin management, and the necessary conservation and management measures. The Government approved the river basin management plans on December 10, 2009. The river basin action plan describes the condition of the river basin, the factors affecting the condition and the measures to achieve a good condition by 2015.	The solutions included in the plans must be taken into account in the decision-making concerning the project and any measures. The river basin management plan must be taken into account in the permit proceedings, and permit decisions must include a statement on how the plan has been taken into account.	Approved by the Government in 2009
Waterfowl Habitats Conservation Program	The objective of the waterfowl habitats conservation program is to preserve the included areas as close to their natural state as possible. A natural reserve as defined in the Nature Conservation Act is to be established for each included habitat.	The closest areas included in the program are the Parhalahti-Syölätinlahti and Heinikarinlampi area, located a few kilometers from the project location. The project's impact on these areas will be assessed within the EIA procedure.	Ratified by the Government in 1982
National Strategy and Action Plan for the Conservation and Sustainable Use of Biodiversity in Finland for the period 2006–2016 (Continuation to the National Action Plan for Biodiversity in Finland 1997–2005)	The objective is to stop the deterioration of Finnish nature's biodiversity by 2010 and to stabilize the positive development of the state of Finnish nature during 2010–2016. Preparations for global environmental changes, and climate change in particular, are to be made by 2016. Objectives also include strengthening Finland's position in the preservation of global natural biodiversity through international cooperation.	Nuclear power can replace combustion-based energy production forms and reduce the average carbon dioxide emissions of electricity production in Finland. The reduction of greenhouse gas emissions in energy production helps to control climate change.	Ratified by the Government in 2006
Forest Biodiversity Program for Southern Finland 2008–2020 (METSO) Continuation to the action plan for preserving forest biodiversity in Southern Finland, the west parts of the Oulu Province and the southwest parts of the Lapland Province (METSO's pilot phase 2003–2007)	The objective of the program is to stop the decline in forest habitat types and forest types and to stabilize a favorable biodiversity trend by 2020. At the pilot phase of the program, the objective was to develop new voluntary conservation methods for securing biodiversity in privately owned forests. One such method based on voluntariness is natural values trading where the forest owner is committed to maintaining the area's natural values for a fixed-term period in exchange for compensation.	The Hanhikivi region was a model area in the "From Sea to Forest" cooperation network of the METSO pilot project (2004–2006). In 2005 and 2006, approximately 150 hectares was decided to be conserved in the region through natural values trading for a ten-year period.	Ratified by the Government in 2008

Name	Content	Relationship with the project	Reference
Natura 2000 network	The purpose of the Natura 2000 network is to preserve biodiversity in the European Union area and to implement the conservation objectives of the Habitats and Birds Directives. The general objective of the Habitats Directive is to achieve and maintain a favorable protection level for certain species and habitat types. Species must be preserved in their natural habitat in the long term, and their natural range must not be narrowed. In addition, there must be a sufficient number of habitats for species to secure the preservation of the population in the long term. The general objective of the Bird Directive is to maintain certain bird populations at a level which corresponds to the ecological, scientific and cultural requirements.	The closest Natura 2000 areas are the Parhalahti-Syölätinlahti and Heinikarinlampi areas located south of the Hanhikivi headland. A Natura impact assessment as referred to in the Nature Conservation Act has been carried out for these areas as part of the regional land use planning in 2009.	Ratified by the Government in 1998

7

Assessment methods, the present state of the environment and the assessed environmental impacts

7.1 Premise of the assessment

As required by the EIA Act, the assessment covers the environmental impacts of the 1,200 MW nuclear power plant on the following:

- human health, living conditions, and wellbeing
- soil, water systems, air, climate, vegetation, organisms, and biodiversity
- infrastructure, buildings, landscape, cityscape, and cultural heritage
- utilization of natural resources, and
- the mutual interaction between the above-mentioned factors.

The assessment particularly focuses on impacts that are different from the impacts assessed in the EIA of 2008 or that were not covered by the previous EIA. Environmental impacts considered important by the stakeholders have also been taken into account.

The studies conducted for the EIA report of 2008, as well as other reports and studies on the environment and the project's environmental impact, were also used in the assessment. The previous EIA report assessed various alternative plant locations and two potential power plant options. The power plant options examined included a plant consisting of one nuclear power plant unit with an electric output of 1,500–1,800 MW, and a plant consisting of two nuclear power plant units with a total electric output of 2,000–2,500 MW. This EIA report utilizes such studies conducted on a 1,500–1,800 MW plant that can be considered to apply to the currently assessed plant alternative in an updated form.

The studies carried out for the 2008 EIA and Decision-in-Principle application included the following:

- Background survey for the assessment of regional economic impacts
- Illustrations of landscape impacts
- Nature and water studies, including the following:
  - Avifauna studies, monitoring of migration in spring and fall
  - Description of the underwater environment, surveys of underwater historical relics, study of benthic fauna in the area, study of the fishing industry, river lamprey fishing on the Pyhäjoki river, surveys of the reproduction areas of fish, phytoplankton research, fish stock and fry production, survey of recreational fishing, assessment of the impact of hydraulic construction works on the fishing industry, grayling report
  - Study of water quality in the sea area, inclusion of local conditions and currents in the cooling water simulation, study of contaminants contained in the sediment, study of the marine spoil area for dredging waste, seismic sounding
  - Primary succession forests; the significance of the Hanhikivi area as a primary succession area; the position of Hanhikivi as an area of special importance for biodiversity; list of endangered species and habitat types, an account of their protection within the project and a plan for more detailed field works; Natura 2000 assessment
  - Moor frog studies, bat study
- Inventory of historic relics in the Hanhikivi headland area
- Soil, groundwater and seismic studies
- The project's conformance with national land use guidelines
- The uncertainty brought into the environmental impact assessment by climate change
- Risks and environmental impacts of spent nuclear fuel
- Essential environmental impacts of the final repository for operating waste.

The following additional studies have been carried out for the environmental impact assessment described in this EIA report:

- Resident survey and small group interviews
- Modeling of the spreading of radioactive releases in case of an accident
- Noise emission modeling
- Cooling water modeling.

Furthermore, calculations included in the previous EIA, such as traffic volume calculations, calculations of the impact on regional economy, and emissions from the zero option, have been updated.

The scope and significance of environmental impacts depend on the nature of the affected target. Some of the impacts only concern the immediate environment, while others may have nationwide impacts.

The environmental impact assessment takes into account the environmental impacts of operations in the power plant area as well as those that extend outside the project area. The observed area is defined as the area within which studies and assessments concerning the environmental specific impact type are carried out. The size of the observed area depends on the environmental impact that is being examined. The observed areas and various environmental impacts are described in the following sections.

The environmental impacts of the construction and use of the power lines will be assessed in a separate EIA procedure, which is expected to begin in 2014. Separate EIA procedures will also be carried out later for the transportation and final disposal of spent nuclear fuel as well as the decommissioning of the power plant.

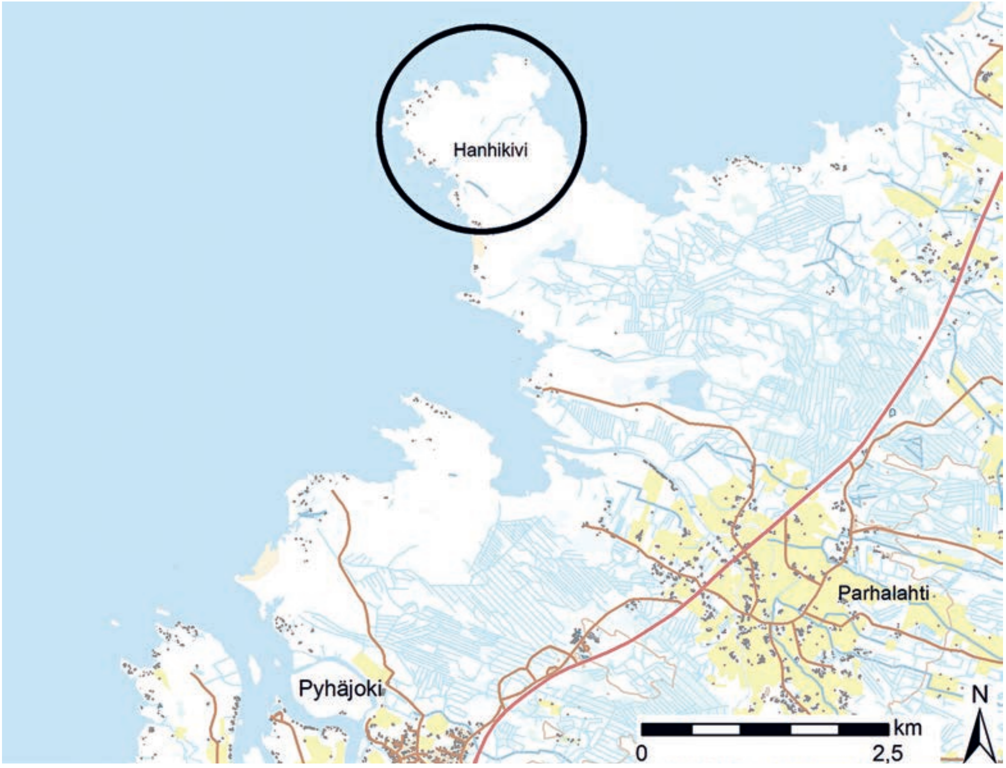
7.2 Land use and the built environment

7.2.1 Present state

The Hanhikivi headland is located in Northern Ostrobothnia and is divided between the municipalities of Pyhäjoki and Raahe. Most of the headland, including the planned power plant site, is located in the municipality of Pyhäjoki, but a part of the northeast edge of the headland belongs to the municipality of Raahe. The power plant location is roughly illustrated in the figure 7-1.

Hanhikivi headland is primarily used for forestry and outdoor activities. There are no permanent settlements on

Figure 7-1.
A rough illustration of the power plant site on the Hanhikivi headland.



the headland. There are approximately 20 holiday homes on the south-western and western shores of the headland. There is a public beach on the west shore. At the tip of the headland, on the border between Pyhäjoki and Raahe, there is a large glacial erratic boulder called Hanhikivi which is classified as a historical monument.

The center of Pyhäjoki is located approximately seven kilometers south of the headland. The village of Parhalahti is located approximately five kilometers from the planned power plant site. The center of Raahe is located approximately 20 kilometers away.

There is no industrial activity in the immediate vicinity of the Hanhikivi headland. There is industrial activity such as engineering works in the Pyhäjoki region. In the town of Raahe, located on the coast of the Gulf of Bothnia approximately 15 kilometers from the Hanhikivi headland, there are Rautaruukki Corporation's steelworks, Oy Polargas Ab's air gas plant and liquid gas storages, among other industrial facilities. To the south of the municipality of Pyhäjoki, more than 20 kilometers from the Hanhikivi headland, there are danger zones of the Finnish Defence Forces Lohtaja site.

7.2.1.1 National land use guidelines

National land use guidelines (VAT) are part of the land use planning system in accordance with the Land Use and Building Act. The project's connections to national land use guidelines have been discussed in more detail in the report sections of the Hanhikivi regional land use plan for nuclear power plant and the partial master plan for the Hanhikivi nuclear power plant site. The land use planning for the region follows the national land use guidelines.

7.2.1.2 Land use planning

The land use in the Hanhikivi headland is controlled by the Hanhikivi regional land use plan for nuclear power plant and the partial master plans and local detailed plans of the town of Raahe and municipality of Pyhäjoki.

Regional land use plan

A regional land use plan for nuclear power plant is legally in force for the Hanhikivi headland area. On April 7, 2008 the Board of the North Ostrobothnia Regional Council decided to launch the preparation of a regional land use plan for the Hanhikivi nuclear power plant project. The Hanhikivi regional land use plan for nuclear power plant was accepted at the meeting of the Board on February 22, 2010, and ratified by the Ministry of the Environment on August 26, 2010 (decision YM/2/5222/2010). On September 21, 2011, the Supreme Administrative Court rejected two complaints filed concerning the ratification of the plan. After subsequent public display, the regional land use plan for nuclear power plant has gained legal force.

The whole of the Hanhikivi plant area is included in the Hanhikivi regional land use plan for nuclear power plant (Figure 7-2). The plan covers the planned nuclear power plant and the protective zone surrounding the plant at an approximate radius of 5 km, the power line connections from the current 220 kV main grid power line to the power plant area, the 400 kV main grid to the substation in Nivala, and to an optional substation in Lumimetsä in Vihanti. Furthermore, the planned area includes a reservation for a navigation channel to a harbor in the power plant area.

Most of the Hanhikivi headland, a total of approximately 300 hectares, has been defined as an energy management zone (EN-yv) in the regional land use plan for nuclear power plant. The EN-yv zone is an area reserved for energy production facilities, buildings and structures. Detailed land use plans define that one or two nuclear power plant units and a final repository for low and intermediate level operating waste can be built to the area as specified in the construction license based on the Nuclear Energy Act. Furthermore, nuclear power plant auxiliary functions may be placed in the area, such as temporary housing or water treatment plants and structures.

The regional land use plan for nuclear power plant does not allow the final disposal of spent nuclear fuel in the Hanhikivi area. However, spent nuclear fuel can be temporarily stored in the area until it can be transported to a final repository. The minimum storage period is 40 years.

Due to the national historical importance of the Hanhikivi border stone located on the border of the EN-yv zone, and the border line on which it stands (the current municipal border), their surroundings must be kept as open as possible.

The nuclear power plant protective zone established in the regional land use plan is a rough outline approximately five kilometers from the nuclear power plant. The Parhalahti village with settlements on both sides of main road 8 is included in the protective zone.

The protective zone defined in the regional land use plan indicates a protective zone pursuant to the YVL Guide A.2 of the Radiation and Nuclear Safety Authority. There are land use restrictions within the protective zone. New permanent, densely populated settlements, hospitals or other facilities that are visited by a significant number of people must not be planned to locate for the area. Furthermore, any major production activities that could be affected by a nuclear power plant accident must not be located in the protective zone. The Radiation and Nuclear Safety Authority and rescue authorities must have the opportunity to issue a statement regarding the planning of the area.

Revision of the North Ostrobothnia regional land use plan, regional land use plan of the first stage

Revision of the North Ostrobothnia regional land use plan has been started in fall 2010. According to the target schedule, the first stage of the revision would be submitted to the Regional Council for approval in fall 2013.

The proposed first stage (Figure 7-3) defines three nature conservation areas on the Hanhikivi headland. The following regulation applies to any land use planning for these nature conservation areas: the land use of the area and its surroundings must be planned and implemented so that the purpose for which the area has been protected is not subjected to any risk; instead, the biodiversity and ecological connections between areas must be protected. A statement from the Centre for Economic Development, Transport and the Environment, as specified in Section 133 of the Land Use and Building Act, shall be requested on any building permit application.

Rocks important for the landscape (ge-1) are found on the south and north shores of the Hanhikivi headland. The ge-1 indication marks geological formations of national importance in terms of nature and landscape conservation.

According to the planning regulation, the land use in the area must be planned so that the landscape is not ruined, significant aesthetic values or special natural formations are not destroyed, and no major or extensive harmful changes are caused to the natural environment.

A preliminary reservation for a 400 kV main power line has been made close to the Pyhäjoki and Raahe municipal border, and for a 110 kV main power line to the south from it.

A need for a bicycle and pedestrian traffic connection has been indicated for main road 8.

Local master plans

Partial master plans for the Hanhikivi nuclear power plant area in the Pyhäjoki and Raahe municipalities apply to the Hanhikivi headland area. The partial master plan for the Hanhikivi nuclear power plant area has been approved by the Pyhäjoki Municipal Council on October 27, 2010, and by the Raahe Municipal Council on November 15, 2010. The land use plans have entered into force in summer 2013 after public display.

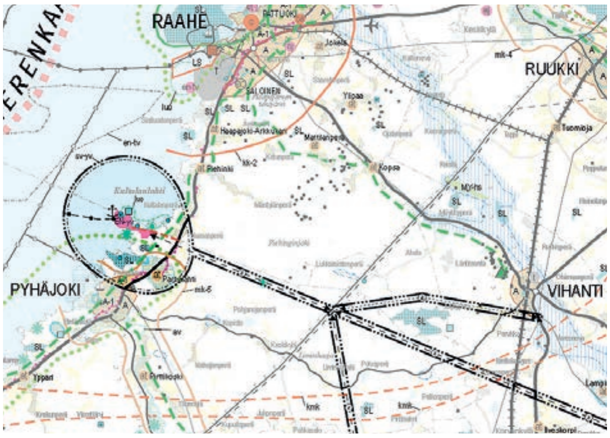


Figure 7-2. The Hanhikivi headland area as defined by the Hanhikivi regional land use plan for nuclear power plant (2010).

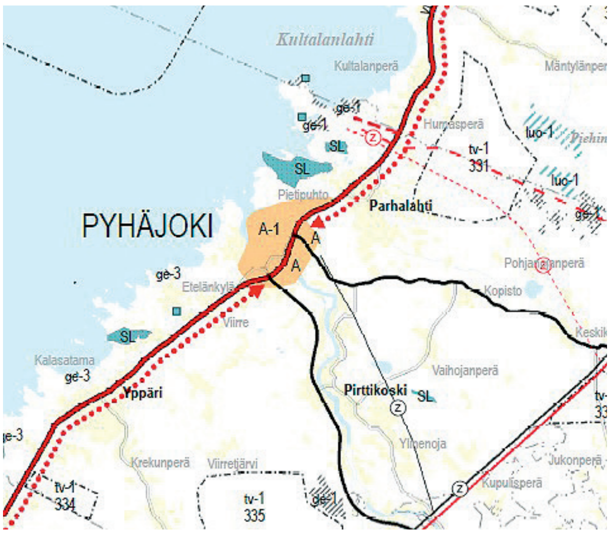


Figure 7-3. The area of Hanhikivi headland in the North Ostrobothnia regional land use plan of the 1st stage (proposed land use plan).

The partial master plan (Figure 7-4) includes area reservations for the nuclear power plant (EN-1) and its auxiliary and maintenance areas (EN-2). The land use plan also includes an area for work site activities (TP-1). The land use plan indicates that areas are to remain in agricultural and forestry use (M-1) along the Hanhikivi road connection which leads to the power plant area from main road 8. Some of the shore and water zone included in the energy management area and located at a distance of approximately 200 meters from the shoreline is indicated as W-1, a zone that can be used for the purposes of the power plant such as the construction of docks and other structures and equipment required by the power plant. The construction must be carried out in compliance with the Water Act. The nature conservation areas (SL, SL-1, SL-2) and protective green areas (EV, EV-1) are also indicated in the partial master plan.

The land use plan area is included in the nuclear power plant's protective zone in accordance with the general stipulation of the partial master plan.

Local detailed plans

Local detailed plans of the Pyhäjoki and Raahe municipalities for the Hanhikivi nuclear power plant area apply to the Hanhikivi area. The local detailed plan for the Hanhikivi nuclear power plant area has been approved by the Pyhäjoki Municipal Council on October 27, 2010, and by the Raahe Municipal Council on November 15, 2010. The land use plans have entered into force in summer 2013 after public display.

The local detailed plan for the Pyhäjoki nuclear power plant area (Figure 7-5) indicates an energy management area that can be used for building a nuclear power plant. The local detailed plan also indicates other necessary facilities required by the power plant: an area for temporary housing, other auxiliary function areas, the necessary traffic areas and a preliminary reservation for a navigation channel, among others. The local detailed plan also indicates the locations of nature conservation areas and a protected historical monument, the Hanhikivi border stone. Passage to these areas is routed through the agricultural and forestry areas.

The entire tip of the Hanhikivi headland is largely reserved as an energy management area under two different indications (EN-1 and EN-2). A nuclear power plant with one or two plant units can be built on the EN-1 area. Interim storage facilities for spent nuclear fuel and final disposal facilities for low and intermediate level operating waste can also be built to the area. The final disposal facilities consist of underground repositories (VLJ repositories) and their entrance buildings and structures, as well as encapsulation facilities and related auxiliary buildings. The water area that can be used for the purposes of the power plant and in which special areas have been defined for the construction of docks and other structures and equipment within the stipulations of the Water Act has been indicated as W-1. Other water areas have been indicated as W.

The total permitted building volume in the local detailed plan is 300,000 m^2 for EN-1 area and 96,000 m^2 for EN-2 area.

The Raahe local detailed plan for the power plant area (Figure 7-6) indicates the areas in which auxiliary

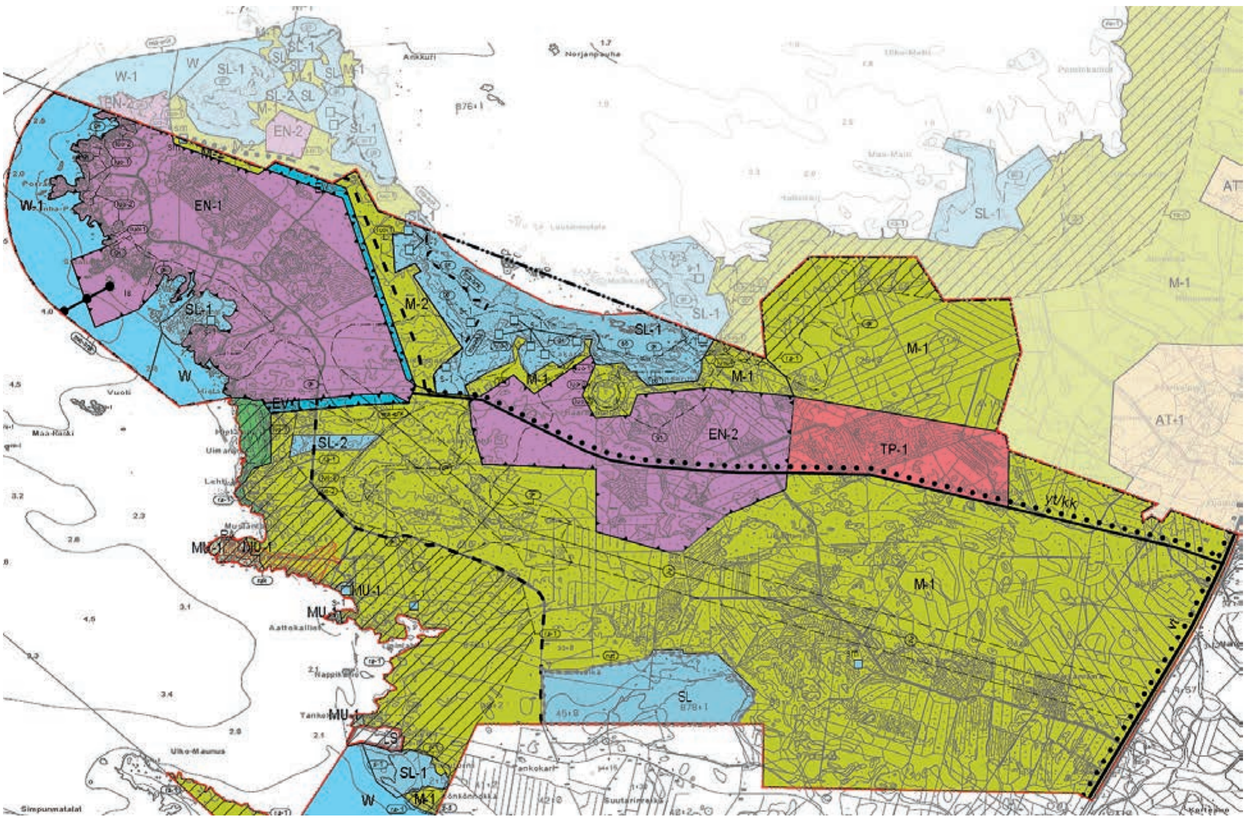


Figure 7-4. Extract from the Pyhäjoki partial master plan for the Hanhikivi nuclear power plant area (2010). The Raahe partial master plan for the nuclear power plant area is printed with dimmed colors.

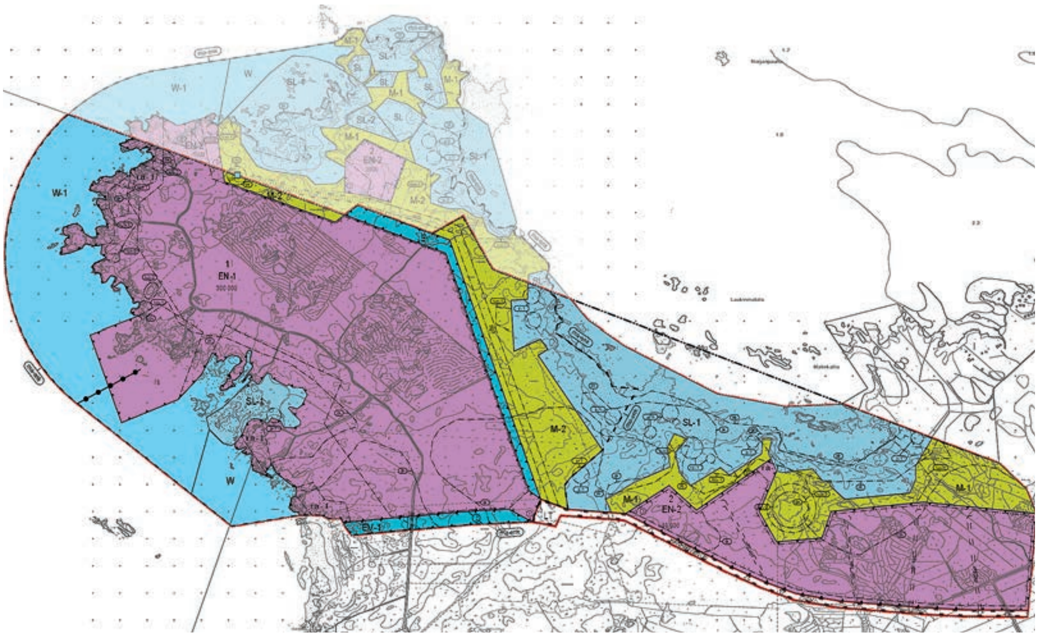


Figure 7-5. The Pyhäjoki local detailed plan for the Hanhikivi nuclear power plant area (2010).

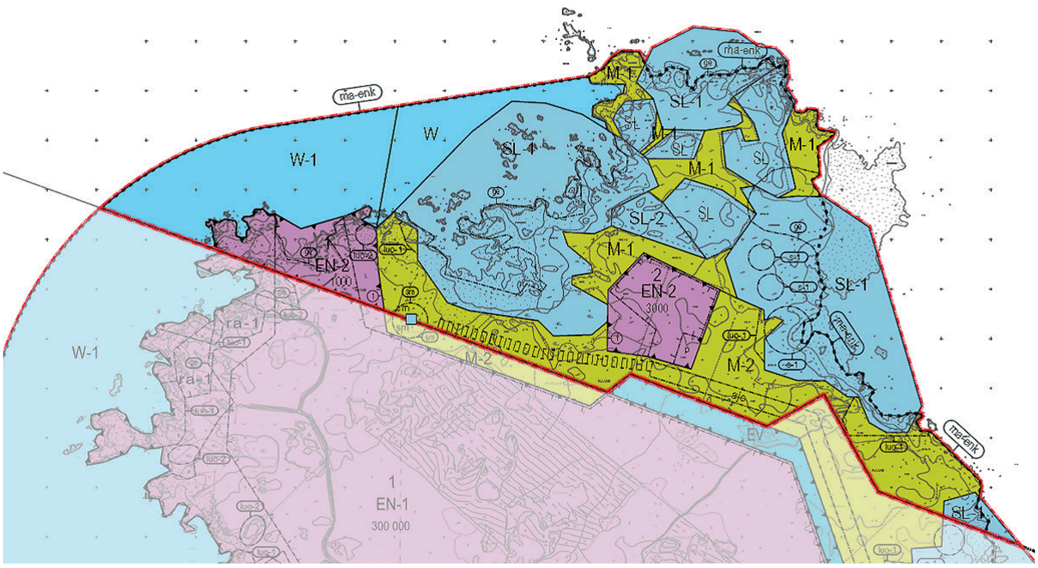


Figure 7-6. The Raahe local detailed plan for the Hanhikivi nuclear power plant area (2010).

facilities for the nuclear power plant as well as housing for construction and maintenance personnel can be built (EN-2). The local detailed plan also indicates the locations of nature conservation areas and the protected Hanhikivi border stone. Preliminary passage to these areas is routed through the agricultural and forestry areas. The water area that can be used for the purposes of the power plant and in which special areas have been defined for the construction of docks and other structures and equipment within the stipulations of the Water Act has been indicated as W-1.

The total permitted building volume indicated in the local detailed plan for EN-2 areas is 4,000 m^2.

In addition to the local detailed plans for the nuclear power plant area, the Hanhikivi headland has a separate local detailed plan for the workplace area located along the road connection that leads to the power plant area from main road 8. The workplace area is included in the partial master plan for the nuclear power plant area.

The local detailed plan for the workplace area (Figure 7-7), or the extension of the local detailed plan for the Hanhikivi nuclear power plant area in blocks 2, 4, 5 and 6, has been approved by the Pyhäjoki Municipal Council on May 22, 2013. A complaint concerning the decision has been filed with the Oulu Administrative Court.

The local detailed plan for the workplace area indicates blocks of workplace and industrial functions in the immediate vicinity of the Hanhikivi nuclear power area. The plan indicates service building areas (P) and industrial and warehouse areas (T-1 and TY). The necessary traffic areas and protective green areas are also indicated (EV). The permitted building volume of the plan area has been defined using the ratio (e) of building volume to the surface area of the plot or building site.

The preparation of an extension of the local detailed plan for the Hanhikivi nuclear power plant area in block 3 has also begun (Figure 7-8, area 4). The area is on the south side of the road connection from main road 8. On

Figure 7-7. The extension of the local detailed plan for the Hanhikivi nuclear power plant area in blocks 2, 4, 5 and 6 (2013).

the north side, the land use plan extension area is limited by the local detailed plan of the Hanhikivi nuclear power plant area.

The purpose of the plan is to place auxiliary functions and construction and maintenance functions to the immediate vicinity of the Hanhikivi nuclear power plant area. The land use plan takes into account potential new power lines.

The Pyhäjoki Municipal Council made the decision to launch the land use planning project on March 27, 2013. Block 3 belongs to the partial master plan area for the nuclear power plant. The draft plan was publically displayed in summer 2013.

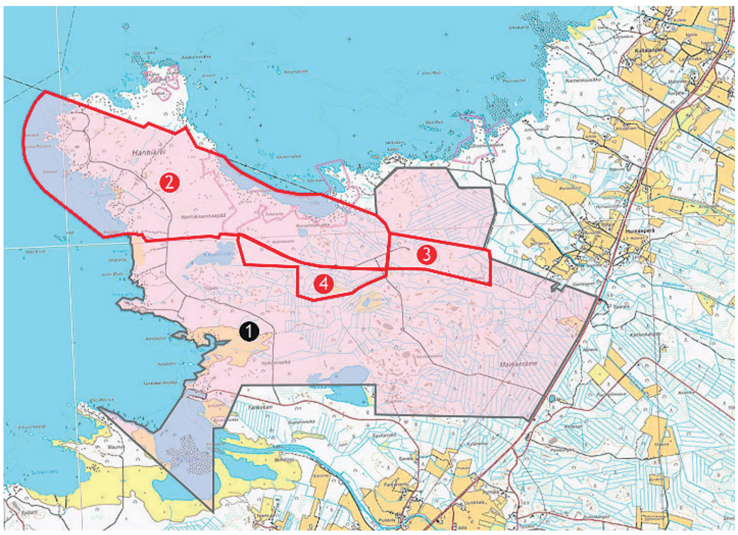
7.2.2 Assessment methods

The EIA report includes an expert evaluation of the project's impact on both the current and the planned land use. The impacts have been assessed on the regional, municipal and local level. The report also includes a description of the project's connections to national land use guidelines. Initial information includes base map data, existing studies and currently valid and pending land use plans.

The immediate land use impact area covers the Hanhikivi headland. Indirect impacts on regional and community structures have been assessed at a municipal level through changes in the starting points of land use in Pyhäjoki and Raahe and at a regional level as part of the regional

Figure 7-8. Combined presentation of the Pyhäjoki partial master plan and local detailed plans of the Hanhikivi headland: location of the plan areas.

Area 1: Partial master plan for the Hanhikivi nuclear power plant area (approved on October 27, 2010). The partial master plan covers the whole of the area in pink.
Area 2: Local detailed plan for the Hanhikivi nuclear power plant area (approved on October 27, 2010).
Area 3: Extension of the local detailed plan for the Hanhikivi nuclear power plant area in blocks 2, 4, 5, and 6 (approved on May 22, 2013).
Area 4: Extension of the local detailed plan for the Hanhikivi nuclear power plant area in block 3 (preparation launched on March 27, 2013).



structure of North Ostrobothnia. In practice, the affected area of changes in land use at a municipal level extends, in addition to the surroundings of the Hanhikivi headland, to the nearby village areas, the center of Pyhäjoki and the southern parts of the center of Raahe. Changes in regional structure have been assessed in the Raahe region.

7.2.3 Impacts during construction and operation

The currently valid land use plans for the nuclear power plant site indicate the areas required by the nuclear power plant. Procedures pursuant to the Land Use and Building Act (132/1999) have been followed to prepare the land use plans of all levels for the Hanhikivi headland, as required by the project. The Council of Oulu Region has been responsible for preparing the regional land use plan. The local master and detailed plans have been prepared by the municipality of Pyhäjoki and the town of Raahe. The plans of all three levels of planning are legally valid. The land use plans allow the construction of the planned nuclear power plant on the Hanhikivi headland; the implementation of the project will not require any changes to the current land use plans.

The construction of the nuclear power plant will change the land use at the actual plant site and in its surroundings. The actual plant site will be built and fenced, which will change passage routes in the headland. The purpose for which the land is used will change in the majority of the headland. The actual plant area is currently mainly forestry area. Some of the holiday residences on the south-west and west shores will be removed, and the south-west and west shores will no longer be used for recreational purposes. However, land use on the north-east and north shores, which are important areas for nature conservation and recreation, will mainly remain unchanged. The local detailed plan defines the area as an agriculture and forestry area. Access to the protected historical monument, the Hanhikivi border stone, will still be possible via an area reserved for agriculture and forestry. The local detailed plan also indicates a new preliminary road connection to the area. The new road connection planned for the nuclear power plant will not cause any significant changes to land use in the area.

The construction of the power plant will have an impact on the community structure of the municipalities by restricting land use in the plant's protective zone and by allowing new construction in settlements and villages and along roads. Densely populated areas, hospitals, or facilities in which a large number of people will visit or reside, or important production activities which could be affected by an accident at the nuclear power plant, may not be placed inside the protective zone. Plans for holiday homes or recreational activities in the area must ensure that the preconditions for appropriate rescue activities are not placed at risk. A more detailed definition of the protective zone is included in the regional land use plan for nuclear power plant. The nuclear power plant will not restrict land use outside the protective zone. The construction of the plant will change the preconditions of land use outside the protective zone, particularly in the villages and settlements of Raahe and Pyhäjoki, by providing new land use opportunities for building workplace and residential areas and services.

The importance of the Raahe district as a strong industrial region increases, which makes the region more attractive for businesses. The project may thus increase the need to plan new workplace and residential areas and to develop the land use.

7.3 Emissions into the air

7.3.1 Present state

The winter is long in the Bothnian Bay area, and the temperature remains relatively low for most of the year. The location of the Bothnian Bay in the western part of a large continent and, simultaneously, near the Atlantic Ocean causes the climate to vary between the marine and continental types, depending on the prevailing winds.

In 1981–2010, the average annual temperature measured at the Oulu Airport measurement point was 2.4 °C. The average annual rainfall was 477 millimeters. *(Ilmatieteen laitos 2012)* In the Pyhäjoki area, the direction of the prevailing wind is from the south-west *(Tuuliatlas 2012)*.

There is no industry with significance to air quality in the Pyhäjoki municipality, and the air quality is not monitored through measurements. The nearest air quality monitoring location is in the town of Raahe. The town of Raahe monitors the impacts of industry and traffic on the air quality through an extensive air quality monitoring program. In 2012, the air quality in Raahe was mostly good *(Ramboll 2013)*.

The air quality in the Hanhikivi headland area can be considered to be good since no activities causing significant emissions are carried out in the immediate surroundings.

Environmental radiation levels are monitored at the Olkiluoto and Loviisa nuclear power plants as well as in various monitoring locations of the Radiation and Nuclear Safety Authority (STUK) around Finland. The STUK monitoring location nearest to the Hanhikivi headland is located in Raahe, where the dose rates have been on the average level of background radiation in Finland.

7.3.2 Assessment methods

The emissions and impacts of radioactive substances into the air have been assessed through expert assessment based on the comparison of preliminary power plant data with the emission limits set for the existing Finnish nuclear power plants and their actual emissions.

The impacts of other emissions, such as emissions resulting from the generation of emergency power and transportation and the dust generated in the construction phase, on the air quality have been assessed on the basis of the emission amounts generated and the current status of the air quality.

7.3.3 Construction phase impacts

7.3.3.1 Radioactive emissions into the air

No emissions of radioactive substances into the air will occur during construction since no radioactive nuclear fuel will be present in the power plant site before the start-up of the nuclear reactor. As fresh nuclear fuel does not contain significant levels of radioactivity, no radiation protection measures are needed for its storage.

7.3.3.2 Other emissions into the air

Earthwork, traffic at the site, and certain operations, such as rock crushing, will generate dust during the construction of the nuclear power plant. Most dust sources will be located at low elevation levels, so the dust cannot spread far and its impact on the air quality will mainly be limited to the construction site.

The emissions from transportation and commuter traffic to and from the nuclear power plant, and the criteria for their calculation, are presented in Chapter 3. Table 7-1 shows a comparison between estimated traffic emissions in the area and the traffic emissions resulting from the nuclear power plant project in 2020 and 2025. The emissions of the Pyhäjoki and Raahe areas were selected for the assessment because the majority of the traffic to and from the nuclear power plant is estimated to run through the territory of these municipalities. The table presents the overall traffic emission estimates for 2020 in the Pyhäjoki and Raahe area. At that time, the construction of the nuclear power plant will be at its most active phase and the traffic levels will be at their highest. Also presented are the estimated traffic emissions in 2025, when the operation phase of the nuclear power plant has begun. Additionally included is a comparison of the average traffic emissions during the construction and operation phases of the nuclear power plant.

Traffic emissions will increase markedly in the construction phase, particularly during the most active construction period. Carbon monoxide (CO) emissions will increase by approximately 20 percent, nitrogen oxide (NO_x) emissions by approximately 15 percent, and small particle (PM) and sulfur dioxide (SO_2) emissions by approximately 10 percent in comparison to the estimated overall traffic emissions in the area in 2020. In addition to the exhaust gas emissions, traffic throws up road dust especially in the spring.

At other times of the construction phase, the traffic levels will be lower, and the traffic emissions smaller. The impacts of traffic emissions will be very local and their impacts on the air quality will depend, in addition to the emission volumes, on the traffic routes used. The concentrations of contaminants resulting from traffic will decrease as the distance to the side of the road increases. As a result, the impacts of the emissions on people's health depend on the location of residential areas in relation to the roads. Traffic to and from the nuclear power plant will mostly run on main roads. The residential areas by these roads are mostly located so far from the road that the increase in the contaminant concentrations will have no significance. The residential building closest to the new road to be constructed in the Hanhikivi headland will be located approximately 300 meters from the road, while the rest of the residential buildings will be located at the distance of some 0.5–1 kilometers. Since the current air quality in the area is assessed to be good and the period of heavy traffic will be limited in duration, the construction phase traffic emissions are assessed to have no major impacts on the air quality in the area and on peoples' health.

Emissions from traffic can be decreased by setting a sufficiently low speed limit for the new road to be constructed to the nuclear power plant. Generation of road dust can be decreased by, for example, paving the road with asphalt.

7.3.4 Operation phase impacts

7.3.4.1 Radioactive emissions into the air

The air emissions from the light water reactors mostly consist of noble gases, gaseous activation products, halogens, and aerosols. Most of the radionuclides released into the environment are short-lived and are only occasionally found in the immediate vicinity of power plants.

The radioactive gases generated during the plant operation are processed using the best available technology to minimize the emissions. Gaseous radioactive substances are collected, filtered, and delayed to decrease the radioactivity. Gases containing small amounts of radioactive substances are released into the air in a controlled manner through the vent stack and the emissions are measured to verify that they remain below the set limits. The remaining emissions are effectively diluted in the air. Consequently, the concentrations of radioactive substances accumulating in the surroundings of power plants are very small and can only be detected using sensitive measurement methods *(STUK 2013l)*.

Table 7-1. The traffic emissions to and from the nuclear power plant and the overall traffic emissions in the surrounding areas in 2020 and 2025 (tons per year).

	CO	NO_x	Particles	SO_2	CO_2
Most active construction phase, 2020					
Traffic emissions in the Pyhäjoki area	126	34	2	0.1	11,904
Traffic emissions in the Raahe area	426	101	5	0.3	40,475
The increase due to the project	111	20	0.5	0.04	6,730
Operation phase, 2025					
Traffic emissions in the Pyhäjoki area	111	29	1	0.1	11,854
Traffic emissions in the Raahe area	375	87	4	0.3	40,305
The increase due to the project	19	4	0.1	0.01	1,219

The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Furthermore, Fennovoima will determine specific emission targets for the nuclear power plant. These target limits will be lower than the set emission limits. Moreover, opportunities for reducing the emissions will be investigated in accordance with the principle of continuous improvement. Strict limit values and continuous monitoring ensure that the emissions of the modern nuclear power plant remain very low and that the radiation impacts on the environment remain very small in comparison to the impacts of radioactive substances existing normally in nature. For example, the emissions of the current Finnish nuclear power plants have amounted to less than one percent of the emission limits set for them.

Table 7-2 shows a preliminary estimate of the maximum annual quantities for air emissions of radioactive substances from the nuclear power plant during normal operation. The estimate is based on the preliminary plant data for the AES-2006 nuclear power plant type. Fennovoima aims to keeping all emissions lower than or equal to those originating from the currently operating Finnish nuclear power plants.

While the preliminary data indicates that the emissions of radioactive substances will be higher than those originating from the currently operating Finnish power plants, they will still only amount to a fraction of the set emission limits. The level of radiation exposure in the vicinity of the plant due to the emissions will be very low, since these emission values will keep the radiation dose well under the limit value set in the Government Decree (717/2013). According to the decree, the annual radiation dose to an individual inhabitant of the surrounding area caused by normal operation of a nuclear power plant may not exceed 0.1 millisieverts. For comparison, the average annual radiation dose of a Finn is 3.7 millisieverts (see Section 4.6).

Table 7-2 additionally shows a comparison of the average annual radioactive emissions into the air from the current Finnish nuclear power plants in 2008–2012. The emission limits for iodine and noble gases are plant specific. Even at the theoretical maximum level, the emissions of tritium, carbon-14, and aerosols remain so low that setting separate emission limits for them is unnecessary. The impacts of radioactive emissions on water systems are discussed in Section 7.4.

7.3.4.2 Other emissions into the air

Impacts of emissions from transportation

The emissions from transportation and commuter traffic to and from the nuclear power plant, and the criteria for their calculation, are presented in Chapter 3. Table 7-1 shows a comparison between estimated traffic emissions in the area and the traffic emissions resulting from the nuclear power plant project. Traffic emissions of the operation phase are compared with the estimated overall traffic emissions for the area in 2025, when the operation phase of the nuclear power plant has begun.

Compared with the emissions from other traffic, the increase in the traffic emissions during the operation phase of the nuclear power plant is fairly small. The emissions of carbon monoxide (CO), nitrogen oxides (NO_x), small particles (PM), and carbon dioxide (CO_2) will increase by less than five percent due to the traffic to and from the nuclear power plant in comparison to the estimated overall traffic emissions in 2025. The increase in the emissions is not assessed to have any significant adverse impacts on the air quality in the area.

Impacts of emissions from the generation of emergency power

Other emissions from the power plant, i.e. emissions resulting from the generation of emergency power, are presented in Chapter 3. The emissions will be very small, and they will have no significant impact on the air quality in the area.

7.4 Water systems and fishing

7.4.1 Present state

7.4.1.1 General description

The coastline around the Hanhikivi headland is open, and water changes efficiently in the area. There are only a few small islands and islets in the vicinity. The coastal waters surrounding the headland are very shallow and rocky. The Kultalanlahti bay to the east of the headland is particularly shallow, no more than one meter deep up to a distance of one kilometer from the shore. Soundings carried out in the area show that the water depth in the planned dock basin and breakwater area varies between 0 and 3.7 meters.

Table 7-2. A preliminary estimate of the maximum annual emissions of radioactive substances from the nuclear power plant during normal operation. Also shown are the average annual radioactive emissions into the air from the Loviisa and Olkiluoto nuclear power plants in 2008–2012. Emission limits are set for iodine and noble gases.

Radioactive emissions	Estimated emissions from 1,200 MW plant (GBq/year)	Loviisa 1 and 2 2 x 496 MW (PWR)		Olkiluoto 1 and 2 2 x 880 MW (BWR)	
		Emission limits (GBq/year)	Actual emissions (GBq/year)	Emission limits (GBq/year)	Actual emissions (GBq/year)
Iodines (I-131 eqv.)	0.49	220	0.015	103	0.023
Noble gases	46,000	14,000,000	6,200	9,420,000	600
Tritium	3,900	-	280	-	320
Carbon-14	300	-	300	-	820
Aerosols	0.051	-	0.1	-	0.017

Water depth in front of the cooling water discharge structures is approximately 0.3 meters. The depth of the water around the Hanhikivi headland increases very slowly, first at the rate of one meter per 100 m distance (Figure 7-9). The increase is more rapid in front of the north-western tip of the headland. The depth of 10 meters is achieved approximately one kilometer from the north-western tip. Depths exceeding 20 meters are not found until 10 kilometers to the west of the headland. In the planned marine spoil area, the water is approximately 15–25 meters deep.

Of the rivers that run into the sea in the region, the most important is the Pyhäjoki river approximately six kilometers to the northwest of the Hanhikivi headland. The average discharge of the Pyhäjoki river is approximately 30 m³/s. No significant rivers flow into the sea on the north-eastern side of the Hanhikivi headland. Therefore, the impact of river water on the sea is smaller around the Hanhikivi headland than in many other parts of the coast of the north-eastern Bothnian Bay.

The Hanhikivi headland has small shallow patches of marshland in the lower parts of the landscape. There are also minor surface water channels and forest ditches. The shore areas have fladas (brackish lagoons with one or more connections to the sea) and gloe lakes typical of land-uplift areas.

7.4.1.2 Sea levels and drift currents

Variations of sea levels in the Bothnian Bay are mainly caused by wind, atmospheric pressure and the water volumes discharged by rivers. The total volume of water in the Baltic Sea also has a major impact on the sea level in the Bothnian Bay. The water volume of the Baltic Sea varies as

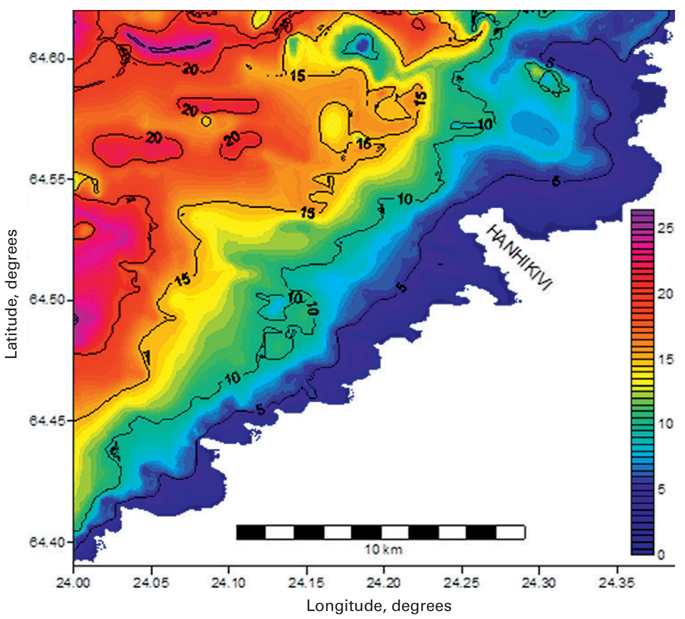


Figure 7-9. Water depth around the Hanhikivi headland. The data has been obtained from the Coherens model that combines nautical charts with the data from precision soundings carried out near the headland. For the meaning of the color indications, see the legend on the right. *(VitusLab 2012)*

a result of factors such as the westerly winds pushing water from the North Sea through the Danish straits. The water level on the Finnish coast also varies as a result of a seiche that exists in the Baltic Sea. The Bothnian Bay has its own pattern of annual water level variation. The water level is up in late fall and goes down toward the end of the winter (*Kronholm et al. 2005*). At the end of winter, the surface rises until it reaches its peak again in the fall.

In 2008, Fennovoima ordered from the Finnish Institute of Marine Research a study of the variation of the average water level as well as the extreme values of water level in the project area (*Merentutkimuslaitos 2008*). The estimate has been updated in 2010 to include even more rare extreme phenomena (*Johansson et al. 2010*). The continuously operating water level measurement points, or marigraphs, closest to Hanhikivi and used in the survey are located in Raahe (approximate distance 18 kilometers) and Jakobstad (approximate distance 120 kilometers). According to the most likely scenario, the effect of land uplift will continue to be greater in the Gulf of Bothnia than the effect the global rise of the sea levels. The updated study states that the average sea water level in Pyhäjoki will decrease approximately ten centimeters by the middle of the century and will then return to the current level by the end of the century. However, uncertainties are significant (Figure 7-10).

Due to the open coastline, waves have a major impact on the shore. Continuous wave measurements have been carried out in the area from November 2012 to October 2013 at two locations (*Luode Consulting Oy 2013*). The Finnish Meteorological Institute has used a mathematical model to simulate waves in the Bothnian Bay (*Tuomi et al. 2011*). A wave simulation has also been developed for the Hanhikivi headland area (*VitusLab 2012*) with results of the same magnitude as those of the model presented by the Finnish Meteorological Institute. The highest waves have been measured at the site of the planned cooling water intake area in November 2012. The significant wave height was three meters. On the cooling water discharge side, the waves were approximately one third lower. After the formation of ice in the winter, wave heights decreased to practically zero. The maximum significant wave heights in the spring were of the level of one meter. The maximum significant wave heights of the summer season were approximately 2.5 meters on the intake side. On both sides, the highest waves rolled in from the west-north-west direction. According to model simulations, significant wave heights of two meters in the summer season and more than four meters in the fall and winter seasons are not exceptional off the Hanhikivi headland. The highest single waves are approximately twice as high as the significant wave height. The bottom friction due to the far-reaching shallow water dissipates wave energy and weakens waves significantly before they break on the Hanhikivi shore.

Drift currents in the Bothnian Bay are mainly caused by winds, which results in great variation in their direction and strength (*Kronholm et al. 2005*). The basic current caused by the Coriolis effect runs in the Bothnian Bay to the north along the Finnish coastline and south along the Swedish coastline. It only flows at the rate of a few centimeters per second. Winds cause higher flow rates that may be directed

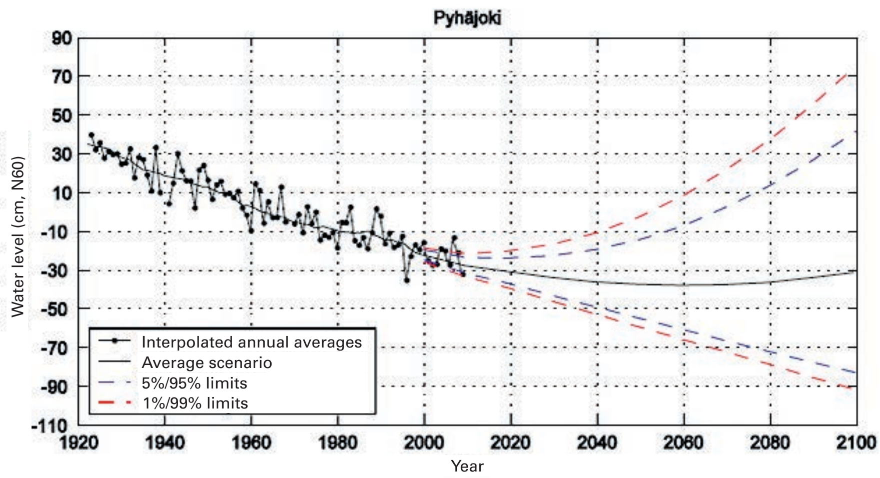


Figure 7-10. Interpolated annual sea level averages and the average water level scenario with uncertainties in Pyhäjoki until 2100. *(Johansson et al. 2010)*

to the same or an opposing direction. For southerly winds prevailing off Hanhikivi, the main current flows from south to north. When ice covers the sea surface, the wind no longer has an effect on flow rates. Instead, flow rates are the result of factors such as river discharges, water level variation, and differences in temperatures and salt contents. The shallow sections of the sea in front of Pyhäjoki cause bends and eddies in the current *(Lauri 2013)*.

Flow measurements have been carried out in the area in the winter 2011–2012 and between November 2012 and October 2013. Flow measurements carried out in the open sea in front of the Hanhikivi headland in winter 2011–2012 indicated that the fastest flow rates occurred in the direction of 40–220°, which means that they flowed either to the south-west or north-east. The maximum flow rates measured in the open sea were 50 cm/s in the surface layer and 30 cm/s close to the seabed. Continuously operating flow measurements (November 2012–October 2013) showed that on the cooling water intake side, the dominating flow direction was from south-west to north-east in the surface layer and from south to north closer to the seabed. The fastest measured flow rates were 25 cm/s close to the seabed and nearly 50 cm/s at the depth of three meters. On the discharge side, currents were significantly weaker, and the main direction of the flow was from south to north (*Luode Consulting Oy 2013*).

According to flow model calculations (*VitusLab 2012*), the tip of the Hanhikivi headland has an area where the flow rates increase to approximately two times the flow rates in the open sea. This is due to the fact that the three kilometer long headland is at a right angle to the general coastline and forms an obstacle to currents that flow along the coast. In the model simulations, flow rates of 80–100 cm/s to the north formed at the tip of the headland during westerly storm winds.

The flow rates are typically slow in the marine spoil area. The marine spoil area is the area where the dredging waste from hydraulic construction work is to be deposited. Based on measurements, the bottom currents flow for 98 per cent of the time at the rate of 10 cm/s or slower. The highest measured flow rates were 33 cm/s at the bottom and 54 cm/s in the surface layer. The shape of the seabed at the marine spoil area steers currents strongly to the south-east and south-west.

7.4.1.3 Ice conditions

Due to the cold climate and low salt content, the Bothnian Bay is usually covered by ice in the winter. Hard wind, particularly when blowing from the south-west, and sea currents may break the ice and pack it into banks by the Finnish coast. The ice cover usually starts to form in the inner coves of the Bothnian Bay in mid-November. The maximum ice thickness found along the northern coastline is typically approximately 70 cm. The ice starts to break away in May. The formation of pack ice is a typical phenomenon in the Bothnian Bay region. Winds and sea currents shape the ice particularly in the outer archipelago and on the open sea. The packed ice walls composed of floes can be very high and also reach below the water surface. The ice normally only reaches a few meters below the surface, but ice has been found to scratch the seabed even at a depth of 28 meters. (*Kronholm et al. 2005*.)

7.4.1.4 Water quality

The quality of water off the Hanhikivi headland is mainly determined by the general state of the Bothnian Bay, as no wastewater is led to the area and the impact of river water is generally small. The impact of river water, most importantly that from the Pyhäjoki river, can be observed in the quality of water in the coastal area particularly in spring, when the runoff is at its highest. The nearest point sources of pollution are in Raahe and consist of the treated waste water led to the sea from the water utility Raahen Vesi Oy and the facilities of Ruukki Metals Oy.

The sea in front of the Hanhikivi headland is open, and water changes effectively due to the mixing impact of winds and currents. These factors keep the water quality close to that of the outer sea. The quality of the sea water in front of the headland corresponds to the water quality typically found along the Bothnian Bay coast. In the ecological assessment of the Finnish environmental administration (2013), the water quality of the sea in front of the Hanhikivi headland was classified as moderate. Further (over 300 meters) from the coast, the quality of the water was classified as good. The state of the coastal waters is affected by eutrophication caused by nutrients carried by rivers, as well as the population centers and industries found in the coastal regions. The project area is included in the Oulujoki-Iijoki River Basin District. The management plan for the Oulujoki-Iijoki River Basin District sets the good state of the coastal waters as a target (*Pohjois-Pohjanmaan ympäristökeskus and Kainuun ympäristökeskus 2009*).

The water quality in the marine spoil area corresponds to the typical quality of sea water in the Bothnian Bay. The water quality in the marine spoil area is classified as good in the ecological assessment of the Finnish environmental administration (2013).

Fennovoima has monitored the state of the sea near the Hanhikivi headland by water samples since 2009 (Figure 7-11). The samples have been tested for temperature, oxygen content, oxygen saturation level, pH value, electrical conductivity, color, turbidity, total phosphorus content, phosphorus in the phosphate form, total nitrogen content, ammonium nitrogen content, nitrate-nitrite nitrogen and chlorophyll a. Fennovoima has also carried out periods of continuously operating water quality measurements since fall 2011 (Figure 7-11). The continuously operating instruments have measured for example the water temperature, salt content and turbidity. Phytoplankton samples have also been taken in 2009 and 2013. The water quality data described below has been obtained from these samples and measurements.

The sea water reaches its maximum temperature at the turn of July and August. Based on the water samples from the sampling points in front of the Hanhikivi headland, the highest temperature between 2009 and 2013 has been 18.7 °C degrees. The continuously operating measurements have also shown the temperature to remain below 20 °C degrees. In the winter, the temperature decreases during January to reach the freezing point of −0.2 °C degrees determined by the salt content (3 per mil). The intensity and pattern of stratification that form in sea water during the summer depend factors such as the weather conditions (Figure 7-12). The stratification is more likely and intense in deep water (approximately 10 meters). The water temperature also varies as a result of coastal upwelling which change the temperatures rapidly. Temperature differences are small in October, November and April (Figure 7-12).

The oxygen conditions have been mostly good or excellent at all depths. The oxygen content has been 8.1–13.9 mg/l

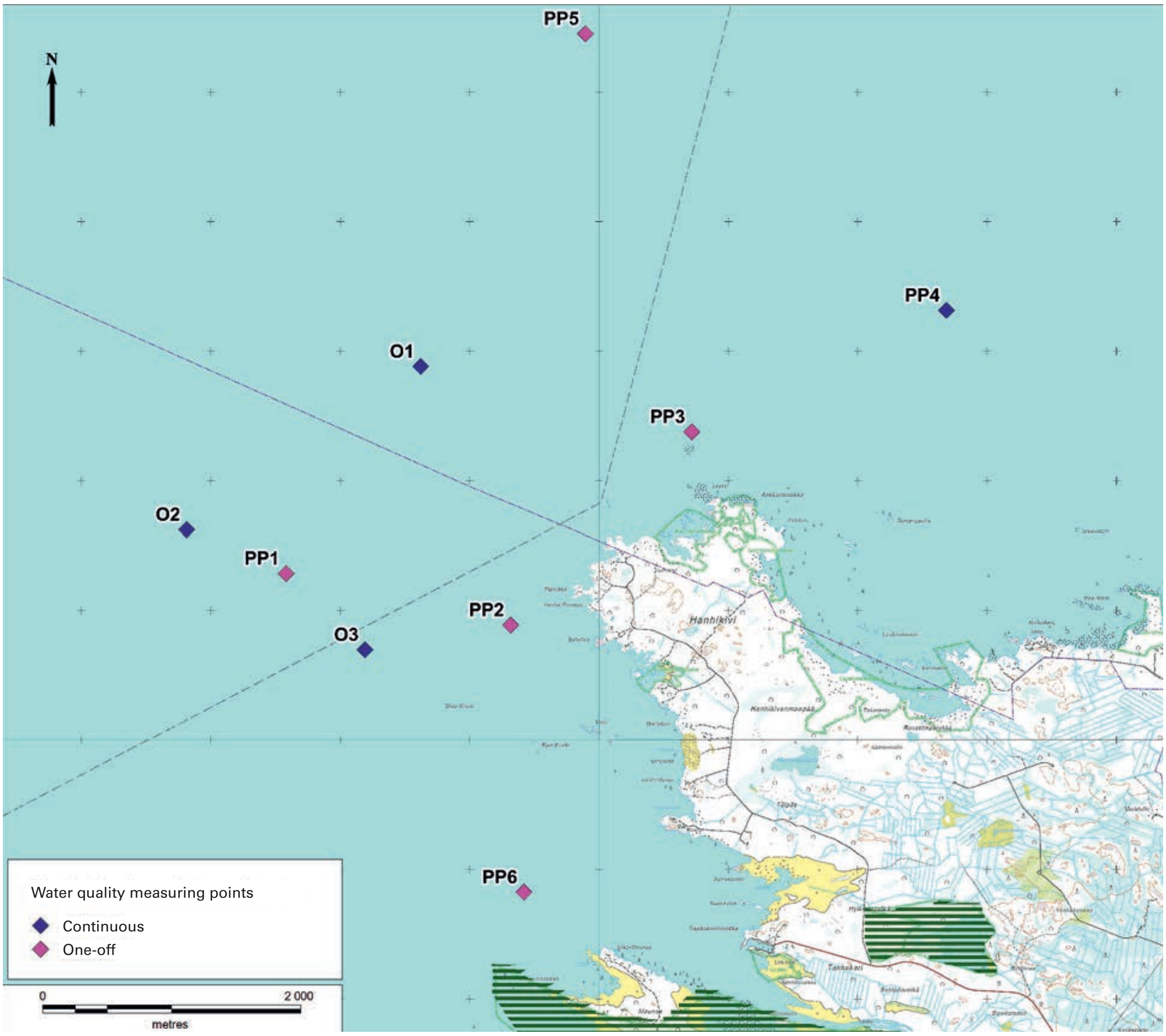


Figure 7-11. The locations of sampling points (red) and continuously operating measurement points (blue).

and oxygen saturation 78–105 %. The water has been mildly alkaline at pH 7.0–8.0, which is typical for brackish water. At times, acidic values caused by the river water have been observed in the surface water at observation point PP6.

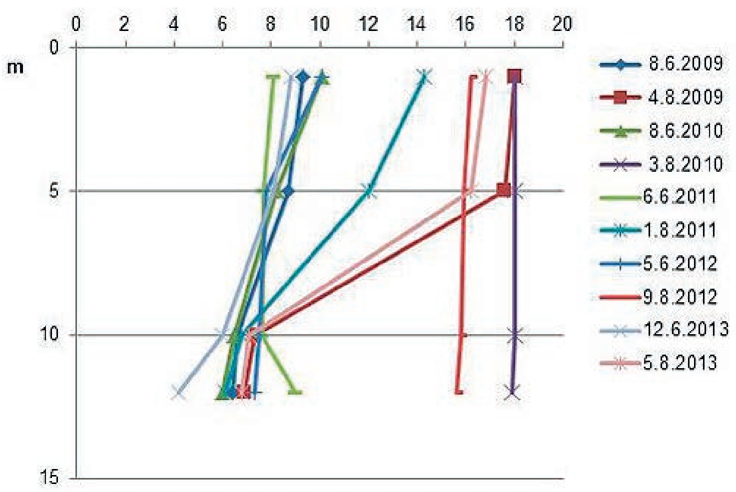
Electrical conductivity has been found to match that typical of the Bothnian Bay, with fairly little variation. The conductivity has been typically higher in the water layer close to the bottom than in the surface layer. The lower conductivity values sometimes observed at observation point PP6 in spring and fall reflect the influence of the river water. Continuously operating measurements in front of the Hanhikivi headland have revealed several river water pulses also described by model simulations (*VitusLab 2012*). The average salinity is 3.0 per mil, which is typical for the sea area. The diluting effect of the river water during high discharge in December and the spring floods of April and May typically lowers the salinity to the level of 2 per mil. The impact of river water is strongest in the surface layer.

Water transparency has varied between 0.3 and 6.5 meters. The best values have been observed in the fall. The most significant reason for turbidity in front of the Hanhikivi headland is the resuspension of bottom sediment caused by waves and currents. The highest turbidity caused by resuspension of sediment were measured in connection with the Tapani and Hannu storms in December 2011. The lowest turbidity values, on the other hand, have been measured under an ice cover. The water has then been generally more turbid than when measured in June. When measured in June, there has been variation from mainly clear to mildly turbid. Brief strong increases of turbidity have been observed at measuring points in winter, connected with a decrease of water temperature. These observations may have been caused by ice crystals, or frazil ice, forming in the water.

Based on color, the water quality has been mainly good or excellent with the exception of the point closest to the mouth of the Pyhäjoki river, where the color values have varied greatly (8–250 mg/l Pt). The high color values have been caused by humus carried by the river water.

The phosphorus content found in the surface water (4–35 µg/l) has been mainly typical of waters with low nutrient content (*Forsberg et al. 1980*), but figures that indicate mild eutrophication have been observed at points PP1–PP5 in

PP5, temperature (°C), June–August



PP5, temperature (°C), October–April

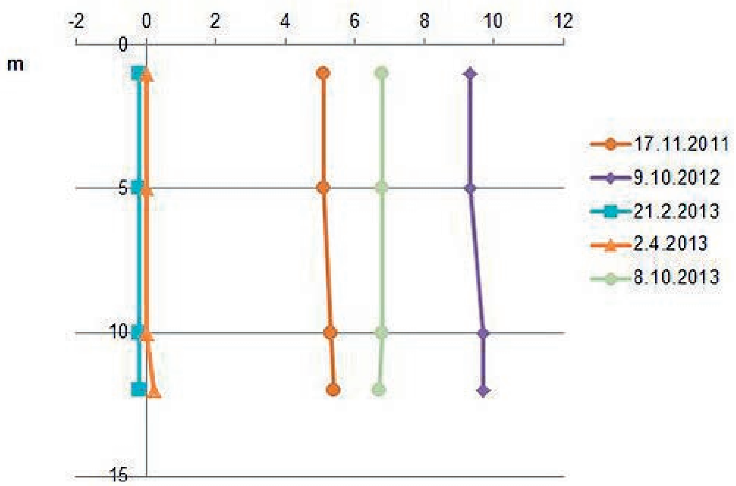


Figure 7-12. Temperature in relation to water depth at the deepest observation point PP5 near the Hanhikivi headland from 2009 to 2013. Due to the water depth, stratification is more likely and often more intense at observation point PP5 than at other observation points (PP1–PP4 and PP6).

measurements performed in June and August. The surface water at point PP6 has shown periodic increases of phosphorus content due to river waters. Measurements made in October and November have indicated higher overall levels than those measured in the summer. The level of phosphate phosphorus, which algae can use, has shown considerable variation (<2–28 µg/l). The highest levels by far have been measured at the surface water of point PP4 in June 2011 (20 µg/l) and at point PP6 in August 2012 (28 µg/l). The value measured at point PP6 in particular is due to the impact of river water.

The total nitrogen content in the entire water mass has varied between 160 and 940 µg/l. The highest contents have generally been measured in the fall. The highest value (940 µg/l) was measured in the surface water of point PP6, strongly influenced by river water, in August 2012. Plenty of inorganic nitrogen has generally been available to algae. The nitrate-nitrite nitrogen levels in the entire water mass have varied at <5–290 µg/l and the ammonium nitrogen levels at <5–140 µg/l. The average proportion of inorganic nitrogen of the total nitrogen in the surface layer has been 22 % in June and August.

The chlorophyll a content used as an indication of the phytoplankton levels has in the summer season reflected the generally low nutrient content of the sea area (<7 µg/l) (*Forsberg et al.* 1980). An exceptionally high value has been measured in November 2011 (12.6 µg/l). The weather in the time period in question had been very warm for the season in the whole of Finland, and the climate conditions had clearly been favorable for algae growth. Based on the proportions of inorganic nutrients, primary production had been mostly limited by phosphorus.

The general low nutrient content of the sea area has also shown in the low biomass levels of phytoplankton samples. Only the spring maximum for phytoplankton has been strong (2.7 mg/l at most), consisting nearly exclusively of diatoms (*Diatomophyceae*). The biomass of other groups of algae was very low. The total biomass has been very low at the measurements carried out late in the summer. The algae group with the highest biomass was the golden algae (*Chrysophyceae*). Other groups with relatively high biomasses were cryptomonads (*Cryptophyceae*), diatoms and green algae (*Chlorophyceae*). A moderate quantity of cyanobacteria (*Nostocophyceae*) was found at one sampling location. Due to the low salinity of the water, fresh water species have prevailed. *(Palomäki 2009)*

7.4.1.5 Type of the seabed

The seabed near the Hanhikivi headland has been studied by carrying out seismic refraction surveys and drilling in 2012 (*Sito Oy 2012a, Sito Oy 2012b*) and by acoustic-seismic sounding of the navigation channel (*Rantataro et al. 2012*). Researches of contaminants in sediment have also been carried out in the Hanhikivi sea area in 2009 and 2012. No contaminated sediment was found, and the general levels of contaminants were low.

The waves and stronger currents at the tip of the headland shape the seabed in the area and cause major resuspension of the finest particles of the bottom sediment. Rocks and boulders dominate the seabed in the shallow parts (0–5 meters) of the coastal waters at the tip of the headland. Gravel is found in some sheltered depressions. The proportion of gravel increases when the water depth increases to 5–10 meters. When the water depth exceeds 10 meters, the seabed is covered by fine sand (125–250 µm). Hard clay lenses can be found below the sand at places. Organic sediment can only be found in sheltered coves near the shore.

The seabed off the Hanhikivi headland mainly consists of coarse soil (sand and gravel) and rock. Clay is found at places. At the outer edge of the zone, the loose soil is slightly finer than around the harbor. Starting from a 200-meter distance from the mouth of the harbor, the layers of soil are mainly composed of sand mixed with silt and silt mixed with sand (*Rantataro et al. 2012*). The layer of loose soil over the rock bottom is seven meters thick at most. According to the acoustic-seismic sounding survey (*Rantataro et al. 2012*) performed in the navigation channel area, the seabed shows signs of erosion caused by storms, currents and pack ice. The surface of the seabed is rocky almost over the entire area, and clay sediments are only found at close proximity to the shore and at the outer end of the navigation channel. The fine sand found in the area moves with currents.

The rock surface is on level -9–+1 in the harbor area and on level -7–+2 at the cooling water discharge structure area. In the navigation channel, the height of the rock shows some abrupt variation.

The seabed is hard in the designated marine spoil area and the sediment nearly exclusively medium fine sand or coarser elements, such as coarse sand.

7.4.1.6 Aquatic vegetation

The aquatic vegetation in the sea area surrounding the Hanhikivi headland has been studied in a survey of the current state of underwater nature (*Ilmarinen et al. 2009*) and in a bioindicator survey in 2012 (*Leinikki & Syväranta 2012*).

The surveys showed that aquatic vegetation in the area is sparse. The shores of the headland are open and flat, and the most sheltered areas with the most diversity can be found in the shallow coves of Takaranta and Kultalanlahti. The marine spoil area is too deep for any aquatic vegetation.

The following habitat types included in the underwater habitat types of the Baltic Sea as listed by the working group on Finnish endangered habitat types (*Raunio et al. 2008*) were found on the shores of the Hanhikivi headland and the waters around it: filamentous algal zone of the hydrolittoral (Least Concern, LC), filamentous algal zone of the sublittoral (Near Threatened, NT), Cladophora aegagropila communities (Data Deficient, DD), bottom dominated by submerged macrophytes (Vulnerable, VU) and Charophyte meadows (Endangered, EN).

The Charophyte meadows classified as endangered were found at the planned cooling water discharge site and in the Takaranta area located a few kilometers away from it, among other locations. Based on observations made in 2012, Charophyte meadows are also fairly common in sheltered coves which can be found to the north and south from the Hanhikivi headland. The locations are typically shallow lagoons in beaches where the water depth is very low. Charophyte meadows have also been found in the depth of two meters in locations where a mud bottom was covered by sand.

Bottom dominated by submerged macrophytes is most frequently found in more sheltered parts of the coastline, such as the flada to the east of the planned cooling water discharge site. Clasping-leaf pondweed is fairly common outside the most sheltered coves. It grows as thick populations in waters up to three meters deep, provided that the impact of waves is not too strong.

Filamentous algal zone of the sublittoral is common along Finnish coastlines, but in the Bothnian Bay it is typically sparse when compared to other parts of the coast. In the Hanhikivi sea area, filamentous algae form more abundant populations on rock surfaces located in the depth of two meters or more than in shallow water, where the impact of waves is the strongest. Annual filamentous algae are dominant in the depths of 0–3 meters, and the perennial Cladophora aegagropila in the depth of 3–7 meters, below the zone which is affected by ice during winters (*Ilmarinen et al. 2009*). As rocky seabed dominates these depths around the Hanhikivi headland, Cladophora aegagropila communities are also found. In the hydrolittoral zone, the rock surfaces have annual filamentous algae species. Excluding sheltered areas, waves prevent the growth of vegetation on sand bottom.

Alleco Oy gathered in 2013 drop video data from 29 locations around Hanhikivi (the VELMU project, *Leinikki 2013*). The video locations used in 2013 were planned so as to complement the diving surveys carried out by Fennovoima in 2009. Interpretation of the video data focused on the quality of the seabed and the coverage and average height of macroscopic flora and fauna. As identification of species is more difficult based on video data than when diving, Alleco states that the results of the video data are not as reliable. The overall characteristics of the underwater habitats in the area were found to correspond to those reported in the 2009 survey (*Ilmarinen et al. 2009*). No endangered species or habitat types were found based on the video data.

Other surveys have revealed the protected Alisma wahlenbergii, classified as vulnerable (VU), 10 kilometers to the south and six kilometers to the north from Hanhikivi. Other species found included Crasuula aquatica (NT) and Sparanium emersum ssp. erectum (NT) (*Risku 1988*). The most diverse species were found in the Takaranta and Juholanranta bays located on the eastern side of the Hanhikivi headland. The endangered or protected aquatic plant species listed above are not found in the project area or the construction work area.

7.4.1.7 Benthic fauna

Alleco Oy has performed research of the benthic fauna in the offshore area around the Hanhikivi headland in 2009 and 2012 (*Ilmarinen et al. 2009, Leinikki & Syväranta 2012*).

In the 2009 survey, the benthic fauna was dominated by Monoporeia affinis and Saduria entomon, of which the Monoporeia affinis requires fairly good water quality. The number of individuals of benthic fauna per square meter was estimated at 616. According to the BBI index calculated from a sample, the ecological state of the benthic fauna is good.

In summer 2012, samples of benthic fauna were taken at six locations by diving. Samples were also taken from the sand bottom in the planned dock basin and navigation channel using a Ponar sampler lowered from a boat. Based on the BBI indices calculated for the sand bottom samples, the state of the benthic fauna varied from adequate to excellent.

The species or genera most commonly found in the benthic fauna samples included Chironomidae, Oligochaeta, Monoporeia affinis, Saduria entomon and Marenzelleria viridis. Turbellaria and Isopoda were also found in the marine spoil area samples. There was some variation in species between the different sampling points. As no reference values for the sea area near Hanhikivi were available, it is difficult to assess the diversity values of the littoral samples compared to the rest of the Bothnian Bay. The factors with the most impact on the diversity of the species are the water depth, seabed quality and the impact of waves within a few square kilometers. The occurrence of vegetation also has an impact on species of fauna; vegetation, in turn, can be strongly affected by waves. In hydraulic construction areas and near them, the seabed mainly consists of rocks and sand, with little vegetation.

Most of the sand bottoms in the Hanhikivi shore area and nearshore waters belong to the zoobenthic communities in the euphotic zone underwater habitat type found in the Baltic Sea, listed by the working group on Finnish endangered habitat types (*Raunio et al. 2008*) and classified as Near Threatened (NT). The habitat type of zoobenthic communities beyond the euphotic zone, also found at the target area, has been classified into the same category. The euphotic zone reaches fairly deep waters in the Hanhikivi sea area, which means that among the hydraulic construction work areas, the latter habitat type is limited to the planned marine spoil area.

7.4.1.8 Fish and the fishing industry

In recent years, the fish stock and fishing industry near the Hanhikivi headland has been surveyed using net sampling, fry fishing and fishing studies *(Kala- ja vesitutkimus Oy 2012a, 2012b, 2013a and 2013b)*. The sea area in front of the Hanhikivi headland is a significant area for the fish stock and the fishing industry, and fish species typical to the Bothnian Bay are common there.

Surveys of fish species

Based on the net sampling carried out in Kultalanlahti and off the Hanhikivi headland, the most abundant species of fish in the area are the perch (*Perca fluviatilis*), roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*), which together compose approximately three quarters of both the number of fish individuals and the mass of the catch. Common fish species that spawn in the spring also include the pike (*Esox lucius)*, carp bream (*Abramis brama*), dace (*Leuciscus leuciscus*), bleak (*Alburnus alburnus*) and ruff (*Osmerus eperlanus*). Cyprinids dominate among the species with a 40 per cent share of the biomass of the total catch. Of cool water fish species, the area has sea-spawning whitefish (*Coregonus lavaretus*), common whitefish, vendace (*Coregonus albula*), Baltic herring (*Clupea harengus membras*) and burbot (*Lota lota*). Based on fishing samples, it seems that the extensive sand bottom areas to the north-east of the Hanhikivi headland function as an area for young whitefish to feed and grow. Other migratory fishes that are common in the area during certain periods include the sea trout (*Salmo trutta trutta*) and salmon (*Salmo salar*). The river lamprey (*Lampetra fluviatilis*) also spawns in the rivers of the area and for example the Pyhäjoki river has been classified as a spawning river of great importance for the river lamprey.

Based on fry researches, the Hanhikivi headland sea area has significance for the fry production of the sea-spawning whitefish, vendace and Baltic herring. The sea-spawning whitefish and the vendace spawn in shallow water in October and November. The spawning of the Baltic herring usually takes place between the middle of June and the middle of July. The most important spawning areas of the whitefish, vendace and Baltic herring can be found on the northern side of the Hanhikivi headland very close to it, and in the Maanahkiainen and Lipinä shallows located approximately 7-9 kilometers to the north from Hanhikivi (Figure 7-13). Other spawning areas can be found in shallows further in the sea. Relatively few fry or spawning areas of spring-spawning species were found in the research area. It is evident that the primary spawning areas of these species can be found in the rivers, creeks and ditches of the region, and in their estuaries.

The Parhalahti bay to the south from Hanhikivi has endangered grayling (*Thymallus thymallus*), at least some of which spawn in the Liminkaoja river that empties into the Parhalahti bay. The grayling may also use other rivers of the area for spawning. There could also be sea-spawning grayling in the area. However, no signs of grayling spawning in the sea in the Hanhikivi area were found in the 2012 fry research. According to the research, it is unlikely that the grayling spawn in the sea in the Hanhikivi area.

Migration routes of common whitefish and salmon can be found near the project area, but migration also takes place further in the sea (Figure 7-14 and Figure 7-15). The salmon mainly use the routes further away from the coast when migrating to the north.

According to the classification of threatened Finnish species (*Rassi et al. 2010*), the sea-migrating stock of the trout and the stock of the grayling have been classified as critically endangered (CR), the common whitefish as endangered (EN) and the Baltic Sea salmon and sea-spawning whitefish as vulnerable (VU).

Fishing surveys

The survey of commercial and recreational fishing in the Hanhikivi area, carried out in 2011, was targeted at the sea area between Yppäri and Raahe. The survey thus covered more than 10 kilometers of the coastline to the north and south of the headland. The sea area up to 20 kilometers offshore was included in the survey.

Commercial fishing was carried out in the area by 28 households. The average level of professional activity was low among the professional fishermen. Three were included in professional fisherman category 1, three to category 2 and the rest to category 3. Most of the fishermen, 80 %, were category 3 fishermen, with less than 15 % of the total income coming from fishing. Bottom gillnets with mesh size under 45 mm were the most popular fishing equipment. Other equipment used included gillnets with mesh size over 45 mm, fyke nets designed for whitefish or salmon, salmon and trout nets, vendace and Baltic herring nets, and fyke nets for Baltic herring. The fishing focused on the summer, between June and September. Gillnet fishing also took place in the winter in nearly the entire survey area. Gillnet fishing locations were mainly found near the coastline and close to the shallows further in the sea. The area to the north of the Hanhikivi headland was a particularly popular gillnet fishing area. Permanent fyke net locations had been established near the coastline at fairly long intervals throughout the survey area (Figure 7-16). A major part of the fyke net locations were off the Hanhikivi headland and in the Kultalanlahti bay.

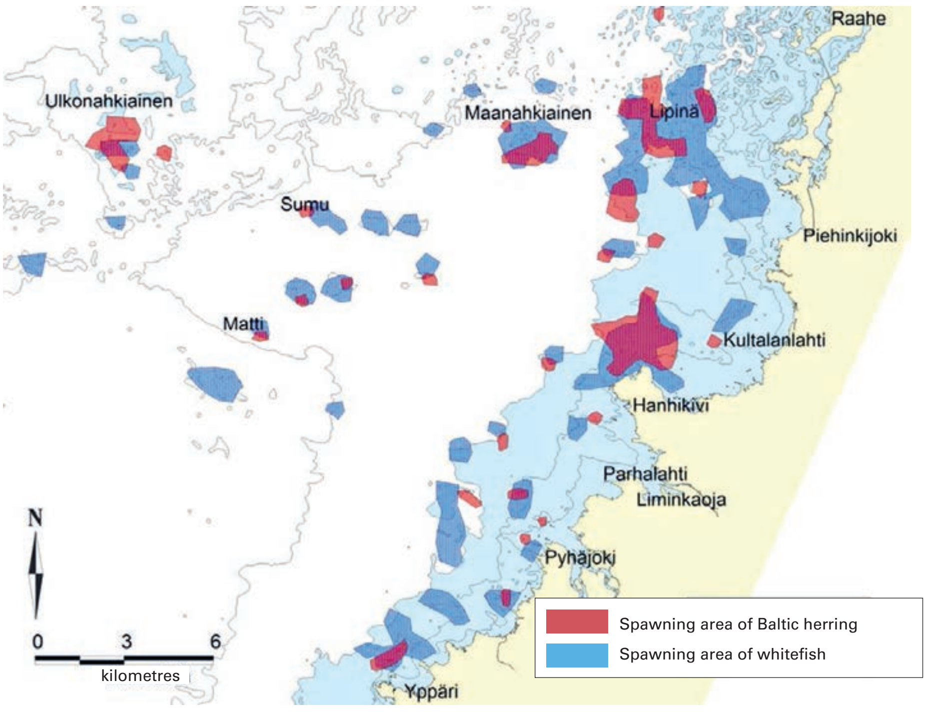


Figure 7-13. Spawning areas of sea-spawning whitefish and Baltic herring as reported by professional fishermen. *(Kala- ja vesitutkimus 2013a)*

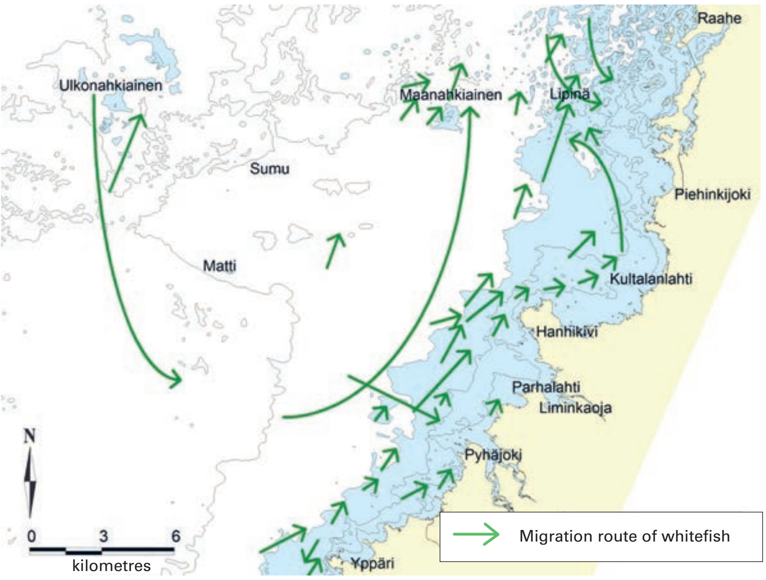


Figure 7-14. The migration routes of common whitefish in the Pyhäjoki and Raahe sea areas as reported by professional fishermen. *(Kala- ja vesitutkimus Oy 2013a)*

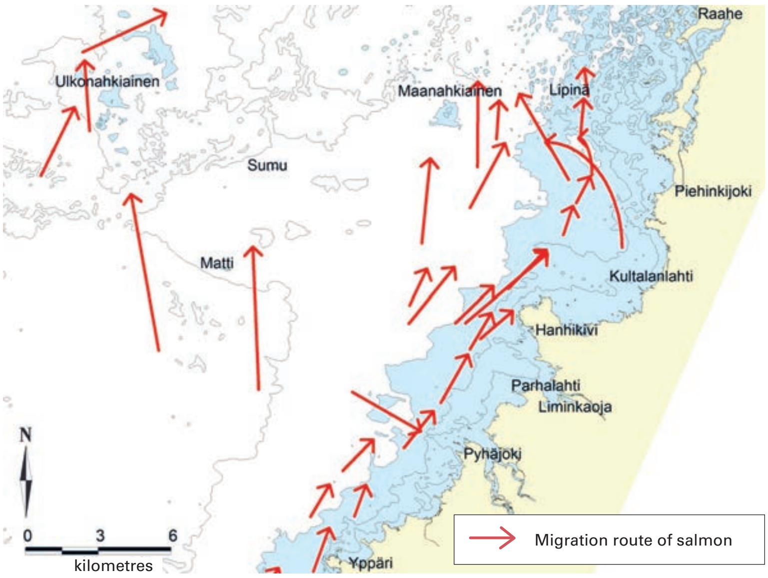


Figure 7-15. The migration routes of salmon in the Pyhäjoki and Raahe sea areas as reported by professional fishermen. *(Kala- ja vesitutkimus Oy 2013a)*

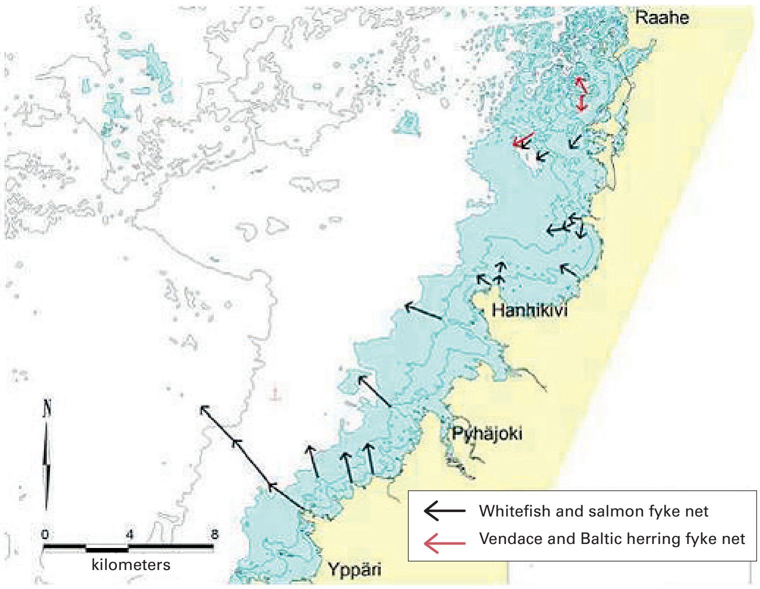


Figure 7-16. The fyke net locations of professional fishermen in the Pyhäjoki and Raahe sea areas. *(Kala- ja vesitutkimus Oy 2012b)*

Recreational fishing was carried out by 737 households in the survey area (calculated value). Bottom gillnets with mesh size under 45 mm were the most popular fishing equipment. Other popular equipment included bait casting and trolling rods, hook and line, vendace and Baltic herring nets, ice fishing rods and bottom gillnets with mesh size over 45 mm. The fishing focused on the summer, between June and August. Approximately 40 % of recreational fishers engaged in winter fishing, mainly ice fishing and gillnet fishing.

The total haul in the survey area in 2011 reached 108 tons, of which more than half was whitefish, one tenth perch and one tenth pike (Table 7-3, Figure 7-17). Other species of financial importance included salmon, sea trout, vendace, Baltic herring and burbot. The share of recreational fishermen of the total haul was 70 %. Whitefish was the most important species in both commercial and recreational fishing. The proportion of whitefish of the total catch was approximately two thirds for professional fishermen and a half for recreational fishermen. Most of the whitefish, approximately 70 %, was of the local sea-spawning variety, and little under one third were migrating common whitefish. The Hanhikivi area is not a particularly important salmon fishing area, with a total salmon haul of less than 1,000 kg in 2011. 2011 was an exceptionally poor year for salmon fishing in the area. The sea trout haul was larger, more than 2,000 kg. The average haul of commercial fishermen was 1,160 kg and that of recreational fishermen 102 kg.

Seal-induced damage, slime build-up of equipment and poor catches was considered the most serious hindrance for fishing.

Fish stock management

The planting of fish fry, carried out each year in the Raahe and Pyhäjoki sea areas, has focused on common whitefish. In 2012, approximately six million newly hatched common whitefish fry were planted in the area. Approximately 4,000 sea trout fry (two years) and 240,000 newly hatched burbot were also planted

7.4.2 Assessment methods

The assessments of the project's impact on water systems, fish and the fishing industry has been carried out based on information of the present state of the environment, cooling water simulations, information of the project's emissions into water, information received from other similar projects, and literature in the field.

The cooling water's impact on the sea water temperature, ice conditions and currents were assessed using the 3D flow model of Suomen YVA Oy *(Lauri 2013)*, applied to years 2009–2013. As initial data, the model used the current, temperature and salinity data received from continuously operating measurements in the Hanhikivi sea area, the wind, temperature and humidity data from the Nahkiainen weather station of the Finnish Meteorological Institute, the discharge data of the major rivers that empty into the Bothnian Bay, and Baltic Sea water depth data. The roughest grid of the model included the entire Bothnian Bay with a 2.15 km resolution. The most detailed data was given for a 14.5 x 15.7 km area in front of the Hanhikivi headland. The resolution for this representation was 80 m. The accuracy of the model was tested by comparing the results yielded by the model with actual measurement data and observations.

Table 7-3. Total haul (kg) of professional and recreational fishermen in the Hanhikivi area between Yppäri and Raahe in 2011.

	Professional fishermen		Recreational fishermen		Total	
	kg	%	kg	%	kg	%
Sea-spawning whitefish	15,920	49.0	25,698	34.2	41,618	38.6
Common whitefish	6,059	18.7	10,830	14.4	16,889	15.7
Salmon	591	1.8	374	0.5	965	0.9
Sea trout	874	2.7	1,347	1.8	2,221	2.1
Vendace	1,196	3.7	1,301	1.7	2,497	2.3
Grayling	20	0.1	113	0.2	133	0.1
Baltic herring	1,362	4.2	5,746	7.6	7,108	6.6
Perch	2,586	8.0	10,084	13.4	12,670	11.8
Pike	262	0.8	10,289	13.7	10,551	9.8
Burbot	229	0.7	2,423	3.2	2,652	2.5
Pike-perch	97	0.3	357	0.5	454	0.4
Carp bream	1,607	4.9	2,482	3.3	4,089	3.8
Roach	1,516	4.7	4,002	5.3	5,518	5.1
Others	163	0.5	161	0.2	324	0.3
Total	32,482	100.0	75,207	100.0	107,689	100.0

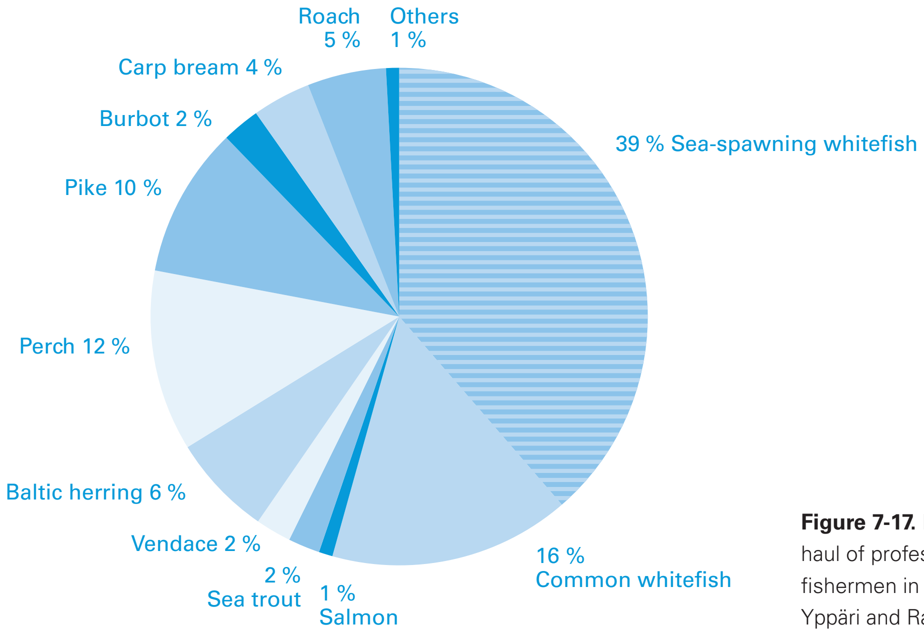


Figure 7-17. Distribution (%) of the total haul of professional and recreational fishermen in the Hanhikivi area between Yppäri and Raahe in 2011.

A similar model was also constructed in connection with the 2008 EIA procedure. A longer period of measurement data was used for this second simulation.

Five separate open water periods were used as the open water calculation period of the model: from May 15 to October 15 in 2009–2012 and from May 15 to August 31 in 2013. This was due to the availability of the data. The ice conditions were simulated for two periods extending from November 1 to March 1 in 2010 and 2012. The five most recent years were chosen for the summer periods; for the winters, the year 2010–2011 was harsher than average and the year 2012–2013 average. Wind, temperature and humidity data measured at the Finnish Meteorological Institute's Nahkiainen weather station was used as environmental condition data. The weather information concerning a more extensive sea area was received from the data of the ECMWF ERA-Interim reanalysis.

The simulation assumed a 45 m^3/s through-flow and a cooling water temperature increase of 12 °C for the power plant. The temperature of discharged cooling water was set by adding a heating effect to the simulated intake water temperature. Salinity of discharged water equaled that of the intake water. The estimated cooling power of the power plant is 2,000 MW, which was increased by approximately 10 % to 2,258 MW for the calculation.

The calculated model results were compared with measured data. The flow was compared with the flow measurements carried out in front of the Hanhikivi headland between September and November 2012. The temperature was compared with the continuously operating temperature measurements carried out in front of the Hanhikivi headland between May and October 2012. The model calculations were also compared with measurements from the Hailuoto intensive observation station. The model's current direction distribution shows a reasonable or good correspondence with the actual measured direction distribution at all the represented depths. The calculated flow rate distributions correspond well with the actual measured flow rate distributions. In the layer near the surface, the flow rates calculated for the model are to some extent too low in the range of 3–5 cm/s, and too high in the range of 1–2 cm/s. On average, the calculated temperatures follow the actual values measured at three points well. Periods of upwelling, with colder water flowing to the bottom, are not always reproduced correctly in the model; no upwelling is present in the model for August and September, even though measurements have detected upwelling during these periods. The model's water temperature decreases a little too rapidly in the fall compared to actual temperatures.

In ice calculation, the model simulates heat exchange and the formation and melting of ice in the water surface layer, but it does not take into account the migration of ice or pack ice. As a result, in areas and over periods where ice movement is significant the model cannot reproduce the real ice situation. The results of the calculations were compared with the satellite-based ice thickness observations of the Finnish Meteorological Institute's ice condition service. The calculated ice thickness typically fell within 10 cm of the measured thickness. The calculated thickness was too high in the early winter and too low in late winter.

The calculation method always introduces some error into numeric models. The quality and quantity of the error depends on the method, and to minimize the error, the appropriate methods must be chosen for each calculation. In the case of a nuclear power plant, the most significant simulation issue is probably the calculation of the flow rate in front of the cooling water discharge location and near the intake, as the flow contains temperature layers.

To achieve adequate precision, turbulence simulation, proper migration algorithms and an appropriately dense grid have been used.

7.4.3 Construction phase impacts

7.4.3.1 The impact of the construction of the harbor, cooling water intake and discharge structures and the navigation channel

In the following, the impact of the project's hydraulic construction work on the waters and the fishing industry is examined based on the water permit applications that concern the hydraulic construction effort *(Fennovoima Oy 2013a & 2013b, Kala- ja vesitutkimus 2012c)*.

Location of structures

The planned cooling water intake (O) will be located in the depth of 411 meters in a dock basin that will be constructed to the western side of the Hanhikivi headland and protected by breakwaters (Figure 7-18). The basin will be 10–12 meters deep, and a navigation channel eight meters deep and 80 meters wide will enter it from the west. At the mouth of the harbor, there will be a sill at a depth of six meters to prevent sand from entering the dock basin. The planned cooling water discharge structure (P) will be located on the north shore of the Hanhikivi headland. The discharge channel will be three meters deep and 80 meters wide at the mouth of the structure. A three meter deep channel will be built to the north of the structure, the length of the channel will be approximately 500 meters.

Impact on water systems

Temporary turbidity is caused by the dredging of the navigation channel, the dock basin, the southern auxiliary intake channel and the cooling water discharge area, the construction of protective earth walls, the draining of water from the depositing area of dredging masses on dry land, and the construction of breakwaters. The scope and spreading of the turbidity depend on many factors such as weather conditions, dredging methods and the grain size of the dredged material. The force and direction of wind in particular have an impact on the spreading and effects of turbidity. The seabed in the area to be dredged mainly consists of quickly settling rough-grained materials, such as sand and gravel. In the dock basin, the materials to be dredged mainly include rough and fine sand that settles at the approximate rate of 1 cm/s. When such rough-grained materials are dredged, the turbidity will spread to approximately 10–100 meters from the dredging or depositing site. The rough solids that mix with the water and cause turbidity typically settle within hours. Hardly any fine-grained or organic sediment has been found in the areas to be dredged. The impact of the finest matter found in the area of the navigation channel, harbor and intake structures will probably be the strongest in the water layer near the seabed, where turbidity may spread to a maximum distance of two kilometers.

The dredging is not expected to cause any releases of nutrients or contaminants into the sea. The dredging masses are mostly rough-grained, with no significant nutrient content.

Blasting is to be carried out using explosives suited for underwater blasting, with minimal nitrogen residues. The inorganic nitrogen load is temporary and will disperse into the large water masses. Increases in inorganic nutrients can in theory result in temporary eutrophication, but dilution and the temporary nature of the load are estimated to keep the impact relatively low. The nitrogen load will have the biggest impact when the water has only little inorganic nitrogen for primary production.

Suction dredging masses deposited into basins on solid land causes some solid matter load in the immediate vicinity of the discharge structures in the north-western part of the headland, as waters from deposited dredging masses basins are drained into the sea. The solid matter load caused to the sea area by the drained water is estimated to remain low, as the dredging waste consists of sand that settles well into the basin. No clay or silt will be deposited on solid land, as they cannot be used in a nuclear power plant's foundation area. Discharge of water into the sea may cause localized turbidity estimated to reach a maximum distance of 100 meters from the discharge location.

Charophyte meadows are found in the area where the cooling water discharge structures will be located. The hydraulic construction works will lead to the disappearance of this habitat type from the discharge channel area. The area that will be changed by the activities is small, however. It has been observed that Charophyte meadows are fairly common in sheltered coves which can be found along the coastline north and south from the Hanhikivi headland. This means that the habitat type will not disappear from the area, but will only cover a smaller area. The temporary turbidity caused by the dredging is not estimated to cause any harm for the habitat types of

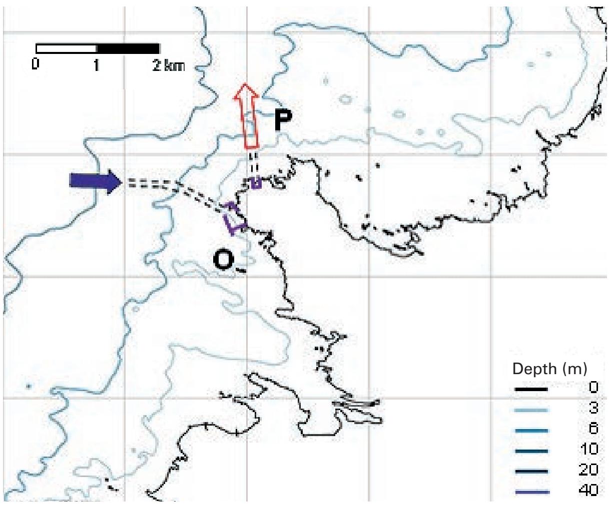


Figure 7-18. The planned cooling water intake (O) and discharge (P) locations.

typical aquatic vegetation, because the turbidity in the discharge area consists of fine sand that is also commonly carried by sea currents. No impacts are expected to extend outside the turbidity area.

In other areas, the project will have only minor impact on aquatic vegetation. The seabed will change in areas where dredging will take place. The temporary turbidity caused by dredging is not estimated to cause any harm to the distant Takaranta habitat types with typical aquatic vegetation. Due to the quality of the dredging mass (sand), no sedimentation detrimental to the natural values of the Siikalahti area is expected either. The sand turbidity that will spread during dredging will not differ from normal migration of sand in the area. At times, turbidity caused by finer sediments may spread to Siikalahti during the work. However, such brief periods of turbidity do not usually cause any permanent harm to bottom vegetation. No changes in vegetation were observed in the follow-up to the dredging and waste soil dumping work in the marine spoil area at the Hamina harbor, for example (*Leinikki 2011*).

The benthic fauna found in the Hanhikivi headland sea area are species typical to the Bothnian Bay. The dredging will destroy the benthic fauna in the immediate dredging area, but the fauna will recover fully within a few years.

Impact on fish stocks and the fishing industry

Fish stock

The most significant impact factor during construction will be the noise caused by excavation and other hydraulic construction works. The most immediate effects will be caused by the blasting. The pressure waves will kill fish within a 20-meter radius and may cause physical injuries to fish several dozens of meters away. Noise may drive fish away and change their behavior. The serious impact zone for the noise and blasting has been set at one kilometer and the potential impact zone five kilometers from the work locations.

The hydraulic construction work will result in the loss of approximately 40 hectares of seabed habitat. The area to be dredged includes spawning areas of sea-spawning whitefish and Baltic herring as well as fry habitats of Baltic herring, sea-spawning whitefish and vendace. The Hanhikivi sea area has many spawning areas of these species, so the destruction of some spawning areas will have no significant impact on the overall fry production in the area. The impact of the loss of habitat on the fishing industry was assessed as moderate. The impact of breakwaters and other fixed structures on the flow rates will remain low. Such structures may also create new sheltered habitats for fish. The impact area has only few reproduction areas of spring-spawning fish, which means that the construction works will have no significant impact on these stocks.

Increased solids content may damage or destroy fry and spawn. Turbidity will make feeding more difficult for fish and harms their food such as the zooplankton. The adverse impact of turbidity rapidly disappears outside the work targets. The overall harmful impacts were assessed as minor, and the impact was estimated to extend no further than two kilometers from the work location.

In the spring, the grayling migrates to the Liminkaoja river located near the hydraulic construction sites. The project may therefore have an impact on the migration of the grayling, if excavation is carried out during the migration season.

There are no important salmon or trout spawning rivers in the Pyhäjoki or Raahe districts. Migration routes of salmon and common whitefish do, however, pass the Hanhikivi headland. The noise and water quality changes may change some of these routes, but will not affect the ability of the fish to find their spawning rivers.

Fishing

The project's impact on fishing during the construction phase will be significant. Fishing at the construction areas and in their immediate vicinity will not be possible during the construction phase. The construction activities in the sea area may also drive away fish from a larger area and possibly influence their migration routes. Excavation, in particular, will cause powerful underwater noise that may drive away fish from an extensive area. Significant impacts are likely in an area extending at least one kilometer from each blasting site. Changes in fish behavior may appear as far as five kilometers from blasting sites.

The hydraulic construction work will destroy spawning areas of sea-spawning whitefish and Baltic herring in the dredging areas, and will certainly affect the spawning of Baltic herring in three consecutive construction years. The fishing activities in the area are mainly based on whitefish. Whitefish come to the area to feed on herring spawn. Thus, the project may have a negative impact on the fishing of whitefish in the project site's immediate vicinity.

While fishing may be possible near the work locations, turbidity will cause increased soiling of fishing equipment. The dredged soil does, however, contain only little organic material, which will probably keep the soiling down and limited to a small area, no more than a few kilometers from the work locations.

7.4.3.2 The impact of waste soil dumping into the marine spoil area

In the following, the impact of dredging waste dumping operations on the waters and fishing industry is examined based on the water permit applications that concern the marine spoil area *(Fennovoima Oy 2013c)*.

Impact on water systems

The impact is related to turbidity caused by the dumping operations and the effect that the turbidity will have on the fish stocks and the fishing industry. The marine spoil area is located in open sea approximately 9.5 kilometers to the west from the Hanhikivi headland. There are no islands within a 10-kilometer radius of the marine spoil area. The surface area of the marine spoil area is approximately 190 hectares.

Most of the material to be dumped (90 %) is rough and fine sand that settles quickly. Based on model calculations, the turbidity caused by the dumping operations will decrease to 1 % within significantly less than 24 hours. The impact of turbidity mostly remains within the marine spoil area. If the grain size of the mass to be dumped is finer, the turbidity may extend to 2–4 km from the marine spoil area. In such cases, turbidity is mostly found in the water layers near to the seabed. The most extensive turbidity impacts caused by dredging waste being dumped into the sea have been observed within 3–4 km from the actual marine spoil site. It is unlikely that any turbidity will be observed in shore areas or near them. (*Luode Consulting Oy 2012.*)

The quality of the seabed at the marine spoil area also has an impact on the quantity of solids that mix with seawater. Based on samples obtained from the sea off the Hanhikivi headland, the seabed at the marine spoil area is hard sand that will not mix with the water extensively when dredging masses are dumped on top of it. Any resuspended sand will settle quickly and is not likely to spread with currents. Based on the results, the maximum distance traveled by the turbidity caused by dumping would remain at the level of 2 km even at the fastest measured flow rates when the settling rate of the dumped mass was set at 0.8 mm/s, which corresponds to the settling rate of the finest observed grain size used in the cooling water simulation. Turbidity would also be strongly diluted due to mixing with water masses. Experience has shown that the hard clay found in the seabed is not easily broken by dredging or dumping.

The currents near the bottom may carry dumped materials towards the shore even after the dumping operations have been completed. Flow measurements carried out in the marine spoil area show that the hardest currents flow towards the north-east and south-west, which means that the migration of solids to the shore is very unlikely.

The marine spoil area is too deep for any aquatic vegetation. Therefore, no valuable underwater habitats can be harmed.

The benthic fauna of the marine spoil area will be buried under the dumped mass. The benthic fauna will recover fully in a few years after the completion of the dumping operations.

Impact on fish stocks and the fishing industry

According to a preliminary plan, dredging waste created during the construction phase will be dumped into the sea in three years. After this, dredging will be carried out approximately every ten years to maintain the channels, and dredging waste will be dumped accordingly. The impact of dumping noise, solids, loss of habitat and changed flow conditions on the fishing industry was estimated to be minor. There are no fish reproduction areas in the marine spoil area or in its immediate environment. Migration routes of salmon and, most likely, common whitefish pass near the marine spoil area, and dumping operations may cause temporary changes to these. Turbidity caused by dumping operations is mainly limited to the deepest waters near the seabed. Migrating fish stay closer to the surface, where the impact of turbidity is minor. Therefore, the detrimental effect of turbidity was estimated to be rare and to have little significance.

No fishing takes place in the planned dredging waste marine spoil area, but it is possible that the noise and turbidity disturb or prevent fishing near the marine spoil area or the transportation route. Some commercial gillnet fishing takes place within the estimated maximum impact area of turbidity, but fishing operations are mainly focused on the shallows around the marine spoil area.

7.4.3.3 Other impacts

The blasting, excavation and stone crushing carried out during the construction phase will increase the solids and nitrogen load in drained rainwater. Oil might also typically be found in the rainwater drained from construction sites. Loading can be reduced by leading drain water first to sedimentation wells and oil separators. If such water protection measures are adequate, solids and oil are not estimated to cause any significant harm to the marine ecosystem. The impact of inorganic nitrogen load also remains minor even at the worst case due to the temporary nature of the construction work and the fact that phosphorus is the most important factor limiting the increase of primary production in the Hanhikivi sea area. The inorganic nitrogen content of drained rainwater is also quickly diluted in the open sea.

The noise caused by the construction of the nuclear power plant and carried from land to sea may drive fish away from the immediate vicinity of the project area.

7.4.4 Operation phase impacts

The impacts on water systems include the impact of cooling water, treated process and washing water, and water intake. The treated process and washing water will be drained into the sea together with the cooling water. Sanitary waste water will be treated at a municipal water treatment plant.

7.4.4.1 The impact of cooling water

Sea currents

The cooling water intake and discharge will have a local impact on the sea currents in the area. These impacts were assessed by Suomen YVA Oy using a model which presented the currents as the difference between the implementation alternative and the zero option. Average currents of June 2012 were used as the starting point of the current simulation, and changes in currents were examined at six different depths (0–1 m, 2–3 m, 3–4 m, 5–7 m, 7–9 m and 9–11 m).

The impact of cooling water discharge on currents was obvious in the surface layer (0–1 m). The impact of cooling water intake, on the other hand, was more definite below the surface layer (Figure 7-19). In the deepest layer (9–11 m), no impact could be detected.

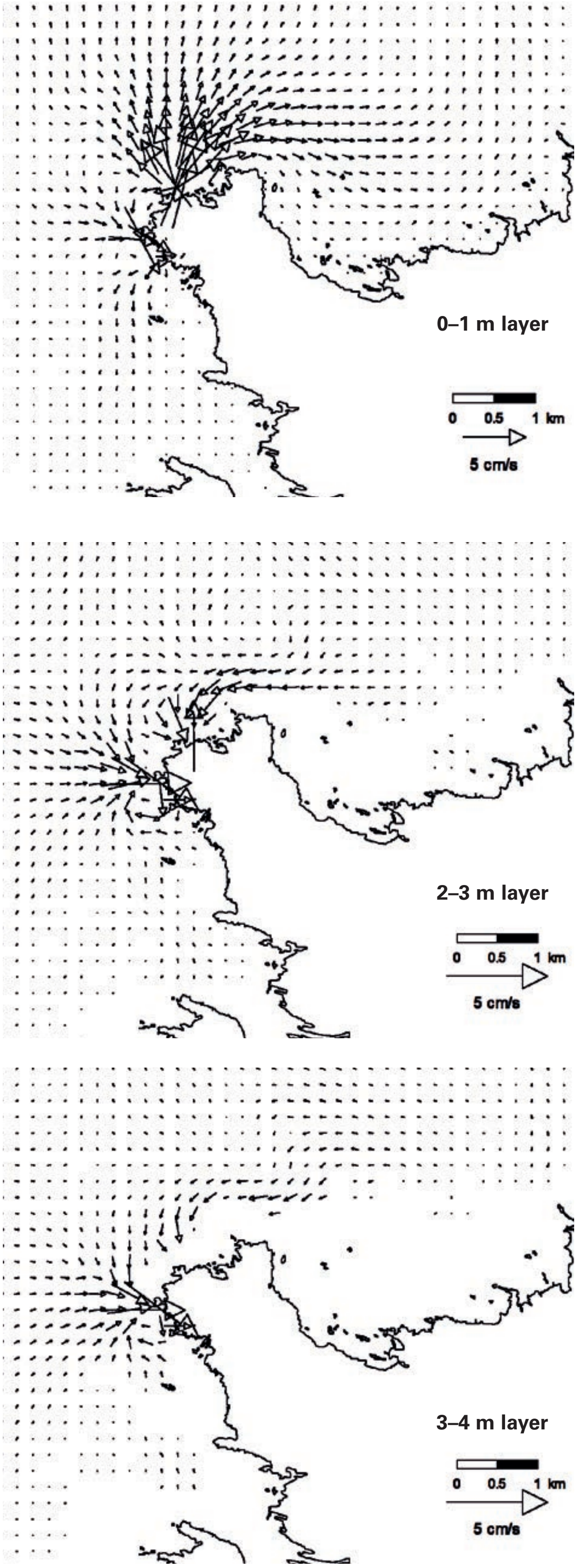


Figure 7-19. Changes in currents caused by cooling water in water layers 0–1 m, 2–3 m and 3–4 m compared to the average current situation of June 2012. The changes have been calculated by subtracting the zero option current situation from the implementation alternative current situation.

Temperature of the sea water

The power plant's cooling waters cause thermal loading of the sea water. Cooling water warms up by 10–12 °C as it flows through the power plant. The impact of the thermal load on sea water temperature was assessed by Suomen YVA Oy using a model that assumed a temperature increase of 12 °C.

The heating impact of the power plant's cooling waters at various depths was assessed using the average temperature field of June 2012 (June 1–July 1). The temperature increase was calculated by subtracting the zero option temperature field from the implementation alternative temperature field. The thermal impact was strongest in the surface water (0–1 m) and decrease in deeper layers. The strongest increase of temperature (more than 9 °C) was restricted to the surface water and to a limited surface area (0.12 km^2) (Figure 7-20 and Figure 7-21). An increase of five degrees in the surface water temperature was limited to a 0.69 km^2 area, and an increase of one degree to an area of 15 km^2. Minor temperature increases took place in deeper layers; below the depth of four meters, the temperature increase caused by cooling water discharge did not exceed one degree.

Annual variation in the cooling water impact in the surface layer (0–1 m) was examined based on the average temperature field between 15 July and 15 August in 2009–2013. The period from July to August was chosen because during this period, the sea water is at its warmest and the cooling water impact therefore the strongest of the summer period. The strongest temperature increase (more than 9 °C) could be observed in a limited area of 0.09–0.19 km^2 near the cooling water discharge location (Figure 7-23). An increase of five degrees in the surface water temperature was limited to a 0.54–0.82 km^2 area, and an increase of one degree to an area of 8.0–13 km^2. An average temperature increase of more than two degrees was limited to a distance of 2–3 km from the cooling water discharge location in all situations. Brief periods may occur when the warm cooling water will be carried significantly further than in the average conditions presented here.

Variation of the cooling water impact between different places was examined for the surface water (0–1 m) focusing on the average change of sea water temperature at five measurement points in the Hanhikivi headland sea area in the summer season (June–September) in 2009–2013 (Figure 7-22). The average sea water temperature increase remains below one degree with the exception of the shallow sea in front of the Takaranta shore section (measurement point K2).

Typical dispersal of thermal discharges under different wind conditions was estimated by choosing from the weather materials periods of three day in which winds remained in the same direction, and calculating temperature increases over these periods. South-westerly winds were examined using a period of two days in July 2009 and northerly winds using another period of two days in the same month.

During typical south-westerly winds, heat tends to accumulate in Kultalanlahti on the north side of Han-

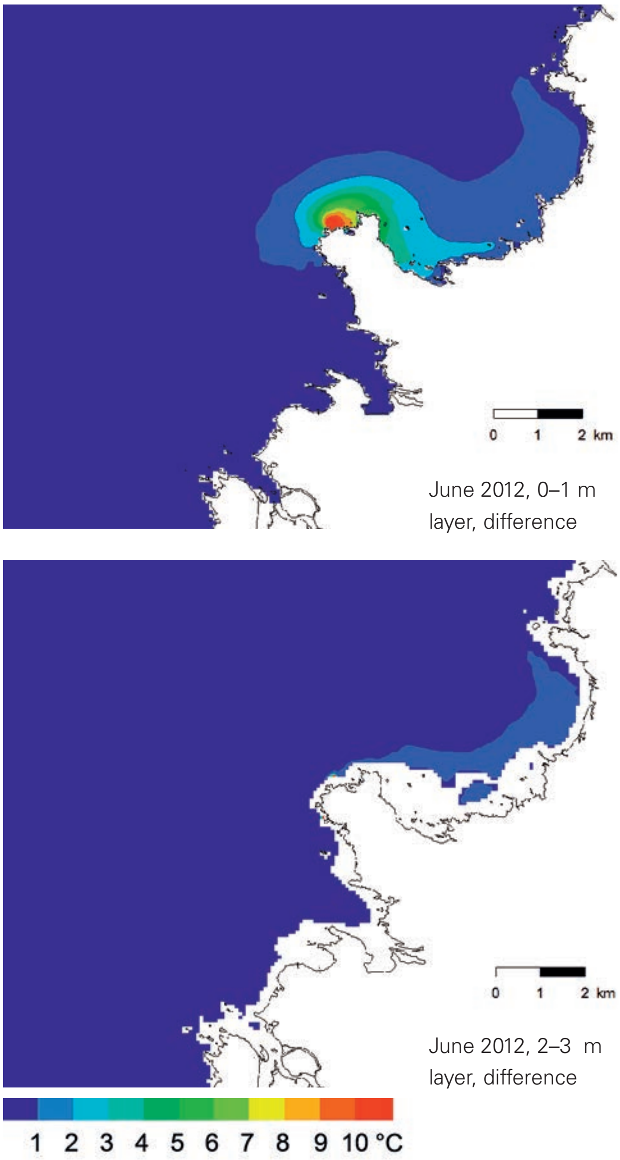


Figure 7-20. Temperature increase in the water layers of 0–1 and 2–3 meters caused by cooling water discharge according to the average June temperature field. The temperature change has been calculated by subtracting the zero option temperature field from the implementation alternative temperature field.

hikivi, in which case the area which warms up by more than one degree is rather large compared with the event of north wind. Warm water does, however, mix reasonably well with the current that flows along the coast. When temperature layers exist in the sea water and northerly winds prevail, upwelling occurs as the wind pushes warm surface water to the open sea and cold water rises from the bottom to the surface layer. In these conditions, the power plant's thermal discharges are efficiently diluted in the rising cold water, and areas of increased temperature remain smaller than in the event of south-westerly winds (Figure 7-24).

Ice conditions

The impact of thermal load on the ice conditions in the sea area were estimated by Suomen YVA Oy using a model. Winter periods were simulated using ice condition data for winters 2010–2011 and 2012–2013 from November 1 to March 1. Freezing began in both years around December 1, and the whole of the Bothnian Bay had an ice cover by January 1.

Based on the simulation, the discharge of cooling water keeps waters unfrozen or the ice thin mainly on the northern and eastern sides of Hanhikivi. When the direction of sea currents changes, the unfrozen area may shift between west, north and east. The size of the open water area and the area where the ice is thin largely depend on the temperature during the winter. Of the periods included in the simulation, the winter of 2011 was colder than the winter of 2013, which was average. Therefore, ice was considerably thicker in 2011 and the open area smaller than at the corresponding time in 2013 (Figure 7-25).

The water area kept open by the cooling waters is naturally the largest in January, when the ice cover in Bothnian Bay is still fairly thin. The size of the open area may vary greatly. According to the simulation, the open area would have been 2.2 km^2 in the ice conditions that prevailed in January 2011 and 26 km^2 in the ice conditions of January 2013. The simulation showed evening out of the annual differences in the thickness of the ice later in the winter, as the ice becomes generally thicker. By February and March, the open water area will be 2.4–2.5 km^2. At this time of the year, the open water area will extend approximately two to five kilometers from the discharge site and the area with thinner ice (thickness below 15 cm) approximately 0.5–2 km further.

Water quality

With the exception of the temperature, the quality of the cooling water does not change as the water flows through the power plant. The water is taken in close to the Hanhikivi shoreline and discharged to shoreline other side of the headland. Warm cooling water may, in certain conditions, strengthen natural stratification in the summer, in which case the potential of oxygen depletion near the bottom increases. However, no such depressions susceptible to oxygen depletion exist near Hanhikivi, nor are there areas with stagnant water. Based on measurements and water analysis, the oxygen conditions in the Hanhikivi sea

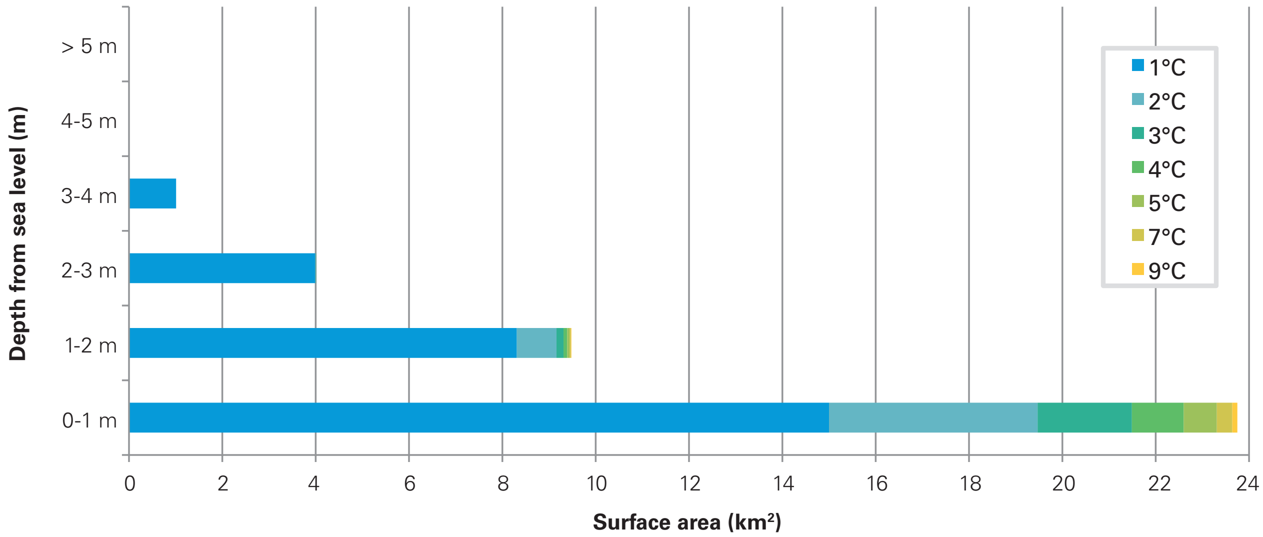
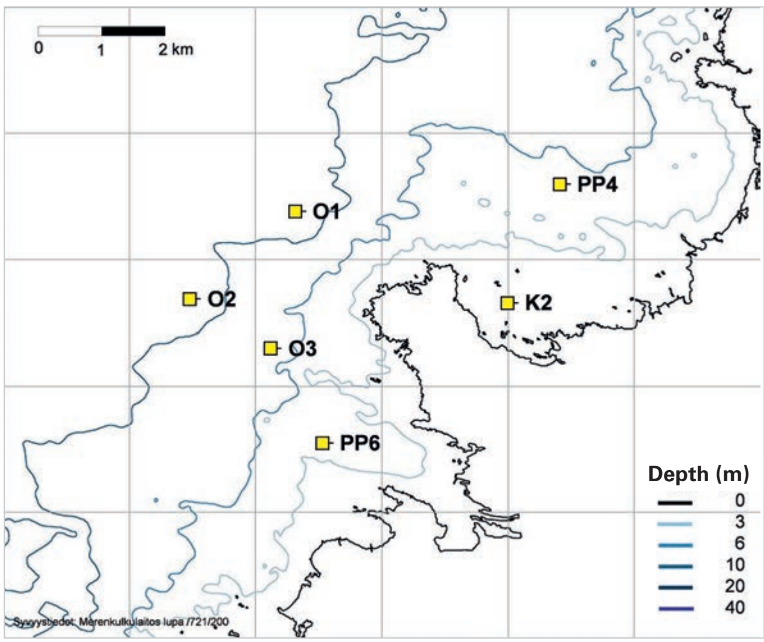


Figure 7-21. Areas where the temperature increase exceeds 1, 2, 3, 4, 5, 7, and 9 degrees Celsius in the June average temperature field.

Figure 7-22. Average increase of sea water temperature simulated for the measurement points. The average derived from the 2009–2012 measured data has been used as initial data. Mean deviation is 0.3–0.4°C for both measured and simulated temperatures.



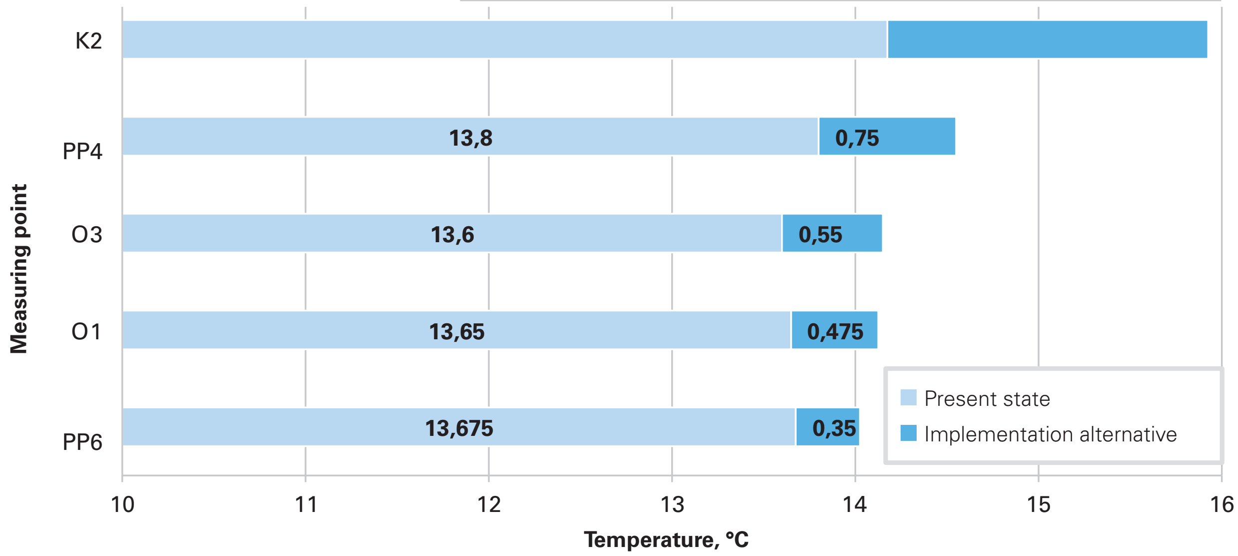
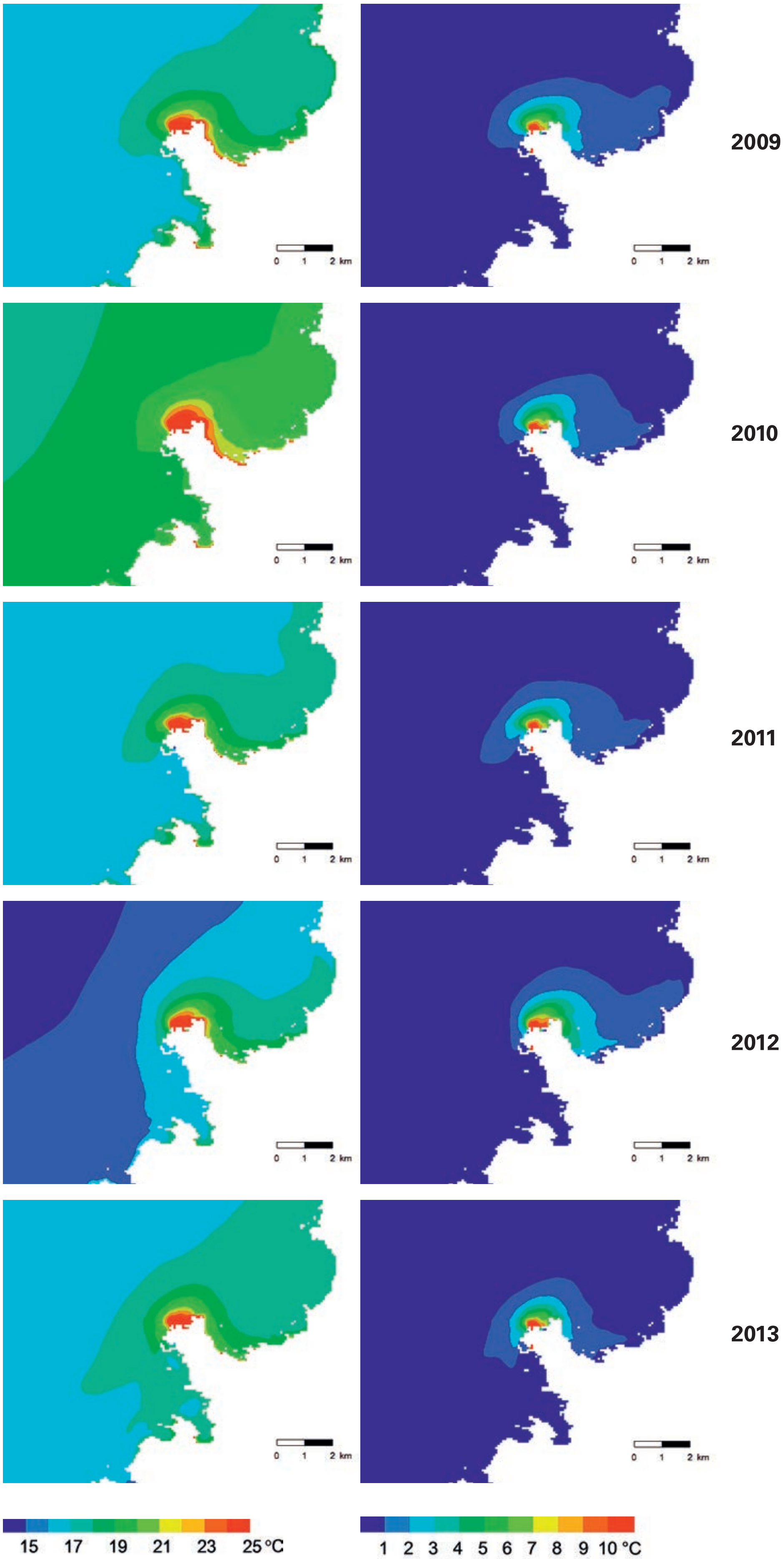


Figure 7-23. Water temperatures after the implementation of the power plant alternative (on the left) and the temperature increase caused by the cooling water (on the right) at 0–1 meters in the average conditions of 15 July–15 August in 2009–2013. The temperature change has been calculated by subtracting the zero option temperature field from the implementation alternative temperature field.



Surface layer, south-west winds **Surface layer, north winds**

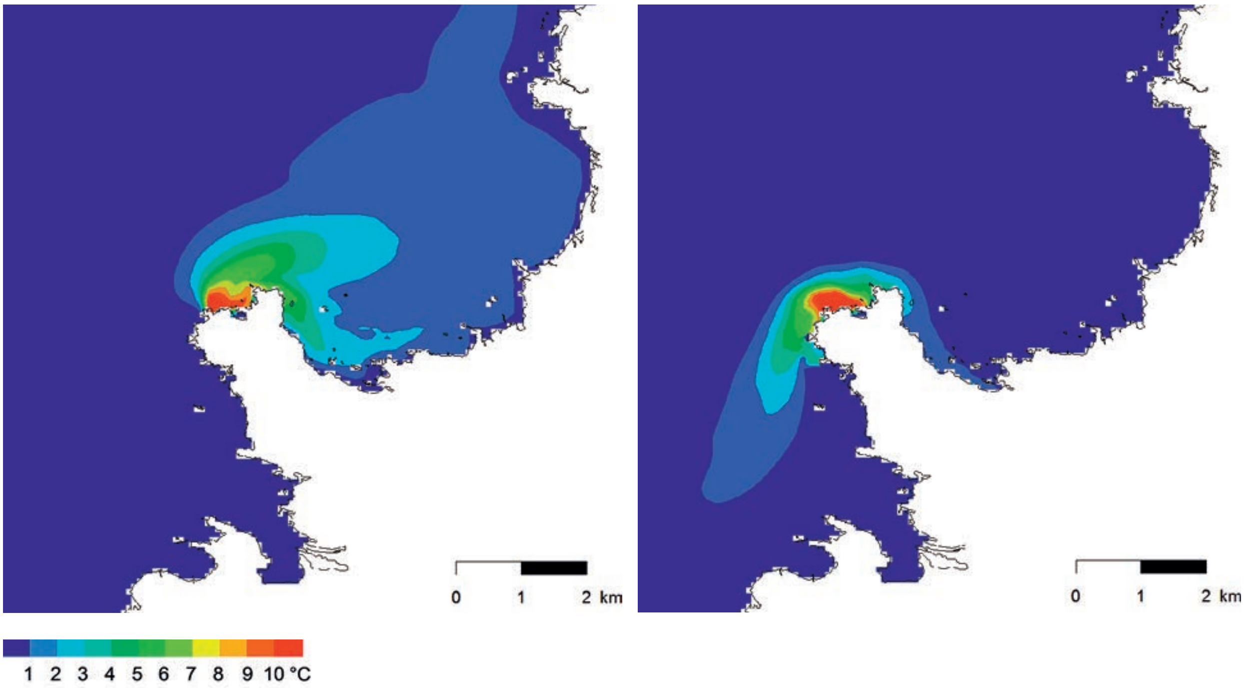


Figure 7-24. Average temperature increase from cooling water discharge in the surface layer (0–1 m) under south-westerly and northerly winds.

area have also been found to be good even in deeper water layers. The area has no particular load of organic materials which could, together with the warm cooling water, lead to oxygen depletion in the deepest water layer through the formation of intense stratification and the warmth-induced accelerated decomposition of organic material. As a result, the project is estimated to have no impact on the oxygen conditions in the sea area. The cumulative impacts of cooling water and treated waste water are discussed in section 7.4.

Phytoplankton and zooplankton

Studies carried out in cooling water discharge zones have shown that thermal load increases the primary production of the discharge area. In the Bothnian Bay, the production of phytoplankton is particularly limited by the short open sea period. Warm cooling waters will extend the open sea period and the growth period. As a result, the annual production of phytoplankton increases in the discharge area. Warm water accelerates decomposition, which may speed up the nutrient cycle between producing and decomposing entities and thus increase the production of phytoplankton in the discharge area. However, it has been observed that the increase in production has been limited to the water area where the temperature has increased. Changes have been found to occur in the phytoplankton species distribution under the influence of warm water. These changes may be a direct or indirect result of the thermal load. For example, the optimum temperature varies between different phytoplankton species.

The summer season chlorophyll concentrations and biomass measured in phytoplankton samples have reflected the typically low nutrient levels of the Hanhikivi sea area. The thermal load from cooling waters is estimated to lead to some increase in the annual production of phytoplankton in the discharge area. There may also be changes in the species distribution, also between seasons. However, the project's impact on the phytoplankton community in the Bothnian Bay area is assessed to remain insignificant and limited to the warmed-up area.

Blooming of cyanobacteria typically occurs in eutrophic sea areas particularly in late summer, when nitrogen acts as a nutrient limiting growth. However, mass blooming of cyanobacteria does not occur in the Bothnian Bay due to the area's low nutrient content and phosphorus-induced limitations. In the Hanhikivi sea area, phosphorus is the most important factor limiting primary production. For this reason, blooming of cyanobacteria is unlikely even though cyanobacteria are known to thrive in warm water and have often been found to exist in increased amounts in cooling water discharge areas.

The project is not expected to have any adverse impact on the zooplankton: no major changes in the zooplankton populations of cooling water discharge areas have been observed in Finnish or foreign studies.

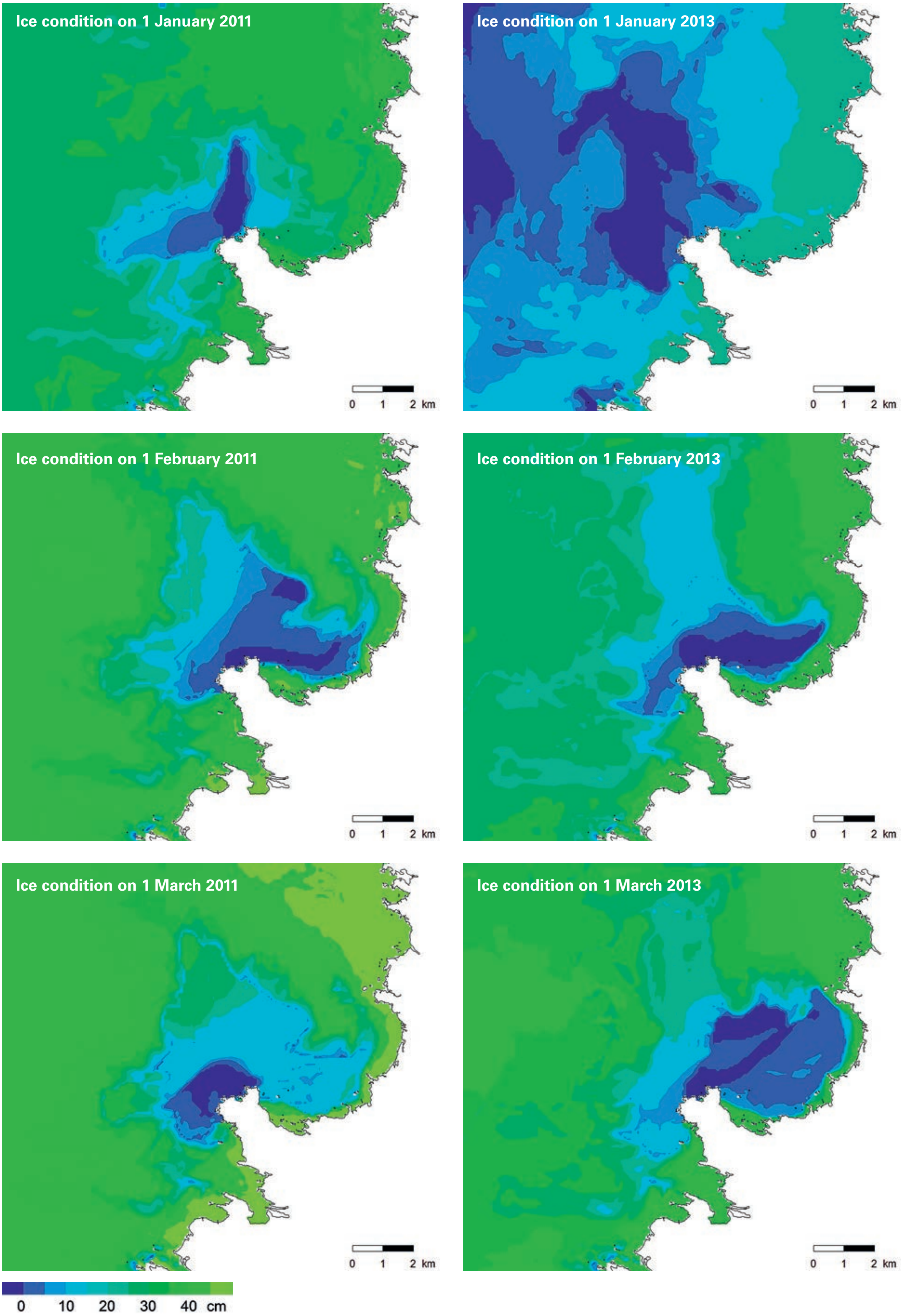


Figure 7-25. Simulated impact of cooling water in the ice conditions of 2011 and 2013.

Aquatic vegetation
Cooling waters could cause erosion, which would change the seabed and thus have an impact on aquatic vegetation. As the seabed of the Hanhikivi area mainly consists of rough-grained soil and rock, hardly any erosion is expected to occur. Due to the quality and shape of the seabed and the erosion caused by ice, the aquatic vegetation of the Hanhikivi sea area is sparse. The most sheltered areas with the most diversity are found in the shallow coves of Takaranta and Kultalanlahti.

The warm cooling water accelerates the growth of aquatic vegetation, which creates progress similar to eutrophication. Discharge areas typically have increased populations of filamentous algae, such as Cladophora glomerata, and some vascular plants with good resistance to thermal loads, such as Potamogeton pectinatus and Myriophyllum spicatum. The lack of ice, which detaches vegetation, may result in changes in species in the vegetation in the area of the coastal zone which remains unfrozen in the winter. In the unfrozen area, perennial species such as common reed (Phragmites australis) may take over space from other species.

The project is expected to increase the total biological primary production levels of aquatic vegetation and change the composition of species by increasing the growth of filamentous algae in the heated area, for instance. These impacts are expected to extend to roughly the area where the average temperature increase will be at least one degree Celsius. In unfavorable wind conditions, this area covers the whole of the Kultalanlahti.

Charophyte meadows classified as endangered are found at the planned cooling water discharge site and in the Takaranta area located a few kilometers away from it, among other locations. Cooling water discharge is likely to have a long-term detrimental impact on the Charophyte meadows as the warmth increases eutrophication. Based on observations made in 2012, however, Charophyte meadows are fairly common in sheltered coves which can also be found to the south from Hanhikivi and to the north from Kultalanlahti. The impact of cooling water does not reach these areas.

Benthic fauna
Benthic fauna in the Hanhikivi sea area mainly consists of species which live on hard surfaces. The potential impacts of cooling water on benthic fauna are mainly indirect and mostly due to changes in primary production. Since no major changes to the primary production levels are expected, the amount of organic matter accumulated into the seabed is expected to remain low, which means that no significant impact on the benthic fauna will occur. Any impact on benthic fauna will thus remain local.

Invasive species
Marenzellaria viridis is found in the Hanhikivi sea area, and the project may result in localized proliferation of the species in the cooling water impact area. However, Marenzellaria viridis has been found to reproduce in the entire Baltic Sea area, and the thermal load of cooling waters is not estimated to make the species more common in the Bothnian Bay as a whole.

Mnemiopsis leidyi has not so far been found in the Bothnian Bay. Its spreading is most likely limited by the small volume of zooplankton and the low salt content combined with other environmental factors such as coldness. The warming impact of cooling waters is directed at the shore areas and the surface layer, whereas the Meniopsis leidyi only exists in deep waters in the Baltic Sea. Warm cooling waters have not been found to have much impact on zooplankton communities. As a result, the project is not considered to have such impact on the appearance of the Mnemiopsis leidyi that could be distinguished from general changes in the state of the Baltic Sea.

Invasive species currently found in the Baltic Sea also include the zebra mussel (Dreissena polymorpha) and dark false mussel (Mytilopsis leucophaeta), both of which belong to zebra mussels. Neither of the species are known to appear in the Bothian Bay area. The discharge of the power plant's cooling waters could create suitable conditions for zebra mussels in the area which warms up. However, the coldness of the Bothnian Bay restricts zebra mussels from thriving outside the warmed-up area, i.e. the cooling water intake area or the Bothnian Bay in general. The low salinity may also limit the spreading of mussels.

Power plants use mechanical and chemical means to prevent mussels from affecting their safety and production operations.

7.4.4.2 The impact of treated process water, washing water and sanitary waste water

The treated process water, washing water, and sanitary waste water will only cause minor nutrient loads when compared to, for instance, the loads entering the sea area through the local rivers. Since these waters will also mix with the cooling water and the cooling water will be discharged into an open sea area, the eutrophication caused by the nutrients will be marginal.

The cumulative impact of cooling water and sanitary water has been examined in the additional materials of the application for the Decision-in-Principle concerning the nuclear power plant *(Fennovoima Oy 2009a)*. In these materials, the dilution of the power plant's waste water load into the cooling water was calculated. The calculated increases to the prevailing sea water nutrient values were less than one per cent for phosphorus and less than two per cent for nitrogen. These nutrient values showed considerable further decrease immediately after the water was discharged from the channel. It was stated that the increases in phosphorus and nitrogen contents in the impact area were insignificant. As a conclusion, it was estimated that the power plant's waste water load does not cause detectable or detrimental changes in eutrophication levels, impacts on the oxygen concentration, or impacts on vegetation or the fishing industry, even when the temperature increase in the discharge area, caused by warm cooling water, is considered. The conclusion mentioned above is still valid, even though the cooling water volume is smaller in the current plans.

The process water contains salts generated during the neutralization process. These salts are also naturally found in the sea water, and will therefore have no adverse impact in the marine ecosystem.

7.4.4.3 Impact on fish stocks and the fishing industry

Adaptation of fish to different temperatures
The most important biological effects of cooling water result from the fact that an increase in temperature accelerates biological activities. As a consequence, the growth and decomposition of organisms speed up provided that the conditions are otherwise favorable. Warm cooling water extends the natural growth period. As a result of these factors, typical impacts observed at cooling water discharge sites include faster growth of certain plankton, plant and animal species, and accelerated decomposition. The impact resembles that of eutrophication, and the effects extend to the fish stocks and fishing industry in the area.

The ability of fish to adapt to different temperatures varies between species. Fish can be roughly divided into cold and warm water species (*Alabaster & Lloyd 1980*). Cold water species include all of our salmonidae, the Baltic herring, ide, burbot and bullheads. Warm water species include the majority of cyprinids, pike-perch, perch, pike and ruffe. For cold water species, the optimum temperature for mature fish for growth is 12–19 °C, and the lethal temperature is over 28 °C (*Alabaster & Lloyd 1980*). For warm water species, the optimum temperature is over 19 °C and the lethal temperature is over 28 °C, and even over 30 °C for certain species. Fish do not endure sudden changes in temperature well. Fry are more sensitive than mature fish and, rapid changes of 1.5–3.0 °C are already damaging to them (*Svobodá et al. 1993*).

The winter-spawning burbot usually spawns in January or February at a depth of less than 3 meters (*Lehtonen 1989*). The spawning generally takes place when the water temperature is at its coldest, the optimum temperature being 0–3 °C (*Evropeitseva 1947*). For the spawn to develop, the optimum water temperature is 4 °C (*Jäger et al. 1981*).

Changes in the water temperature may change the spawning period and have an impact on the development rate of spawn. If the water is too warm, fry could hatch before a sufficient volume of their most important source of nutrition, i.e. zooplankton, has developed. By contrast, an appropriate increase in the temperature may improve the living conditions of spring-spawning fish species. If the water temperature exceeds the optimum temperature for the fish, they will reduce swimming and nutrition intake. Longer exposure to high temperatures will cause stress and increase the risk of disease. The immune system of fish is the most efficient when the water temperature is approximately 15 °C (*Svobodá et al. 1993*).

Fish have an accurate temperature sense and they actively seek a suitable temperature; thus, they can usually avoid cooling water discharge areas when the temperature increases too much. According to studies conducted in several countries, warm cooling water has not been found to have an impact on the migration of fish to rivers (*Langford 1990*). According to the studies, no significant adverse impact on migration can be observed in cases where warm cooling water does not directly prevent fish from accessing rivers. Access could be prevented in a situation where the entire water area in front of a river from the surface to the bottom is warmed up to a temperature that is actively avoided by fish.

A high water temperature and extended warm season expose fish to various parasite infections and diseases, which has been proven at fish farms. The conditions at sea cannot, however, be directly compared to those at fish farms, where large quantities of fish live in small areas. As far as is known, there are no parasite studies concerning the discharge areas of Finnish power plants (*Fagerholm, H., Åbo Academi, verbal information*). Swedish studies have not found any differences between the occurrence of parasites in a heated water area and a reference area (*Höglund & Thulin 1988, Sandström & Svensson 1990*).

Gas bubble disease of fish may occur in the immediate vicinity of the cooling water discharge site. As water temperature increases, the volume of gas dissolving in water decreases. A supersaturated state may occur in water where excessive nitrogen or oxygen contained by water generates bubbles. With regard to oxygen, supersaturation also occurs naturally, particularly in euthropic waters during the maximum production of phytoplankton. As fish move from cold water to warm supersaturated water, bubbles may appear in the fish's interstitial fluid, damaging the fish or causing death. Fish are able to avoid supersaturated water to some extent (*Langford 1990*). Furthermore, the swimming depth of fish, i.e. environmental pressure, has an impact on the release of gas. The gas bubble disease may cause mortality to a significant extent in discharge sites where the natural migration route of fish runs through a shallow, significantly warming water area. No damage has been observed in discharge sites of Finnish power plants.

Fish stocks
The moderate temperature increase in the water system in front of Hanhikivi basically favors spring-spawning fish species and creates unfavorable conditions for the more demanding fall-spawning fish species. According to the simulation *(Lauri 2013)*, the cooling water increases the temperature of the surface water (0–1 m) in summer at the warmest time up to 26–28 °C at the immediate vicinity of the discharge area, which approaches the lethal level for fish. In summer, the temperature of the surface layer (0–1 m) of the sea will increase by more than 3 °C within an area of 2 km^2 at most, and by more than 5 °C within an area of less than 1 km^2. Warming will be minor at the depth of more than 2 m. The local warming up of surface water is not estimated to have a significant adverse impact on the area's fish stocks because the deeper water layers are cooler and fish can actively seek suitable temperatures. In summer, the area affected by cooling waters will be suitable for spring-spawning warm water species but, in winter, the area will also attract cold water species such as whitefish and trout.

The shallow rocky areas around the Hanhikivi headland are important spawning sites for sea-spawning whitefish and Baltic herring, and the warming up of the water will affect their reproduction potential. The harmful warming up of hypolimnion caused by cooling waters in the spawning areas of these fish species will be limited near the discharge area, and will not have a significant impact on these fish stocks on a wider scale. The increased temperature will also have an adverse impact on the reproduction of burbot in the vicinity of the discharge area, but it will not have a significant impact on the burbot stock in the area. The burbot stock in the sea area between Raahe and Pyhäjoki is not particularly strong, and burbot fishing is relatively rare in the area.

Some of the northern migration routes of common whitefish pass in front of Hanhikivi. The main migration route of salmon runs farther out at sea. According to the simulation *(Lauri 2013)*, significant warming up of the surface water (0–1 m) will, in summer, be restricted to the area north of Hanhikivi and Kultalanlahti bay when average winds prevail. Significant warming may also occur west of Hanhikivi under suitable wind and current conditions. Warming will be minor at the depth of more than 2 m. Migrating fish usually migrate in the surface layer a few meters deep. The local warming up of surface water is not estimated to have a significant impact on the migration behavior of fish that migrate north, but the common whitefish will most likely be less common in the shore area north of Hanhikivi, which is a traditional whitefish fishing area.

A suitable increase in temperature may advance the spawning season of fish and speed up the development of spawn and the growth at the fry and mature stages, which may have positive impacts on the stocks of spring-spawning fish. Earlier spawning has been found among the Baltic herring and perch in cooling water discharge areas in Sweden (*Neuman & Andersson 1990*). Evidence of earlier spawning of the Baltic herring has been found off the Olkiluoto power plant in the Bothnian Sea (*Vahteri 2000*). At the Olkiluoto power plant in the 1990s, the growth speed of the perch was found to be slightly improved in the cooling water discharge area compared to the surrounding sea area (*Oy Vesi-Hydro Ab 1995*), but, in 2006, differences in the growth of the perch were small in different areas and improved growth could not be found in the discharge area (*Ramboll Finland Oy 2007*).

The impacts of increased temperature on different fish stocks will vary. Taking into account the size of the water area which will warm up significantly, and the mobility of fish and their ability to actively seek suitable temperatures, cooling waters are not estimated to cause significant or extensive damage to the fish stocks in the Hanhikivi headland area. On the other hand, the increase in the temperature and its consequences will, over the long term, favor spring-spawning fish species such as pike, perch, carp bream and roach.

Fishing

Fishing is currently carried out in the sea area off Hanhikivi using both fyke nets and gillnets. In summer, the slight eutrophication of the sea area accelerates the growth of algae, causing slime build-up and increased cleaning needs, and reduced fishing efficiency. Fishing is becomes practically impossible in the fyke net locations north from Hanhikivi. The harm caused to fishing by cooling waters is assumed to remain limited in open water period to an area north of Hanhikivi within a distance of about 2 km, and to the Kultalanlahti bay. Depending on wind and current conditions, the adverse impact on fishing may extend to a distance of a few kilometers from Hanhikivi, and to any direction. Whitefish will probably appear less frequently in the shore areas north of Hanhikivi, which are important traditional whitefish fishing areas.

The most concrete impact of cooling waters on fishing will occur in winter when unfrozen areas and thin ice will restrict ice fishing to the north and east from Hanhikivi. According to the simulation *(Lauri 2013)*, the calculated open water area is 2.4–4.5 km^2 during the thick ice season and larger when ice is generally thinner. The open sea area extends to a distance of 2–5 km from the discharge site in February and the beginning of March, and the thin ice area 0.5–2 km further. When the direction of sea currents changes, the unfrozen area may shift between west, north and east. In winter, gillnet fishing off Hanhikivi is rather rare. As the possibilities for ice fishing are reduced, the possibilities for longer-term open sea fishing and winter fishing in the open sea will improve. The unfrozen area will attract cold water species, such as whitefish and trout.

In summer, salmonidae that favor cold water will avoid the area clearly affected by cooling waters, and spring-spawning fish species and those that prefer warm water will dominate. This may cause fishing distances to become somewhat longer in summer, particularly with regard to whitefish. Cooling waters and their resulting impacts will not affect the quality of fish.

Seals cause significant harm to fishing off Hanhikivi. The project will not have an impact on the reproduction of seals because no seal reproduction areas are located within the cooling water impact area. The project is also not estimated to have an impact on the seal stock or the appearance of seals in the area.

Fish drifted into the power plant along cooling water

The location of the cooling water intake has great significance on the number of fish drifted along the cooling water. The number of small fish, in particular, is greater close to the shore than in deep sea areas. In the two Olkiluoto plant units, cooling waters carry in 1.5–7 tons of fish per year (*Teollisuuden Voima Oy 2006*). In Neste Oil Corporation's Porvoo refinery, where water intake is 30 m^3/s, 39–56 tons of fish are carried in each year (*Neste Oil Corporation 2006*).

At Hanhikivi, most of the fish to be taken in with cooling water would probably be spring-spawning fish such as Baltic herring, roach, perch and ruffe. The highest numbers of fish would be taken in during the spawning season in spring and early summer. When the distribution of the fish stocks is taken into consideration, it can be estimated that fewer fish will be drifted in than in southern Finland. The access of fish to the power plant can be reduced by installing barrier nets in front of the intake channel during the spawning season in spring or using various repellents.

The volume of fish drifted into the plant is not estimated to have a significant impact on the fish stocks in the sea area as a whole.

7.4.4.4 Radioactive emissions into the water

Table 7-4 shows a preliminary estimate of maximum annual emissions of radioactive substances into the water system from the nuclear power plant during operation. The estimate is based on the preliminary plant data for the AES-2006 nuclear power plant type. The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits. Fennovoima has set the target of limiting all emissions to the level of the nuclear power plants currently operating in Finland. Emissions can be influenced by the design of the power plant and through various measures during operation.

The strict emission limits and monitoring of the emissions from nuclear power plants keep the radioactive emissions of modern nuclear power plants very low. The impact of radiation on the environment remains extremely low when compared to the impact of radioactive substances normally existing in the nature. For example, the tritium emissions into the water from operating Finnish nuclear power plants have been about 10 per cent and other emissions well below one per cent of the set emission limits (see Section 3.16.2). Tritium emissions into the water system from nuclear power plants are small and are diluted to a very small level when dispersing in the immediate vicinity of the plant.

The sea water samples taken from the nuclear power plant areas have annually contained tritium originating from power plants, but other radioactive substances originating from power plant emissions have been rare. Similarly, fish have only rarely been observed to contain even small signs of local emissions. The observed content of radioactive substances originating from nuclear power plants and fallout has been smaller than the natural radioactive content in the observed areas. The tritium content found in the sea water is mainly natural, as tritium is continuously generated in the upper atmosphere under the impact of cosmic radiation. Minor quantities of tritium originating from nuclear weapon testing also exists in nature. *(STUK 2013r)* Tritium is only harmful when ingested. Tritium is not as detrimental to health as many other radioactive substances. *(STUK 2013s)* The plant's radioactive emissions into the water system will not have any adverse impact on the environment or people.

The amounts of radioactive emissions have a direct impact on the radiation dose accumulated by the most exposed person in the environment. The behavior and impact of radioactive substances are controlled by their biological, chemical and physical characteristics, such as half-life. *(STUK 2013r & 2013t)* The contents of radioactive substances originating from Finnish nuclear power plants have been higher in marine environments than on land. They have, however, usually been considerably lower than the cesium contents originating from the Chernobyl fallout. Radioactive substances discharged into the water system enter food chains or sink to the bottom. Monitoring performed in the sea areas of the operating Finnish nuclear power plants has revealed radioactive substances in algae and other aquatic plants, benthic fauna and sedimenting materials.

7.5 Soil, bedrock, and groundwater

7.5.1 Present state

The ground level in the Hanhikivi area varies from 0 to +4 m above sea level. The loose soil layer is generally 0–6 meters deep, 8–12 meters in depressions. The loose soil layer mainly consists of sand and moraine, although intermediate layers of silt or clay may also be found. In depressions, the top layer may be peat. The loose soil layer is mostly thin and discontinuous. (*Pitkäranta 2012*)

The bedrock in the area mainly consists of metaconglomerate approximately 1,900 million years old and with good structural load-bearing capacity. The Hanhikivi metaconglomerate area is classified as a valuable bedrock area in terms of nature and landscape conservation *(Husa et al. 2001)*. The bedrock has no major fracture zones, although smaller fractures and cracks have been found in surveys. The bedrock level varies between +5 and –10. The Hanhikivi area has fairly many patches of exposed bedrock.

Hanhikivi is located in the central part of the continental platform, on the Fennoscandian Shield, where average seismic activity is low.

The planned nuclear power plant area is not on a classified groundwater area. The nearest classified groundwater area (Kopisto, category I, ID 11625001) is located

Table 7-4. A preliminary estimate of maximum annual emissions of radioactive substances into water system from the nuclear power plant during operation. The table also shows the emission limits and the annual emissions of radioactive substances from the Loviisa and Olkiluoto nuclear power plants, average in 2008–2012.

Radioactive emissions	**Estimated emissions from 1,200 MW plant (GBq/year)**	**Loviisa 1 and 2** 2 x 496 MW (PWR)		**Olkiluoto 1 and 2** 2 x 880 MW (BWR)	
		Emission limits (GBq/year)	Actual emissions (GBq/year)	Emission limits (GBq/year)	Actual emissions (GBq/year)
Tritium	9,100	150,000	17,000	18,300	1,700
Other beta and gamma	0.065	890	0.56	296	0.22

approximately 10 km to the south-east from the power plant location.

The surface of Hanhikivi groundwater in soil is approximately 0–+1.5 m above sea level; the pressure level of the groundwater in bedrock has been found to be below the level of the groundwater in soil (*Pitkäranta 2012*).

The calculated volume of soil and bedrock groundwater in the Hanhikivi area (a surface area of 350 hectares) is 1,000 m^3 per day. According to surveys, the quality of the soil and bedrock groundwater does not meet all the requirements or recommendations set out for potable water stipulated by the Ministry of Social Affairs and Health (Stm 461/2000). Some of the holiday residences located in the Hanhikivi headland have soil groundwater wells. (*Pitkäranta 2012.*)

7.5.2 Assessment methods

The impacts on the soil, bedrock and groundwater in the power plant area have been assessed based on soil, bedrock and groundwater studies, as well as the area required by the plant and related structures, the scope of the underground sections, plant operations, and planned construction work.

The report includes information on groundwater areas located near the plant area. Potential risks targeted at the groundwater and the impacts of exceptional situations are presented in section 7.13.

7.5.3 Construction phase impacts

7.5.3.1 Impacts on soil and bedrock

Potential measures of the plant and infrastructure construction phase that may have impacts on the soil include excavation, dumping of soil and other masses, and the strengthening of the ground. Excavation will be carried out at places, mostly to remove materials unsuited for construction such as peat and clay, which will often be replaced by suitable materials brought in from other areas. The removed materials may be dumped to designated areas, used for landscaping, or transported away. The ground is strengthened to make it better suited for construction by adding binding agents such as lime to the soil.

The impact on bedrock during construction mainly consists of excavation. Excavation can be either open-cast or underground. On the ground surface, excavation mainly aims at evening out the bedrock to a certain level to allow construction on top of it, or detaching rock material to be used elsewhere. Underground excavation is necessary, for example, when building tunnels or other facilities into the bedrock. Both types of excavation are usually carried out by blasting. Sealing and strengthening of the bedrock typically takes place during or after the excavation of underground tunnels and facilities. Sealing usually take places by injecting cement-based grout into cracks in the bedrock. Strengthening is usually made by shotcrete or bolts.

Excavation blasts cause vibration that may occasionally have impacts on the buildings, holiday residences or wildlife in the area. The harm caused by the vibration may be reduced by planning of the excavation and appropriate working methods.

The most significant impact on the bedrock is the fact that the excavation takes place in the Hanhikivi conglomerate area that differs geologically from the rest of the region, which decreases the geological value of the area. As indicated in the report sections of the area's land use plans, representative parts of the bedrock will be left exposed.

Accidents or damage that occur during construction may result in hazardous substances contaminating soil or bedrock. The impacts of accidents on soil and bedrock are described in section 7.13.

7.5.3.2 Impacts on groundwater

The impacts on groundwater can be divided to the impacts on the volume and the impacts on the quality of the groundwater. The impacts on the volume of groundwater refer to the slowing down of the formation of groundwater or a decrease in the yield of a groundwater formation, both of which are significant for groundwater use. Changes in the volume of the groundwater also refer to lowering of the surface or pressure level of the groundwater. The impacts on the quality of the groundwater refer to changes in the chemical, physical or biological composition or state of the groundwater.

The most significant construction phase impact on the groundwater will probably concern the volume of the groundwater. Structures placed below the groundwater level are usually preferred to be carried out as dry work, which requires lowering the groundwater level during construction. As a result, the groundwater surface or pressure level around the target under construction is likely to fall during the construction phase. The impact can be limited to the area under construction by sealing the area from its environment by a watertight structure such as support wall, or by ground sealing measures such as soil grouting.

The surface or pressure level of bedrock groundwater is also likely to fall near the facilities excavated into the bedrock. This is caused by the fact that the groundwater is able to flow into the excavated space from the cracks where it is usually found in the bedrock. The lowering of the bedrock groundwater level can be limited by rock sealing measures such as preliminary grouting carried out before excavation. More grouting can be performed after the excavation when necessary to ensure water tightness. The impacts are estimated to remain local, as the surface or pressure level of the groundwater is only affected near the excavation sites.

Changes in the quality of the groundwater may take place if explosives used in bedrock blasting do not explode and dissolve into groundwater. This may increase the groundwater's nitrogen compound content. In addition, the cement-based grout may increase the pH value of the bedrock groundwater.

The impacts listed above are likely to remain local, only extending to the immediate vicinity of the excavation or grouting site. The impacts on bedrock groundwater mainly show as changes in the quality of the groundwater, as the volume and flow rate of the water in the cracks of the bedrock are usually considerably lower than the volume and flow rate of the groundwater within the soil. Therefore, dilution such as in soil groundwater cannot occur in the bedrock. The impacts can be reduced by choosing an explosive that is not easily dissolved in water, and by appropriate planning and performance of the excavation work.

Changes in the groundwater's flow direction may lead to changes in the quality of the groundwater. This may happen for example when the level of the groundwater is lowered during the construction of structures below sea level. Sea water may then be mixed with the groundwater, which will change the chemical composition of the groundwater. Restricting the lowering of the groundwater surface or pressure level to the construction site as described above also prevents the changing of the groundwater flow direction that could allow the mixing of sea water with the groundwater. These measures thus prevent changes in the quality of the groundwater.

Changes in the quality of the groundwater may result from accidents or damage that occur during construction. Potential risks targeted at the groundwater and the impacts of exceptional situations are presented in section 7.13.

To summarize, it can be stated that the impact of the project's construction phase on groundwater is local and mostly limited to the construction phase. Considering the necessary prevention and mitigation methods, the impacts are estimated to remain minor.

7.5.4 Operation phase impacts

Normal operation of the nuclear power plant will not have any significant impact on the soil or bedrock. The risk of soil contamination will be eliminated by appropriate technical means, such as drainage arrangements for leakages and wastewater. The impacts of accidents on soil and bedrock are described in section 7.13. The impacts of operating waste and spent nuclear fuel on soil, bedrock and groundwater are described in section 7.11.

The formation of groundwater will decrease as a result of watertight surfaces and the draining of rainwater. On the other hand, even now no such formation of groundwater occurs in the soil and bedrock of the Hanhikivi area that would give the area any importance as a source of groundwater. Decrease in the formation of groundwater does not therefore constitute any significant threat to the water supply of the area.

The decrease in the formation of groundwater, together with methods such as subsurface draining to keep structures dry below the prevailing groundwater surface level, may lower the groundwater surface or pressure level. Decrease in the formation of groundwater causes the groundwater level to fall in a wide area, while the drying of structures mostly only lowers the level at one location centered around those structures. When necessary, the lowering of the groundwater level caused by the drying of structures can be prevented by raising the foundation of the structures, which also raises the level on which drying takes place. Another alternative is to make the structures watertight below the groundwater surface level, which may completely remove the need for actual drying systems.

If roads or underground pipe or cable lines are built so that structural layers are placed below the prevailing groundwater surface level, the structural layers may function as underground drains that gather groundwater. In such cases, the groundwater level may fall around these structures. This underground drains effect can, when necessary, be prevented by adding transverse clay stoppers to break any continuous structural layers. This will prevent the flow of groundwater in the structural layers.

Lowering of groundwater surface or pressure level may have harmful impacts such as an increased risk of subsiding of ground-supported structures or buildings built on areas susceptible to subsidence.

In addition, lowered groundwater level may lead to changes in the groundwater's direction of flow in such a manner that sea water is able to mix with the groundwater, which will alter the chemical composition of groundwater. The groundwater's suitability to be used as potable water is then weakened further. The Hanhikivi area does not, however, have significance for the water supply of any community, which means that this impact is not significant.

The concrete structures that come into contact with the groundwater in the soil or bedrock may increase the pH value of the groundwater. The impact is limited to the immediate vicinity of the structures.

Possible changes in the chemical quality of the groundwater do not have any harmful impacts if the possible impacts of the sea water, such as its corrosion properties, are considered in the engineering and material selections of the buildings and structures placed in the area.

The risk of contamination of the soil and the groundwater will be prevented by appropriate technical means. Underground external structures will be cast from waterproof concrete. Waste water from the plant area's non-controlled premises (no radiation control) is conducted through a floor drain system to the plant area's sewer system and from there to the waste water treatment plant. Waste water is conducted through oil separators if oil may have had access to the water. Chemicals are stored in containers intended for each chemical type and labeled appropriately. In the event of leaks, all premises that contain chemical tanks or storage facilities are drained to shielding pools, sludge and oil separation wells and the neutralization pool. Fuel oils and chemicals are stored in containers placed into shielding pools. Storage and handling of fuel oil and chemicals makes use of tight protective structures and sewer protection so that in the eventuality of a malfunction, chemicals released into the shielding pool or floor can be collected. Oil separators are equipped with automatic alarms, and the separators are emptied regularly. Rain and foundation water as well as any other water that ends up on surfaces in the area are collected in a controlled manner and led away so that they will not cause a contamination risk to groundwater or soil. Waste water from the controlled area (radiation controlled premises) is pumped to a liquid waste treatment system located in the nuclear power plant area.

The impacts of accidents on the groundwater are described in section 7.13.2.

The impacts of the project on the soil, bedrock and groundwater during operation are estimated to remain local and relatively minor, taking into account the required prevention and mitigation measures.

7.6 Flora, fauna, and conservation areas

7.6.1 Present state, flora

The Hanhikivi area belongs to the western part of the central boreal zone of Ostrobothnia and Kainuu. The zone is among the most typical of the northern taiga with dry heath forests and plenty of marshland. The special characteristics of the Hanhikivi natural environment include its location on the shores of the Bothnian Bay where land uplift has great significance. Wet meadows and slowly paludificating shallow bays typical of the area have formed as a result of land uplift (*Pöyry Energy Oy 2009b*). The forests on shores with land uplift change as land uplift proceeds, creating succession areas that are in various stages of development.

There are extensive shore meadows in the eastern and northern parts of the headland. Low-growing rushes, grass and sedge dominate these meadows (PrRnNi). Species include slim-stem reed grass (*Calamagrostis stricta*), creeping bentgrass (*Agrostis stolonifera*), marsh pea (*Lathyrus palustris*), tufted loosestrife (*Lysimachia thyrsiflora*), *Valeriana sambucifolia*, sea arrowgrass (*Triglochin maritima*), cowbane (*Cicuta virosa*), *Carex mackenziei*, chaffy sedge (*Carex paleacea*) and marsh lousewort (*Pedicularis palustris*). In places, the meadows are reed, spike-rush and rush meadows dominated by reed thickets, sea club rush (*Bolboschoenus maritimus*) and common spike-rush (*Eleocharis palustris*) (RkRnNi). In places, the meadows close to the shoreline also have Siberian primrose (*Primula nutans*) and adders-tongue fern (*Ophioglossum vulgatum*). The shore meadows on the western shores of the Hanhikivi headland are relatively narrow and soon give way to bushes and seashore forests. Yellow iris (*Iris pseudacorus*) is found among typical shore vegetation. There are low-growing shore meadows and higher growths of common reed around the Hietakarinlahti bay located in the central part of the headland. The Hietalahti bay has a public beach that is partly overgrowing. There are rocks on shore on both sides of the headland. (*Pöyry Energy Oy 2009a*.)

On the mainland side, the seashore meadows are limited by tea-leaved willow bushes which gradually grow denser and are replaced by deciduous forests. There are groves dominated by meadowsweet in the area. The dominating tree species in these areas is the grey alder (FiT). The bush layer has tea-leaved willow, red currant and raspberry. The field layer has meadowsweet, tufted hair-grass, elder-leaved valerian, marsh cinquefoil and woodland angelica. There is also some grey alder and downy birch groves with wood millet, woodland angelica, chickweed wintergreen, red campion and stone bramble (MiT). Some shore forests are dominated by Lapland cornel and grasses, with downy birch as the prevailing tree species. (*Pöyry Energy Oy 2009a*.)

Towards the inner parts of the headland, the succession of flora continues to spruce and mixed forest and further to pine-dominated sub-xeric heath forests (EVT). Rocky and stony areas covered by reindeer lichen are also found in places. Some of the forests have the characteristics of a hardwood swamp. The forests are mainly managed forests at various stages of succession. Ditches have been made in many places, particularly in the eastern parts of the headland. (*Pöyry Energy Oy 2009a*.)

Endangered and protected flora are presented in section 7.6.4.5.

7.6.2 Present state, avifauna

Information on the bird species that nest in the Hanhikivi headland was updated for an area of 320 hectares, considered important for the nuclear power plant project, in summer 2013 (*Sito Oy 2013a*). Previous surveys of the avifauna in the headland had been carried out in 2008 and 2009 (*Pöyry Environment Oy 2008 and Fennovoima Oy 2009*). Earlier observations have also been collected from the area (*Tuohimaa 2009*). Based on the studies, Hanhikivi has a wide range of nesting bird species due to its varied habitats. The wetlands with the most abundant avifauna are found on the north shore in Takaranta, in central parts of the headland at Hietakarinlahti, and on the south shore in Heinikarinlampi, Parhalahti and Syölätinlahti. Varied species are also found in the forests in the inner parts of the headland.

Of the species that nest in sea and shore areas, the most abundant include black-headed gull, goldeneye, teal, Eurasian wigeon, mallard, graylag, coot, and horned grebe (*Fennovoima Oy 2009b*). Other species which regularly nest in the area but are less numerous include garganey, little gull, spotted crake, hobby, marsh harrier, northern harrier, red-necked phalarope, and Temminck's stint. The most common wader species are curlew and common redshank. Most of the seagulls and terns of the Hanhikivi area nest on the islets off Takaranta. The number of nesting black-headed gull pairs typically exceeds 200. Several dozen pairs of mew gull, Arctic tern, common tern and little gull have also usually been found. Plenty of graylag and dabbler ducks nest in the Hietakarinlahti bay. Hietakarinlahti has the most extensive reed bed of the Hanhikivi headland. Species regularly nesting in the reed bed include marsh harrier, Eurasian bittern, and water rail. The species that nest in the Heinikarinlampi pond include dabbler ducks and whooper swan, coot, and horned grebe. The waders in both ponds include wood sandpiper and common greenshank. Many seagull species also visit the ponds to feed. The spotted crake has been found to nest in Heinikarinlampi nearly every year. A wide range of waterfowl nest in the Parhalahti and Syölätinlahti bays on the south side of the Hanhikivi headland. The most abundant of these include teal, graylag and red-breasted merganser. Waders such as northern lapwing, curlew, and ruff are found in great abundance in the meadow between the bays.

Based on the 2013 nesting study, the western and northern parts of the headland have varied bird stocks, but the south-eastern parts have less variety (*Sito Oy 2013a*). The species that nest in forests are typical to the Bothnian Bay coast, but some noteworthy species are included as well. The proportion of deciduous forests is large compared to the total land area, which makes species such as hazel grouse and lesser spotted woodpecker common. Of game fowl, both hazel grouse and black grouse are common in the area.

Willow ptarmigan has been known to nest in the headland, but no certainty of this could be achieved in 2009. One brood was found in 2013. Owls and birds of prey were also found in the central parts of the headland. The total number of nesting species was 65. Endangered and noteworthy bird species are presented in section 7.6.4.5.

Spring and fall migration has been monitored in the Hanhikivi area in 2009 (*Luoma 2009a and 2009b*). Based on the monitoring, many large species such as cormorants, swans, geese and curlews migrate over Parhalahti and Hanhikivi. The number of migrating birds observed was very high for Finland, and the routes are exceptionally dense. Plenty of waterfowl and waders in particular rest in the area during migration. The most important resting locations include the shallow shore waters, muddy shores and the extensive open shore meadows. Takaranta, Parhalahti and Syölätinlahti are resting and feeding areas of particular importance (*Tuohimaa 2009*). Hanhikivi has regional importance as a resting and feeding place for migrating birds.

7.6.3 Present state, other fauna

The fauna in the Hanhikivi area includes forest species of varying habitats, such as moose, mountain hare and squirrel. Roe-deer have also been observed in the area. Endangered fauna and the species listed in Annex IV(a) of the Habitats Directive are described in section 7.6.4.5.

7.6.4 Present state, nature conservation areas

7.6.4.1 Natura 2000 areas

The Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area

The Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area (FI1104201) is located in the municipality of Pyhäjoki, less than two kilometers to the south from the power plant area (Figure 7-26 and Table 7-5). The area is a 275-hectare entity of nature typical of the land-uplift coast, divided in two parts. The Parhalahti-Syölätinlahti part is stony, low land-uplift seashore (*Pohjois-Pohjanmaan ELY-keskus 2013a*). Between the bays, there is the Maunus seashore meadow that is a traditional landscape of regional importance. The vegetation in the meadow mainly consists of grasses and rushes. There are also Mackenzie sedge, common spike rush and common mare's-tail populations as well as common club-rush and reed beds. The area is protected based on both the Habitats Directive and the Birds Directive (SCI and SPA).

The area is included into the Waterfowl Habitats Conservation Program (LVO110253) under the same name. Most

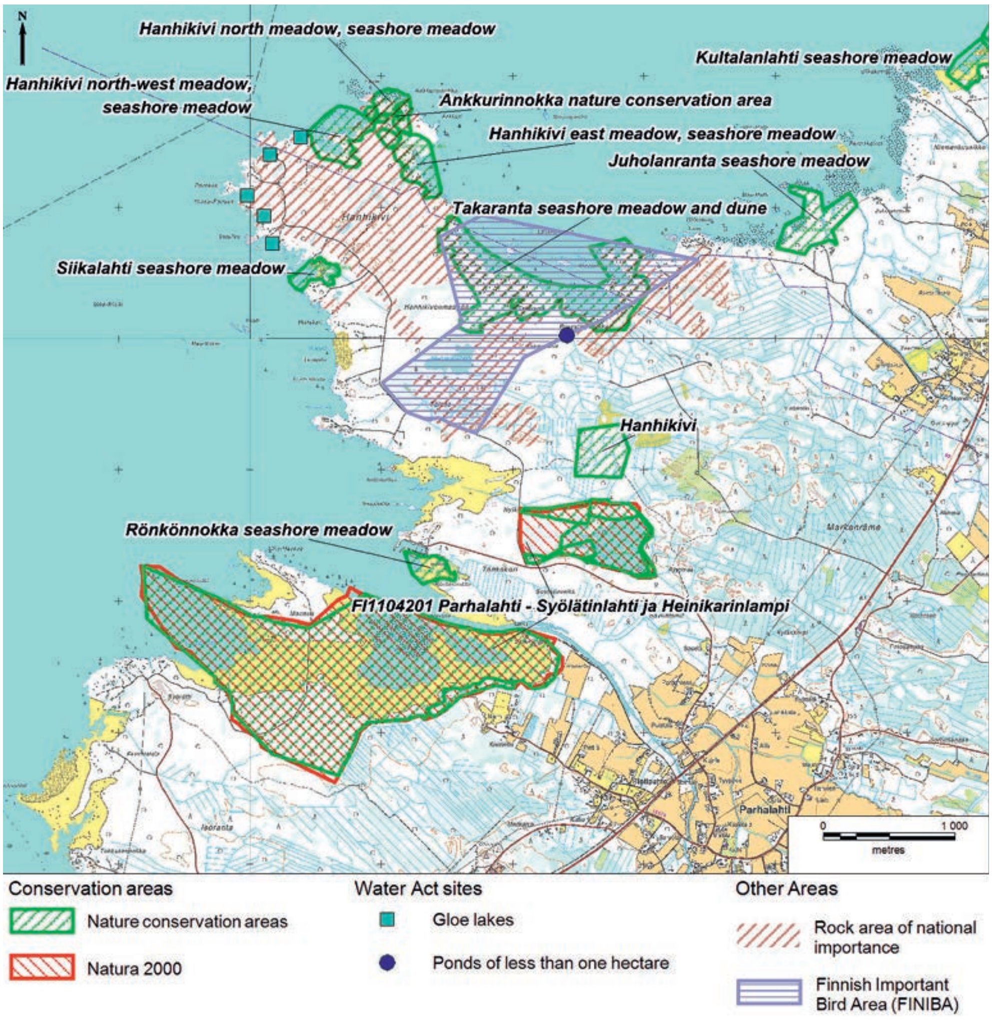


Figure 7-26. Natura 2000 areas and nature conservation areas in the Hanhikivi headland and its surrounding area.

Table 7-5. Protected areas in the Hanhikivi headland and its surrounding area, and the basis on which these areas are protected.

Name	ID	ha	Grounds for protection
Ankkurinnokka nature conservation area	YSA200525	4.6	Preservation of natural forests that remain in their natural state in the land uplift coast
Hanhimaa nature conservation area	YSA200962	4.3	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Niemi nature conservation area	YSA201654	4.6	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Ojala nature conservation area	YSA201440	2.6	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Parhalahti-Syölätinlahti and Heinikarin-lampi nature conservation area	YSA202820	243.5	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Parhaniemi nature conservation area	YSA201439	0.2	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Pikkukallio nature conservation area	YSA201321	1.1	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Puistola nature conservation area	YSA201435	1.3	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Rantala pine swamp	YSA206454	5.0	Implementation of the Natura 2000 network and the Finnish Waterfowl Habitats Conservation Program
Hanhikivi east meadow	LTA202061	10.8	Habitat type protected under the Nature Conservation Act: seashore meadow. Low-growing, typical, in a natural state, distinctive zones.
Hanhikivi north meadow	LTA202062	3.6	Habitat type protected under the Nature Conservation Act: seashore meadow. Low-growing, typical, in a natural state, open.
Hanhikivi north-west meadow	LTA202060	14.1	Habitat type protected under the Nature Conservation Act: seashore meadow. Low-growing, typical, in a natural state.
Siikalahti seashore meadow	LTA202063	5.0	Habitat type protected under the Nature Conservation Act: seashore meadow. Low-growing meadow.
Takaranta seashore meadow and dune	LTA110013	60.9	Habitat type protected under the Nature Conservation Act: seashore meadow. Open, unchanged, low-growing, varied and representative, with endangered species.
Rönkönnokka seashore meadow	LTA203185	5.6	Habitat type protected under the Nature Conservation Act: seashore meadow
Juholanranta seashore meadow	LTA110005	15.7	Habitat type protected under the Nature Conservation Act: seashore meadow

of the area is protected as the *Parhalahti-Syölätinlahti and Heinikarinlampi* nature conservation area (YSA202820). The area also includes the nature conservation areas of *Niemi* (YSA201321), *Hanhimaa* (YSA200962), *Ojala* (YSA201440) and *Pikkukallio* (YSA201321), and the pine swamp of *Rantala* (YSA206454).

Other Natura 2000 areas

The next Natura 2000 areas are the Rajalahti-Perilahti (FI1104202) and Rytilampi and Arkkukari (FI1104605), located more than ten kilometers from the nuclear power plant area.

7.6.4.2 Other nature conservation areas and protected habitat types

In addition to the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area, there is the *Ankkurinnokka* nature conservation area (YSA200525) (Figure 7-26 and Table 7-5) that consists of four parts in the northern tip of the Hanhikivi headland.

In the Hanhikivi headland area, there are several seashore meadows, a habitat type listed as protected in Section 29 of the Nature Conservation Act: *Hanhikivi east meadow* (LTA202061), *Hanhikivi north-west meadow* (LTA202060), *Hanhikivi north meadow* (LTA202062), *Siikalahti* (LTA202063) and *Takaranta* (LTA110013). On the southern side of the Hanhikivi headland, there is the *Rönkönnokka seashore meadow* (LTA203185), and on the eastern side the *Juholanranta seashore meadow* (LTA110005) (Figure 7-26 and Table 7-5). Any areas that are in their natural state or in a state comparable to their natural state and that belong to protected habitat types must not be changed so that the preservation of the habitat type's typical characteristics is endangered. This restriction enters into force when the Centre for Economic Development, Transport and the Environment has issued a decision on the boundaries of the area that belongs to a protected habitat type.

The Niemi area also has an area protected as a habitat of a species under strict protection.

7.6.4.3 Other areas of importance

Hanhikivi is classified as a rocky area of national importance for nature and landscape conservation (KAO110016) (*Husa et al. 2001*) (Figure 7-26). On a seven-step scale, its importance is defined as 4 (valuable rocky area). Rocky areas classified into category 1 are the most valuable for nature and landscape conservation. The geological value of the Hanhikivi headland has been assessed as very significant, the landscape value as significant and biological value as less significant. Another rocky area of national importance, Halkokari (KAO110015), is located on the east side of the Hanhikivi headland. It is also classified into category 4.

In the inventory of the North Ostrobothnia traditional landscapes, Takaranta, the Juholanranta meadow and the Maunus seashore meadows have been estimated to have regional value (*Vainio & Kekäläinen 1997*). The two first have their own boundary-marked areas as habitat types protected under the Nature Conservation Act, and the third is located in the Parhalahti-Syölätinlahti and Heinikarinlampi nature conservation area (Figure 7-26).

The Hietakarinlahti-Takaranta area (171 ha) in the eastern part of the Hanhikivi headland is one of Finland's important FINIBA avifauna area (*Leivo et al. 2002*) (Figure 7-26). The area has been selected based on the occurrence of swan, which is particularly abundant in the area during migration. The most significant sites for birds in the FINIBA area include the Hietakarinlahti bay and the reed beds surrounding it, a seashore meadow to the north of Hietakarinlahti bay, and the Takaranta area.

In addition to the areas mentioned above, the Hanhikivi headland has two areas included in the Forest Biodiversity Program for Southern Finland (METSO). In 2005–2006, the Hanhikivi area was included in the experimental "From Sea to Forest" project of the Forest Biodiversity Program for Southern Finland (METSO). The experimental project aimed at gathering information on the state and natural values of succession forests, and voluntary preservation of diversity in the included areas. During the program, 150 hectares of land was protected in the Hanhikivi headland under natural values trading agreements, environmental support agreements and through purchases of land by the state *(Ruokanen 2007).*

According to a vegetation study (*Pöyry Energy Oy 2009a*), the small shore meadows located at the tip of the headland would also be potential seashore meadows, which is a habitat type protected under Section 29 of the Nature Conservation Act. The gloe lakes of the north-eastern shore, the flada located in the north-east meadow and the Rovastinperukka pond can be considered water habitats protected under the Water Act (Chapter 2, Section 11). Changing habitat types protected under the Water Act is prohibited without an exemption from the protection measures. Potential habitats of special importance as referred to in Section 10 of the Forest Act include the Hietakarinlahti coastal flood meadows and the immediate environment of the small pond in Rovastinperukka (*Pöyry Energy Oy 2009a*). The forest management of these areas must always be carried out so that the natural values of the area are preserved. It is recommended that these areas be taken into consideration in land use planning.

7.6.4.4 Endangered habitat types

In the assessment of the conservation status of habitat types (*Raunio et al. 2008*), many of the habitat types found in the Hanhikivi area were defined as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT) in southern Finland. Endangered habitat types have no legal status or conservation obligation, but representative areas should always be taken into account. Habitat types found in the Hanhikivi headland have been defined and their frequency and representativeness assessed in connection with the vegetation studies (*Pöyry Energy Oy 2009a).* (Figure 7-27 and Table 7-6.)

The natural forest succession series of the land uplift coast habitat type, assessed as critically endangered (CR), covers the main part of the Hanhikivi headland. On a regional scale, Hanhikivi is likely to be among the top ten seashore natural forest succession areas (*Pöyry Energy Oy 2009b*). Of the endangered habitat types included in the forest succession series, the representativeness of coastal deciduous-dominated herb-rich heath forests (VU) is good, although some of them are sapling stands. Coastal spruce-dominated herb-rich heath forests (EN) and spruce-dominated xeric heath forests (EN) are found in very small areas in the central part of the headland. Coastal spruce-dominated mesic heath forests (EN) are found in the central part of the headland, but they are mainly sapling stands. Most of the surface area is classified into the coastal herb-rich birch and bird cherry forests (NT). The primary succession series are fragmented by ditches made at the base of the headland, and the partial commercial use of the forests in central parts of the headland. There are no old forests, the final forest type of primary succession, in the area.

The seashore meadow habitat type, assessed as critically endangered (CR), is focused on the north and east shores of the Hanhikivi headland. Coves in the process of being separated from the sea, called fladas (VU) are found at the bottom of the Siikalahti and Lipinlahti bays and in the northern parts of the headland. Gloe lakes (EN) found in the shores of Hanhikivi are small and located in the western and northern parts of the headland. Some of the gloe lakes meet the description of the habitat type well, but others are nearly paludified and dried out. The occasionally brackish-water-inflected lakes and ponds habitat type (VU) includes the Hietakarinlahti bay, Heinikarinlahti pond, Rovastinperukka and two small ponds in the western part of the headland. There are only a few minor coastal sand beaches (EN) and fixed

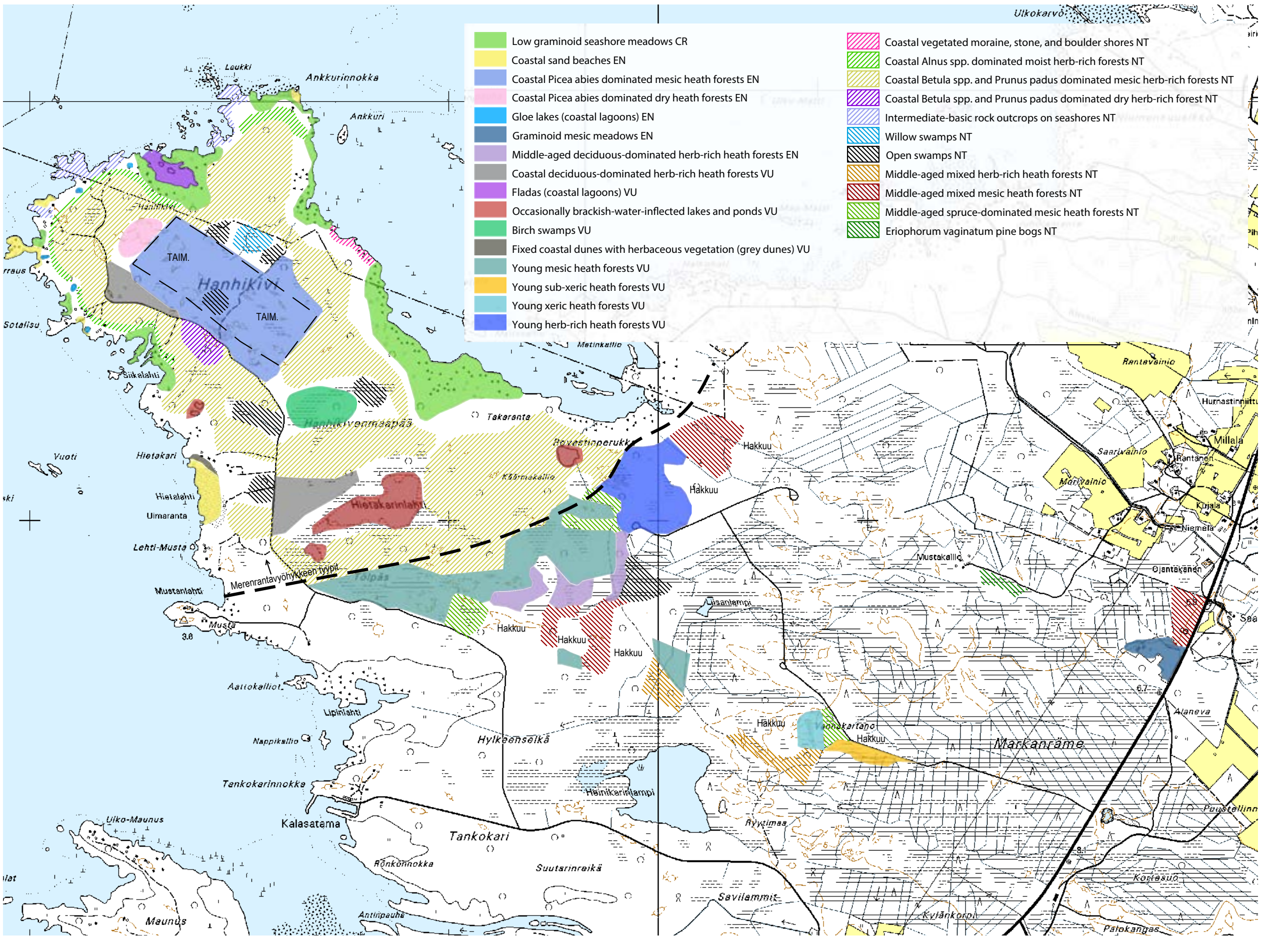


Figure 7-27. Endangered habitat types in the Hanhikivi headland. The habitat type of natural forest succession series of the land uplift coast is not indicated in the map, as it covers the main part of the headland. *(Pöyry Energy Oy 2009a)*

coastal dunes with herbaceous vegetation (grey dunes, VU) in the Hanhikivi headland. The largest beach is the Hietalahti public beach, but it is nearly completely paludified.

7.6.4.5 Endangered and protected species and species listed in Annex IV of the Habitats Directive

Endangered and protected flora

Five endangered or protected vascular plants have been found in the Hanhikivi area *(Pöyry Energy Oy 2009a; Sito Oy 2012; Uhanalaisrekisteriote 4/2012)* (Figure 7-28 and Table 7-7). Three of these, Siberian primrose (*Primula nutans*), *Artemisia campestris* ssp. *bottnica* and fourleaf mare's-tail (*Hippuris tetraphylla*), are listed in Annex IV(b) of the Habitats Directive. The destruction and deterioration prohibition issued in Section 49 of the Nature Conservation Act applies to the flora listed in Annex IV(b).

The Siberian primrose classified as vulnerable (VU) appears in many places in the Hanhikivi headland. The species is found in the Takaranta seashore meadow, the Ankkurinnokka nature conservation area, the Lipinlahti bay, and the surroundings of the Parhalahti bay. Most of the sightings are from the east shore of the headland. The most extensive stands are found in the Lipinlahti seashore meadow (*Pöyry Energy Oy 2009a*). The occurrence of the species in the area reserved for the road south from Takaranta was surveyed in 2013, and the species was not found in that area (*Sito Oy 2013*).

The occurrence of Artemisia campestris classified as critically endangered (CR) seems to have disappeared, and the species was not found in the vegetation study of 2008. In the 2009 study, only hybrids between the common mare's tail and the fourleaf mare's tail were found at the habitats of the fourleaf mare's-tail, classified as endangered (EN), on the east shore of the headland. Of the species classified as near threatened (NT), Fries' pondweed (*Potamogeton friesii*) has been found in the Rovastinperukka pond, and leathery grapefern (*Botrychium multifidum*) on the sands of the Hietalahti beach. Leathery grapefern was not found in the studies of 2008 and 2009.

The yellow iris (*Iris pseudacorus*), protected in North Ostrobothnia, is found on the west shore of the Hanhikivi headland. The yellow iris has been classified as least concern (LC) in North Ostrobothnia. A total of 20 stands were found in 2011 and 2012 (*Sito Oy 2012*). Most of these are located between the Siikalahti bay and the Sotalisu cape.

Table 7-6. Endangered habitat types and their representativeness. *(Pöyry Energy Oy 2009a)*

Habitat	Status (whole of Finland)	Occurrence in the studied area	Representativeness
Coastal vegetated moraine, stone, and boulder shores	NT	Small area on the eastern shore of the Hanhikivi headland.	Few, good.
Coastal sand beaches	EN	Hietalahti (a public beach). Sotalisu. Porraus.	The Hietalahti public beach is overgrowing. Others small areas, good.
Fixed coastal dunes with herbaceous vegetation (grey dunes)	VU	Eastern end of Takaranta. Hietalahti. Sotalisu. Porraus.	Small, significant.
Coastal Alnus spp. dominated moist herb-rich forests	NT	Here and there towards the center of the head-land due to the land uplift coast succession.	Few, good.
Coastal Betula spp. and Prunus padus dominated mesic herb-rich forests	NT	In the middle of the headland and close to the shores; often right after willow zone.	Excellent.
Coastal Betula spp. and Prunus padus dominated dry herb-rich forest	NT	In the middle of the headland.	Small, good.
Coastal deciduous-dominated herb-rich heath forests	VU	In the middle of the headland close to Hietakarinlahti bay.	Good, partly seedling stands.
Coastal Picea abies dominated herb-rich heath forests	EN	In the middle of the headland.	Very small, good.
Coastal Picea abies dominated mesic heath forests	EN	In the middle of the headland.	Mostly seedling stands. A few older trees as well. Good.
Coastal Picea abies dominated dry heath forests	EN	In the middle of the headland.	Fairly small, good.
Natural forest succession series of the land uplift coast	CR	Entire Hanhikivi headland.	Excellent.
Fladas (coastal lagoons)	VU	Bottoms of Siikalahti and Lipinlahti bays. A cove close to the Hanhikivi north-east meadow.	Excellent.
Gloe lakes (coastal lagoons)	EN	Small ponds to the west of the headland.	Good, small. Some completely overgrown.
Occasionally brackish-water-in-flected lakes and ponds	VU	Hietakarinlahti. Heinikarinlampi. Rovastinpe-rukka. Liisanlampi. In addition, some smaller gloe lakes to the west of the Hanhikivi headland.	Good.
Spike-rush, glaucous, and sea club-rush seashore meadows	DD	Here and there in the eastern and northern parts of the headland. Takaranta. Siikalahti. Hietakarinlahti.	A narrow zone in between the shore and the water's edge. Excellent.
Low graminoid seashore meadows	CR	More extensive seashore meadows in the eastern and northern part of the Hanhikivi headland. Takaranta. Siikalahti. Hanhikivi north-west meadow. Hanhikivi east meadow. Hanhikivi north meadow. Hietakarinlahti.	Excellent.
Tall sedge seashore meadows	CR	Ankkurinokka. Porraus.	Small. Excellent.
Intermediate-basic rock outcrops on seashores	NT	Rocky shores of the Hanhikivi headland. Mostly the north shores of the Hanhikivi headland.	Good.
Birch swamps	VU	Hanhikivenmaapää.	Small, good.
Willow swamps	NT	In the middle of the Hanhikivi headland.	Small, good.
Open swamps	NT	Here and there in the middle of the Hanhikivi headland.	Small, good.
Eriophorum vaginatum pine bogs	NT	Along the new road line.	Small, good.
Graminoid mesic meadows	EN	Along main road 8, along the new road line.	Unkempt, poor.
Young herb-rich heath forests	VU	Close to Rovastinperukka.	In forestry use, poor representativeness.
Young mesic heath forests	VU	Along the power line route and new road line area.	In forestry use, poor representativeness.
Young sub-xeric heath forests	VU	Along the power line route and new road line area.	In forestry use, poor representativeness.

Habitat	Status (whole of Finland)	Occurrence in the studied area	Representativeness
Young xeric heath forests	VU	Along the power line route.	In forestry use, poor representativeness.
Middle-aged mixed herb-rich heath forests	NT	Along the power line route and new road line area.	In forestry use, poor representativeness.
Middle-aged deciduous-dominated herb-rich heath forests	EN	Along the new road line.	In forestry use, poor representativeness.
Middle-aged mixed mesic heath forests	NT	Along the power line route and new road line area.	In forestry use, poor representativeness.
Middle-aged spruce-dominated mesic heath forests	NT	Along the power line route and new road line area.	In forestry use, poor representativeness.

Endangered and important bird species
In the 2013 nesting survey (*Sito Oy 2013*) of the Hanhikivi nuclear power plant construction area, two endangered bird species were found: northern pintail and northern wheatear, both classified as vulnerable (VU). The following species classified as near threatened (NT) were found: red-breasted merganser, goosander, willow ptarmigan, black grouse, spotted crake, common redshank, common sandpiper, Eurasian wryneck, wood warbler and common rosefinch. Seven species listed in Annex I of the Birds Directive (hazel grouse, black grouse, great gray owl, spotted crake, crane, common tern, and black woodpecker) were observed, together with eight species for which Finland has special responsibility (goldeneye, red-breasted merganser, goosander, black grouse, curlew, common sandpiper, common tern, and common redstart). The bird species listed in Annex I of the Birds Directive are protected by the Natura network. Other endangered and near threatened bird species have also been observed in the headland and the shores and waters around it (*Fennovoima Oy 2008 & 2009; Tuohimaa 2009*). In addition, a bird species included in species under strict protection nests in the headland further away from the construction areas. The destruction or deterioration of site important for the preservation of a species under strict protection is prohibited after the site has been boundary-marked by a decision of the Centre for Economic Development, Transport and the Environment.

Animal species listed in Annex IV(a) of the Habitats Directive

Moor frog
The occurrence of the moor frog (*Rana arvalis*) in the area of the planned nuclear power plant was studied in 2010 (*Pöyry Finland Oy 2010*) and 2011 (*Sito Oy 2011*). In the 2011 study, which focused on the area north from Hietakari, moor frogs were found at five places (Figure 7-28). These places were small wetlands of the gloe lake type, where the sound of a few male moor frogs (from 1 to 5) were heard. Based on studies, the Hanhikivi headland probably has several spawning sites of the moor frog. Larger water bodies such as the Heinikarinlampi pond, where moor frogs were found in abundance in spring 2011, are likely to be the most important spawning sites. Land uplift slowly transforms the wetlands in the central part of the headland less suitable for the species, and new suitable habitats form on the shores. The destruction and deterioration of breeding sites or resting places used by moor frogs, listed in Annex IV(a) of the Habitats Directive, is prohibited under Section 49 the Nature Conservation Act.

Bats
A study of bats was carried out in the Hanhikivi area in 2012 (*Suomen Luontotieto Oy 2012*). Based on fourteen nights of detector monitoring and a search of wintering and nesting places, the bat population in the area can be considered sparse. All the bat observations made in the area of the planned nuclear power plant were of the northern bat (*Eptesicus nilssonii*), which was found in the shore areas as single individuals and pairs. No colonies of bats were found in the headland, and there are not many trees with suitable holes in them, which bats such as Daubenton's bat (*Myotis daubentonii*) may use. Bats are likely to nest in the buildings of the Parhalahti fish port on the south side of the headland.

Siberian flying squirrel
No Siberian flying squirrels (*Pteromys volans*) have been found in the Hanhikivi area (*Fennovoima Oy 2008*). Small patches of spruce-dominated mixed forests suited for the Siberian flying squirrel were found in 2008 and 2009 in the inner parts and the tip of the headland. No signs of the Siberian flying squirrel were found. The closest observation of the species has been made approximately seven kilometers from the Hanhikivi headland.

7.6.5 Assessment methods

The assessment of environmental impacts includes the description of the present state of the natural environment and an assessment of the impacts that the implementation of the project will have on flora, fauna, habitat types and objects with importance for the preservation of nature, as well as on biodiversity and interaction on a wider scale. The assessment takes into account the direct and indirect impacts of the nuclear power plant during both construction and operation. The impact assessment was carried out on the basis of surveys of the scope and scale of the impacts, prepared during the EIA procedure. The impact

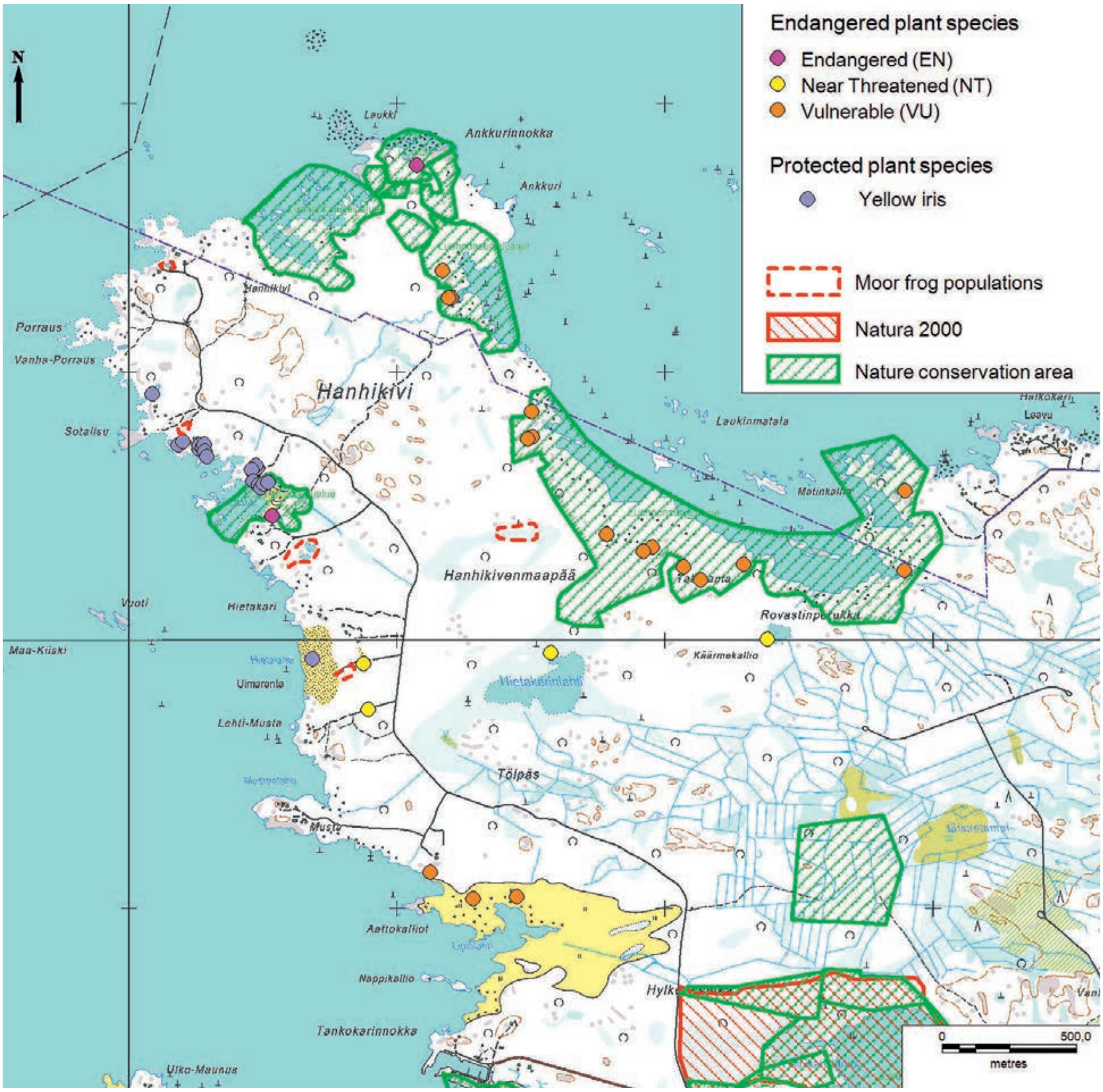


Figure 7-28. Habitats of endangered fauna and moor frog in the Hanhikivi headland.

assessments carried out in earlier stages of the project have also been utilized as appropriate. Land use in the area has been assumed to follow the ratified partial master plans and local detailed plans.

The following reports, carried out for the project, were available for the description of the present state and the assessment of impacts:

Vegetation reports:

- Vegetation and habitat type studies in Hanhikivi, Pyhäjoki, in 2008–2009 (*Pöyry Energy Oy 2009a*)
- Assessment of the Hanhikivi area's significance as a primary succession forest area (*Pöyry Energy Oy 2009b*)
- Study of the yellow iris in the harbor and discharge area 2012 (*Sito Oy 2012*)
- Study of the Siberian primrose in the planned road area 2013 (*Sito Oy 2013b*)

Bird reports:

- Summary of observations of birds in the Hanhikivi headland by five bird-watchers in 1996–2009 (*Tuohimaa 2009*)
- Study of birds nesting in the Hanhikivi headland in 2008 (*Pöyry Environment Oy 2008*)
- Study of birds nesting in the Hanhikivi headland in 2009 (reported in the application for a Decision-in-Principle DD-01-P10-014, *Fennovoima Oy 2009*)
- Study of birds nesting in the Hanhikivi headland in 2013 (*Sito Oy 2013a*)
- Monitoring of white-tailed eagle in Hanhikivi, Pyhäjoki in 2011 and 2012 (*Sito Oy 2011 and Suomen Luontotieto Oy 2012*)
- Monitoring of the spring migration in Hanhikivi, Pyhäjoki, and a study of the present state of the Natura areas in spring 2009 (*Luoma 2009a*)
- Monitoring of the fall migration in Hanhikivi, Pyhäjoki in 2009 (*Luoma 2009b*)

Table 7-7. Endangered vascular plants found in the Hanhikivi headland.
CR = Critically Endangered, EN = Endangered, NT = Near Threatened, RE = Regionally Extinct, RT = Regionally Threatened, Prot. = protected Str. = species under strict protectionDir. = species listed in Annex IV of the Habitats DirectiveResp. = Finland's special responsibility species.

Species	Endang.	Prot.	Str.	Dir.	Resp.	Observed	Number of occurrences and viability
Artemisia campestris ssp. bottnica Field wormwood	CR, RE	X	X	X	X	Disappeared	
Botrychium multifidum Leathery grapefern	NT, RT				X	1999, (possibly disappeared)	1 occurrence, no exact data, not found in 2008/2009
Hippuris tetraphylla fourleaf mare's-tail	EN	X		X	X	2002, 2006	3 occurrences, only hybrids found in 2009
Iris pseudacorus yellow iris		X				2008, 2009, 2012	20 occurrences, good viability, small areas
Potamogeton friesii Fries' pondweed	NT					1994, (possibly disappeared)	1 occurrence no exact data, not found in 2009
Primula nutans var. jokelae Siberian primrose	VU	X		X	X	2003-2009	12 occurrences (2009), possible overlapping between records of occurrences in different years, mainly good vitality, size of occurrences varies (from a few to thousands)

Reports of other fauna:

- Study of the moor frog in Hanhikivi, Pyhäjoki in 2010 (*Pöyry Finland Oy 2010*)
- Monitoring of the moor frog in Hanhikivi, Pyhäjoki in 2011 (*Sito Oy 2011*)
- Study of bats in Hanhikivi, Pyhäjoki in 2012 (*Suomen Luontotieto Oy 2012*).

Other sources of information include the Finnish Environmental Institute's information of endangered species (April 2, 2012) and the environmental information of the OIVA environmental and geographical information service (2013).

The assessment of the impacts on species and the natural environment was carried out in accordance with the Finnish Environmental Institute's guides "Luontoselvitykset ja luontovaikutusten arviointi kaavoituksessa, YVA-menettelyssä ja Natura-arvioinnissa" (*Söderman 2003*) and "Direktiivilajien huomioon ottaminen suunnittelussa" (*Sierla et al. 2004*). The project's impact on the conservation status of species (*Rassi et al. 2010*) and habitat types (*Raunio et al. 2008*) was also considered. The assessment of the significance of the impacts was based on an examination of each object's special characteristics and the habitat requirements of the species. Assessment of the impact on the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area (*Pöyry Environment Oy 2009*) was updated to correspond to the properties of the new plant option.

7.6.6 Construction phase impacts

The direct impacts of the project during the construction phase affect the area in which the buildings and structures of the nuclear power plant and various related functions are built. The main part of the construction effort will take place in an area of 1 km² in the central part of the Hanhikivi headland. A new road connection to the plant area will also be built in the inner parts of the headland. The shore area will have a dock basin with breakwaters, and the cooling water intake and discharge structures. Other parts of the shores will remain unbuilt. The construction work will transform the current forest environment into a built power plant area. The current flora, fauna and habitat types will be permanently removed from the area that will be covered by buildings, dredging masses deposit areas, roads, gravel and asphalt yards and lawns.

During the construction phase, indirect impacts of the noise and dust from the construction site and the related traffic, and the vibration from blasts and excavation, will affect the surrounding nature. According to a noise simulation, the noise during construction will vary but the reference values set for nature conservation areas may be exceeded in the immediate environment of the power plant construction site and the road that leads to it if no protection measures are performed (section 7.9).

According to the groundwater impact assessment, the construction of underground bedrock facilities may lower the surface level of bedrock groundwater in the immediate environment *(Pitkäranta 2012).* The project will have no such groundwater impact that would affect the water balance of the shore areas and nature conservation areas. According to the water system impact assessment, the construction of the harbor and the cooling water intake and discharge structures will cause temporary turbidity that extends 10–100 meters from the dredging site and marine spoil area (section

7.4). Hardly any fine-grained or organic sediment has been found in the areas to be dredged. The impact of the finest matter found in the area will probably be the strongest in the water layer near the seabed, where turbidity may spread to a maximum distance of two kilometers. The dredging is not expected to cause any releases of nutrients or contaminants into the sea. The solids load from the water drained from the construction site and the volume of nitrogen compounds originating from explosives are estimated to remain low. It is unlikely that the impact of the dumping of dredging waste into the marine spoil area will reach the shores.

As a result of the construction, the species and habitat types found in the immediate environment of the built areas may change over the short or the long term, as edge effect become more intense and changes may take place in the microclimate and the water economy. Construction work may also result in the fragmentation of current continuous shore and forest areas, which may affect the habitats of some species and weaken the local ecological connections between areas. Changes may take longer than the actual length of the construction phase.

For a description of construction phase impacts on birds and conservation areas, see the following sections.

7.6.6.1 Impacts on Natura 2000 areas and nature conservation areas, protected habitat types and nature objects

The partial master plans and local detailed plans define the power plant construction area so that the Hanhikivi headland's nature conservation areas and areas defined as habitat types protected under the Nature Conservation Act remain outside the energy production zones (EN-1 ja EN-2). These are indicated in the land use plans as nature conservation areas (SL and SL-1), and a buffer zone is usually defined between them and the construction areas. An exception is formed by the Siikalahti seashore meadow (LTA202063) which is limited directly by the power plant area, and Takaranta (LTA110013), which is limited by a road at its south-western edge. The closest protected areas are seashore meadows, and the construction work carried out in the inner parts of the headland is not estimated to bring about significant changes to properties of the areas, such as the water economy or microclimate. The noise simulation (section 7.9) showed that noise from the construction site reaches the Siikalahti seashore meadow and the Hanhikivi north-west meadow, and that the noise from the traffic reaches a small part of the Takaranta area. Construction impacts such as noise, dust or vibration do not reach the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area.

In the construction area, there are some objects of the natural environment indicated as items of particular importance for biodiversity within the area (luo-1, luo-2 and luo-3), which will be taken into account in the planning of the layout of the area. The objects are small seashore meadows that may meet the criteria of a protected habitat type as specified in the Nature Conservation Act, and potential objects for which the Forest Act or the Water Act may apply. Parts of the meadows and one small gloe lake will be covered by the harbor structures and the cooling water intake and discharge structures to be built at the tip of the headland. This impact cannot be considered significant, as similar objects are found in a larger and more representative form in the nature conservation areas and in areas defined as protected habitat types under the Nature Conservation Act. Due to the large distance and the lack of a hydraulic connection, cooling water discharge structures are not estimated to have an impact on the water balance of the gloe lakes close to them (*Pitkäranta 2012*).

The impact on the avifauna of these areas and the FINIBA bird area have been assessed in section 7.6.6.4.

The project's impacts on rocky areas of national importance have been assessed in section 7.7.

Impacts on the Natura 2000 network have been assessed in section 7.6.7.2.

7.6.6.2 Impacts on endangered flora and the species listed in Annex IV of the Habitats Directive

The endangered Siberian primrose, classified as vulnerable (VU) and listed in Annex IV(b) of the Habitats Directive, is found in the Hanhikivi headland. The habitats of the Siberian primrose that have been previously known or found in the 2008 EIA studies are focused on the east shore of the headland and around the Parhalahti bay in the south. The habitats remain outside of the construction areas, and no direct impacts of the project affect them.

Observations have been made in the Hanhikivi area of the endangered Artemisia campestris subsp. bottnica and fourleaf mare's-tail, both listed in Annex IV(b) of the Habitats Directive, and the leathery grapefern and Fries' pondweed that are classified as near threatened (NT). Artemisia campestris subsp. bottnica, classified as critically endangered (CR), is likely to have disappeared from the area. The habitats of the fourleaf mare's tail, classified as endangered (EN), were recently only found to contain hybrids of the species. Potential habitats of the species are located outside the construction areas. The potential habitats of leathery grapefern and Fries' pondweed are also located outside the construction areas.

Yellow iris that is protected in North Ostrobothnia is found on the west shore of the Hanhikivi headland, among other places. One of the approximately 20 stands is located in the harbor area. An exemption from the protection measures as specified in the Nature Conservation Act has been applied for to allow the removal of the stand located in the harbor area. Removal of a single stand will have no adverse impact on the population as a whole. The species is easy to move, and the stand can be transferred to another location.

Two of the five habitats of the moor frog, listed in Annex IV(a) of the Habitats Directive, are located in the harbor area. An exemption of the protection of the species was applied for concerning these two habitats. The Oulu Administrative Court dismissed the complaints filed concerning the exemption on October 7, 2013. Similar small wetlands well suited for the spawning of the moor frog will remain elsewhere in the headland, and new ones are formed on the shores as a result of land uplift. The most important spawning areas of the moor frog are found outside the power plant area, and the project will have no impact on these.

7.6.6.3 Impacts on endangered habitat types

On a regional scale, the Hanhikivi area has been estimated to be among the top ten occurrences of natural forest succession series of the land uplift coast habitat type *(Pöyry Energy Oy 2009b).* The estimate is based on the primary succession forests and representative shore biotopes found in the area. The natural forest succession series of the land uplift coast has been classified as a critically endangered (CR) habitat type in the assessment of the conservation status of Finnish habitat types *(Raunio et al. 2008)*. The implementation of the power plant project will result in partial fragmentation of the succession series and affect the significance of the Hanhikivi area as an exemplary location of unbroken natural forest succession series. A significant part of the habitat type can, however, be preserved outside the areas reserved for construction.

Most of the energy management zone (EN-1) area at the tip of the headland, defined in the partial master plans and local detailed plans, is coastal Picea abies dominated mesic heath forest classified as an endangered (EN) habitat type, or coastal Betula spp. and Prunus padus dominated mesic herb-rich forest, classified as near threatened (NT) as habitat type but which is not endangered. The Picea abies dominated mesic heath forest in the inner part of the tip of the headland is the only occurrence of this habitat type in the headland, and will be completely destroyed as a result of the construction project. However, most of the forest is very young, and only part of it is representative old spruce forest. Some of the coastal Betula spp. and Prunus padus dominated mesic herb-rich forests will be lost as a result of the construction work, as this habitat type is also found in the energy management zones (EN-2) defined at the base of the headland and in its northern parts. Most of the surface area of forests in the headland are estimated to belong in this habitat type, and many parts of it will be preserved outside the construction areas. The Betula spp. and Prunus padus dominated mesic herb-rich forests that are found in connection with seashore meadows and are therefore the most important for the succession series will be preserved. Approximately half of the coastal deciduous-dominated herb-rich heath forests (VU) are located in the construction area at the tip of the headland, and half outside of it at the Hietakarinlahti shore. Construction will destroy some of the forest habitat types of small surface area. The eastern part of the EN-2 energy management zone at the base of the headland consists of young and middle-aged forests.

Of other endangered habitat types, nearly all the seashore meadows, classified as critically endangered (CR), are protected as nature conservation areas or habitat types protected under the Nature Conservation Act and boundary-marked outside the construction operations (see section 7.6.6.1). The flada (VU) in the Hanhikivi northwest meadow, the Hietakarinlahti, Heinikarinlampi and Rovastinperukka that represent the habitat type of occasionally brackish-water-inflected lakes and ponds (VU), and some of the small gloe lakes (EN) remain outside of the construction area.

7.6.6.4 Impacts on avifauna

The nuclear power plant and other construction operations related to it are mainly located in the inner parts of the Hanhikivi headland, where most of the birds are of forest species. Bird studies have shown that of the species listed in Annex I of the Birds Directive, the loss of habitats as a result of construction operations mainly concerns hazel grouse, black grouse and great horned owl. The current nesting environments of the boreal owl and Eurasian sparrowhawk will also be changed. The shore areas of the harbor and the cooling water intake and discharge areas are not particularly valuable as bird habitats, which means that their construction phase impact on birds remains minor. Seashore meadows defined as protected habitat types are found in the surroundings of the nuclear power plant. These meadows have a diverse avifauna, but they are not the most important nesting areas of the headland, and birds do not use them as resting or gathering areas during migration. According to the noise simulation (section 7.9), the noise level in the Siikalahti seashore meadow and Hanhikivi north-west meadow, which are closest to the power plant construction site, will be approximately 50–53 dB(A) during the noisiest phase of the construction project.

The new road leading to the power plant will run through the Hietakarinlahti–Takaranta FINIBA area at its most narrow point. Of the important bird areas, the Hietakarinlahti bay will remain on the south side and the Takaranta seashore meadow on the north side of the connection road. The 45 dB(A) noise zone created by daytime traffic in the busiest phase of the construction project will extend to the distance of slightly under 250 meters from the road on both sides of the road. The noise level will be lower in the night time.

Increase of background noise may cause stress to birds and disturb their sound-based communication and search of food. For example, the pair formation of the western capercaillie and the birds of the herb-rich heath forest, as well as the food hunting of owls, may be difficult in the noisy area. The noise zones at the construction site and near the road are relatively small, and the impact of noise on nesting or bird populations is not likely to be significant. Loud noises during construction may also drive birds away, but the impact will be brief and temporary. The noise level will vary greatly between the phases of the construction project. Birds may get used to continuous noise such as the sound of the traffic.

7.6.7 Operation phase impacts

During the operation of the power plant, emissions and traffic can cause environmental impacts. Discharge of the power plant's cooling water into the sea will increase the temperature of the sea water within a few kilometers of the discharge location, and will keep the water area in front of the tip of the headland unfrozen during the winter. According to a simulation, average temperature increase of more than two degrees Celsius is limited to approximately 2–3 kilometers from the cooling water discharge location (*Lauri 2013*). Under typical south-west winds, the thermal emission gathers in a bay on the north side of the Hanhikivi headland, off the Takaranta shore. Warming up of the sea water and the lack of ice may lead to local increase of primary production and the paludufication of seashore meadows, among other things. According to the noise simulation, noise will be lower during the operation phase than during the construction phase, and it will be limited to the immediate environment of the power plant, harbor and road (section 7.9). Traffic during operation will create noise but also some dust and minor emissions into the atmosphere. Amounts of radioactive emissions during the operation, and the radiation doses accumulating from these, will be so low that they are not estimated to have an adverse impact on nature.

7.6.7.1 Impacts on nature conservation areas, protected and endangered habitat types and nature objects

Through the thermal effect of the cooling water, the project may have an indirect impact on the seashore meadows found at the tip of the headland and on the north shore. According to the cooling water simulation, the average sea water temperature increases more than two degrees Celsius in front of the Hanhikivi north-west meadow (LTA202060), Hanhikivi north meadow (LTA202062), Hanhikivi east meadow (LTA202061) and Takaranta (LTA110013), all defined as protected habitat types under the Nature Conservation Act. Low vegetation typical of the habitat type grows on gently sloping sand, silt and clay lands and is maintained by the variation in the sea water level, waves and ice (*Raunio et al. 2008*). Areas of this habitat type continuously move lower as a result of land uplift. The increased primary production and the lack or decrease of the forming and clearing impact of ice on the shores may increase the growth of reed beds and bushes in these seashore meadows. If the meadows will be paludified, the surface area of the habitat type, classified as critically endangered (CR), will decrease, and the conservation value of the meadows will be affected.

7.6.7.2 Impacts on the Natura 2000 network

Background

An assessment on the need for a Natura assessment concerning the impact of the planned Hanhikivi nuclear power plant on the nearest Natura 2000 areas was carried out as a part of the 2008 EIA procedure (*Pöyry Energy Oy 2008b*). In its statement on the EIA report (7131/815/2008), the Ministry of Employment and the Economy that acts as the coordinating authority, proposed that the party responsible for the project consider conducting a Natura assessment. A Natura assessment as referred to in Section 65 of the Nature Conservation Act was conducted on the impact of the construction of the nuclear power plant and the related power lines, as well as the changes to the regional land use plan, on the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area (*Pöyry Environment Oy 2009*). The conclusion of the Natura assessment was that when considered as a single project or together with other projects, the project is not likely to cause any major adverse impacts on the habitat types of bird species based on which the Natura 2000 area has been established, or on the Natura 2000 area as a whole.

In its statement given to the Council of Oulu Region on December 17, 2009, the North Ostrobothnia Regional Environment Centre (currently the North Ostrobothnia Centre for Economic Development, Transport and the Environment) considered the assessment adequate. The North Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre) further clarified the conclusion in its statement on February 1, 2010, stating that the project seemed to have no direct impacts that would significantly deteriorate the habitat types and species mentioned. The ELY Centre also stated that the long-term risks described in the statement are such that no evidence of them or any significant deteriorating impacts of them can be found in the studies carried out in connection with the Natura assessment, but that the risks still cannot be completely ruled out over the long term based on the conducted studies. The statement paid particular attention to the fact that the reduction of natural primary succession forest area in the Hanhikivi headland and the change of the Takaranta seashore meadows as a result of the discharge of cooling water will emphasize the significance of similar habitat types included in the Natura 2000 area, increase the pressure for change that they are under and intensify even more the changes that occur in them. The impacts may show in the Siberian primrose population and be reflected in the avifauna over long term.

Changes in the project information

The 2009 Natura assessment (*Pöyry Environment Oy 2009*) was carried out for a 1,500–2,500 MW nuclear power plant, while the power output of the power plant currently under review is approximately 1,200 MW. The central buildings and structures and the surface area required by them, as well as the plant location, have remained the same. The cooling water volume required by the power plant will be reduced from the earlier estimate of 60–85 m^3/s to 40–45 m^3/s.

Impact of the project changes on the Natura 2000 area

In the 2009 Natura assessment (*Pöyry Environment Oy 2009*), impacts were assessed based on land use that follows the drafts of partial master plans. There are no significant differences between these and the final land use plans. The harbor location indicated at the Sotalisu cape in the partial master plan is moved slightly to the north. The minimum distance between the energy management zones indicated in the partial master plans and the Heinikarinlampi is 400 meters. The distance to the Natura 2000 area from the border of the area reserved for the construction of the nuclear power plant is approximately 1.7 kilometers. The distance of the Parhalahti and Syölätinlahti water areas is 3.7 kilometers from the cooling water discharge site and 1.9 kilometers from the auxiliary intake channel. Locations of the project-related construction activities has not changed in any manner that would result in differences in the conservation criteria of the Natura 2000 area compared to the 2009 Natura assessment.

When compared to the 2009 Natura assessment (*Pöyry Environment Oy 2009*), changes in the project are limited to the volume of cooling water, which in turn change the impact that the cooling water will have on the sea. Compared to a plant with a higher power output, the heating impact of the cooling water covers a somewhat smaller water area in the project currently under review. Average temperature increase of more than two degrees Celsius is limited to approximately 2–3 kilometers from the cooling water discharge location (*Lauri 2013*). Under typical southwest winds, the cooling water is mixed with a current that flows along the coast, and is carried to north and east. The direction of the flow is away from the Natura 2000 area. Under north winds, cooling water is carried to the southwest in the direction of the Natura 2000 area, but upwelling will cool it faster. In some temporary circumstances, cooling water may be carried longer distances than in average circumstances.

According to the Natura assessment (*Pöyry Environment Oy 2009*), the heating impact of the cooling water could only reach the Parhalahti-Syölätinlahti area under atypical and rare wind conditions. Even then, the thermal impact would be brief and minor in the Natura 2000 area. For vegetation, such an impact is not different from natural temperature variations resulting from the shallowness of the waters and the weather conditions, particularly the upwelling caused by winds at the open coast. The cooling water will have no impact on the ice conditions in or around the Natura 2000 area. During construction, the turbidity caused by dredging and dumping of the masses will reach the distance of 100 meters from the dredging site or marine spoil area, and will thus not reach the Natura 2000 area. Hardly any fine-grained or organic sediment has been found in the areas to be dredged. The impact of the finest matter found in the area will probably be the strongest in the water layer near the seabed, where turbidity may spread to a maximum distance of two kilometers and will thus not reach the Natura 2000 area.

Conclusions

The 2009 Natura 2000 assessment (*Pöyry Environment Oy 2009*) found the project to have no significant deteriorating impacts on the habitat types described in the Habitats Directive or the species listed in Annex II of the Habitats Directive, based on which the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area has been established. The project was also not estimated to cause any such significant harm to the nesting or migrating stock of any bird species that would risk the successful conservation of the species or deteriorate the species' possibilities to use the Natura 2000 area in its current manner. The decrease of forest areas in the Hanhikivi headland and the potential change of seashore meadows may emphasize the significance of these habitat types in the Natura 2000 area, as was stated by the North Ostrobothnia ELY Centre in its statement on the Natura assessment. For the seashore meadows, the impact can be mitigated by monitoring their state and conducting management measures to retain their typical characteristics.

In the project currently under review, the impact of the discharged cooling water reaches a somewhat smaller area than in the project that was under review in 2008. The environmental impact of the construction and use of the power lines will be assessed in a separate EIA procedure. Other impacts of the project remain unchanged. Thus, the impacts and their significance are the same as in 2009, and somewhat smaller concerning the cooling water. The conclusion of the Natura assessment remains unchanged, and there is no need to conduct a Natura assessment as referred to Section 65 of the Nature Conservation Act for the project.

7.6.7.3 Impacts on endangered species and the species listed in Annex IV of the Habitats Directive

The thermal impact of the nuclear power plant's discharged cooling water may have an indirect impact on the habitats of the Siberian primrose and the potential habitats of the fourleaf mare's tail. An increase of temperature may cause the paludification of open seashore meadows and shores, and the deterioration or disappearance of habitats suitable for the species. The fourleaf mare's tail is also sensitive to increased nutrient loads in the water. According to the assessment of the water system impacts, the power plant's waste water load does not cause detectable or detrimental changes in eutrophication levels or impacts on vegetation even when the temperature increase in the discharge area, caused by warm cooling water, is considered. During the construction phase, only minor release of nutrients due to dredging and blasting will occur.

7.6.7.4 Impacts on avifauna

During plant operation, there will be an unfrozen area of a few square kilometers in front of the Hanhikivi headland in winter. The unfrozen area can be used by migrating waterfowl, for example, as a resting and feeding area. Some of the migrating birds may stay in the unfrozen area longer than usual, or return earlier in the spring. The transfer of the edge of the ice further away from the shore may move the early spring migration of seagulls to outer sea. This is not, however, estimated to have a significant impact on the migration behavior of seagulls. Species that feed on fish, such as common tern and Arctic tern, may have better feeding opportunities, and waterfowl and birds that nest on the shore may begin their nesting period earlier. However, the timing of the nesting season will also depend on other environmental conditions.

The power plant and other buildings will be massive and easy to notice, and they are not estimated to cause any risk of collision to flying birds. Collision of birds into buildings is usually caused by large reflecting window surfaces *(Koistinen 2004)*, and the nuclear power plant buildings will have no such surfaces. The collision risk caused to birds by the power lines is assessed within a separate EIA procedure.

According to the noise simulation (section 7.9), noise will be relatively low during plant operation. The maximum noise level at the Siikalahti seashore meadow and the Hanhikivi north-west meadow will be 35–40 dB(A). The maximum noise level around the road between the Hietakarinlahti and the Takaranta seashore meadow, caused by traffic during operation, will be approximately 45 dB. The noise will not be estimated to cause any significant harm to birds during plant operation.

7.7 Landscape and cultural environment

7.7.1 Present state

The coastal zone in the Pyhäjoki region is very even with alternating natural landscape sections and small-scale built areas. The area has no archipelago zone. The Hanhikivi headland is mainly in its natural state, although felling and ditches have altered the landscape to a certain degree. The terrain is very even and low-lying. With the exception of a few small hills, the height the headland and surrounding areas is less than 2.5 meters above sea level. *(Pohjois-Pohjanmaan liitto 2005, Ympäristöhallinnon Oiva-tietokanta 2013, Maanmittauslaitos 2013)*

The Hanhikivi headland and its immediate environment is for the most part in its natural state, characterized by vegetation typical of land-uplift coast. The natural forest succession series of the land uplift coast covers most of the Hanhikivi headland, but there are no oldest stages of the series, old forests. Land uplift also characterizes the landscape in other respects: the shores of the headland have lagoons, called gloe lakes, clearly separated from the shoreline. These gloe lakes only have a connection with the sea during high water, when storm winds blow from the south or west. There is also a flada, or a cove in the process of being separated from the sea, in the area.

In addition to the aspects of the natural environment described above, there are some holiday residences, seashore meadows, a boat harbor and a beach on the shores of Hanhikivi. The north-east shore is unbuilt and has extensive shallows. The nearest permanent settlement, the Parhalahti village, is located approximately five kilometers to the southeast from the tip of the headland. Construction in the area of the village is confined to an open valley used for cultivation, the open landscape of which faces towards the northwest and the Hanhikivi headland. In addition to natural landscape sections, the coastal zone of the Hanhikivi headland environment has holiday residences and meadows.

With the exception of sea views from the shores, the views in the Hanhikivi headland area are mainly limited due to the dense vegetation. Open views within the headland and towards the power plant area could extend via suitably oriented open bog or swamp areas, direct road routes and open shore areas. From outside the area, open, unrestricted views towards the Hanhikivi headland extend in every direction from the sea, because there are no islands to cut off the view. The headlands and shores in the surrounding area also have open views towards Hanhikivi headland stretching into the open sea.

7.7.1.1 Valuable objects

The inventory published by the Finnish Environmental Institute classifies the Hanhikivi area (the Hanhikivi and Halkokari rock areas) as a valuable bedrock area in terms of natural and landscape conservation, with high geological importance *(Oiva-paikkatietopalvelu 2012, Hanhikivi regional land use plan for nuclear power)*. The symbol of the Hanhikivi headland has been removed from the valid Hanhikivi regional land use plan for nuclear power plant, as the planned nuclear power plant structures will be located in central parts of the bedrock area, largely removing the natural and landscape values based on which the classification was made. In the report section of the land use plan, it is recommended that the rock area be surveyed before construction, and that the survey is then used to leave representative parts of the rock uncovered. Similar mention of a survey is also made in the report sections of the local master plan and local detailed plan. The other landscape bedrock area in the planning area (Halkokari) will be left outside the power plant area, and its plan symbol has not been changed.

There is a border stone, Hanhikivi, originating from the era of written history, in the Hanhikivi headland. The stone is a fixed historical monument protected by the Antiquities Act (295/63) and an object of national value *(Museovirasto 2013a)*. Such class 1 historical monuments must be preserved under all circumstances. The stone is located in the immediate vicinity of the plant area on its north side, on the borderline between the Raahe and Pyhäjoki municipalities. The stone is indicated with the symbol sm, meaning a fixed historical monument protected by the Antiquities Act, in the local detailed plan (Kuva 7-5). The stone is well known in the area, and marked as a tourist attraction. *(Pyhäjoki local detailed plan for the nuclear power plant area)*

The nearest built cultural environment of national significance (RKY 2009) is the Parhalahti fish dock on the south side of the headland. The Ostrobothnia coastal road's section that passes through the Parhalahti village is also a built cultural environment of national significance. *(Museovirasto 2013 b)*

There are also two heritage landscapes of regional importance in the immediate surroundings of the project area: the Takaranta landscape on the north shore of the headland, and the Maunus seashore meadows on the south side. The southern shore zone of the headland is also part of a multiple-use natural area indicated in the regional land use plan. In such areas, particular attention must be paid to the preservation of the landscape and natural values. The regional land use plan indicates the Parhalahti village as an area of regional importance for the preservation of a cultural environment or landscape, and the road that passes through the village as a road section with importance for the cultural history or landscape. *(Pohjois-Pohjanmaan ympäristökeskus 1997, Hanhikivi regional land use plan for nuclear power)*

7.7.2 Assessment methods

The project's impacts on the landscape and the cultural environment have been assessed based on existing surveys, examination of maps and aerial photographs, photographic illustrations included in the 2008 YVA, analysis of geographical information, local field surveys carried out in May 2008, and the preliminary design materials of the project.

The description of the present state of the area consisted of identification of the basic characteristics of the landscape at the power plant location and in its environment, and listing of valuable objects in the landscape and cultural environment known on the basis of the available source material. The impacts have been assessed in relation to the present state of the area.

In addition to the actual project area, the area under review includes the whole of the Hanhikivi headland, the nearest village (Parhalahti) and the surrounding shore and sea areas that have a view to the Hanhikivi headland. For other areas, the potential visual impacts of the project have been described on a general level.

7.7.3 Construction phase impacts

In addition to the actual construction site, landscape impacts during construction work will be caused by the heavy traffic generated by the transportation of large structural parts, as well as the construction of new road connections and the improvement of current roads required by such transportation operations. High cranes will be visible in the landscape from far away. Some of the buildings, outdoor areas, and traffic connections will only be implemented for the period of construction and will undergo landscaping when no longer needed.

7.7.4 Operation phase impacts

The nuclear power plant will be located on a headland clearly visible in an open sea landscape. In a larger landscape, the headland is currently an integral part of a natural environment. The plant milieu will differ significantly from its environment in terms of its size and character, thus creating a new landmark that dominates an extensive area of the landscape, changes the character and hierarchy of the landscape and affects the continuity of the natural environment. However, when viewed from the sea at a sufficient distance, the large open water surface and outline of the continental coast in the background lend support to the large structure as the smaller features disappear from view. Figure 7-29 is an illustration of the nuclear power plant seen from the beach on the west shore of the Hanhikivi headland.

From the closest permanent settlement in the area, the Parhalahti village, views towards the power plant exist due to the open farmland and other open landscape. Based on examination of maps and the information of the height of the plant structures, the plant structures will rise above the forest horizon and will be visible from the direction of the Parhalahti fields. Due to the distance (over 4 kilometers), changes in the wider landscape are unlikely to cause significant changes to the character and hierarchy of the village landscape. Views towards the power plant may extend from other places in the mainland through suitably oriented open fields, clear felling areas, roads, and open swamp areas. In forested areas, vegetation close to the observation point effectively cuts off the views.

With regard to holiday residences, the most significant changes will occur in the views that extend towards the sea from the holiday residences located on the north shores of the Maunus and Syölatti areas located on the south side of the Hanhikivi headland, and in views from certain other holiday residences for which the main direction of the view faces the plant area. Due to expectations related to holiday residences, the characteristics and types of environment in the region, as well as the size and nature of the project, the impact of the project on the sea landscape as viewed from the holiday residences will probably often be perceived as adverse. *(Weckman 2006)*

Local impacts on the landscape in the power plant construction area will be significant when the current natural forest area becomes a large-scale built environment. The landscape will also change on a larger scale: the landscape impact extending outside the actual plant area include those of the housing area and the new road from main road 8 to the power plant area, both to be built on areas that are currently in their natural state. The current buildings in the plant area will be removed from use or their purpose will be changed. The new large dock basin will alter the landscape of the shore area, but will be perceived as an integral part of the built power plant environment when completed.

The power plant's water intake structures will be located within the dock basin, and only a concrete structure resembling a pier will be visible of them. A channel structure will be built on the north shore of the Hanhikivi headland for discharge of cooling water, limited by protective banks. Due to the impact of warm water, the sea in front of the discharge site will remain open in the winter in an area of varying size. A cloud of fog may form above the unfrozen area on calm, subzero days.

In the dark, the power plant lighting will be visible in an area that is otherwise almost completely dark. The glow may be visible from afar. The significance of the plant as a new landmark in the region may be emphasized in the dark.

Since the scale of the nuclear power plant and the adjoining structures will deviate from the surrounding nature, 'hiding' the buildings or structures in the landscape will not be possible. It is possible to make the power plant more fitting for the landscape, however, by selecting the correct surface materials and colors, carefully planning where buildings will be placed and adding vegetation to the power plant area.

Local impacts can be reduced in detailed design by, for example, forming embankments at shores that are in their natural state or almost in their natural state, and adding vegetation in such a manner that they will fit into the natural shoreline of the area. This should be done if there are any recreational sites or holiday residences in the area. The lighting used on the roads to the power plant can be designed in such a manner that it will not be visible from far away (light fixtures spreading light downwards). When designing the power line routes and roads, attention should be paid to how they blend in the landscape. Valuable landscapes and objects of the cultural environment shall also be taken into account. Architectural solutions may also be used to make the power plant blend into the surrounding landscape.

7.7.4.1 Impacts on valuable objects

The construction of the power plant will have a significant impact on the immediate environment of the Hanhikivi border stone, which is a historical monument of national importance originating from the era of written history, even though the project will have no direct impact on the stone

Figure 7-29. Photographic illustration: the nuclear power plant in the Hanhikivi landscape, seen from the direction of the public beach.

itself. The historical monument is indicated in the valid Pyhäjoki local detailed plan for the nuclear power plant area, and it is located on an agricultural zone in the immediate vicinity of the energy management block area, on its north side. Passage to the stone is indicated as a preliminary road connection through the agricultural zone.

The highest structures of the power plant are likely to show at places above the trees from the Parhalahti fish dock of national value *(RKY 2009)*, from the Ostrobothnia coastal road's section that passes through the Parhalahti village, also of national value *(RKY 2009)*, and from the Parhalahti village, which has regional value. However, when considered as a whole, buildings and vegetation fairly effectively cut off the view to the power plant.

Potential visual impact is not likely to significantly affect the values of the objects due to the character and orientation of the areas, the extent of the visual impact in relation to the whole of the view, and the distance (no less than 34 kilometers). The importance of the Takaranta seashore meadow of regional value will be affected when the power plant replaces the existing low-lying natural area in the immediate vicinity (no less than one kilometer) of the meadow. Views from the Maunus shore meadow and its importance to the overall landscape will change.

Bedrock surveys and the necessary ground surveys will be carried out in the construction areas before a building permit is applied for. As indicated by the land use plans, representative parts of the bedrock are to be left exposed.

The plant will not have significant impacts on other valuable landscape or cultural environment objects in the region.

7.8 Traffic and traffic safety

7.8.1 Present state

The Hanhikivi headland is located to the west from main road 8 (E8). A pedestrian and bicycle way was constructed at the side of the main road in 2008. There is a local road, Puustellintie, leading from the Parhalahti village to the Hanhikivi headland, the fishing harbor in Tankokarinnokka, and the recreational residences located in the southwestern and western coastlines of the headland.

Road traffic to and from the Hanhikivi headland nuclear power plant area will run on main road 8 and a branch road to be constructed specifically for the nuclear power plant. The current working-day traffic volume on main road 8 at the location where the road leading to the nuclear power plant will branch off is approximately 3,700–4,100 vehicles per day. Of this volume, heavy traffic accounts for some 500 vehicles per day. The traffic volume on main road 8 north of the power plant area is approximately 3,800 vehicles per day, and south of the area, approximately 4,100 vehicles per day. On both road sections, heavy traffic accounts for some 500 vehicles per day. *(Liikennevirasto 2013)* The estimated traffic volume on main road 8 north of the Hanhikivi headland intersection in 2020–2025 is approximately 3,800 vehicles per day, and south of the intersection, approximately 4,200 vehicles per day *(Tiehallinto 2007)*.

In the plans of the Council of Oulu Region and the North Ostrobothnia Centre for Economic Development, Transport and the Environment, satisfying the need for overhaul of main road 8 now appears as one of the short-term goals for regional investments. Among the areas for development are the performance of measures required for the construction of the nuclear power plant, upgrade of bridges and main intersections, and facilitation of the flow of traffic and improvement of traffic safety. The construction of the new road leading from main road 8 to the power plant area, the Hanhikivi road, will be accompanied by the construction of the necessary pedestrian and bicycle ways and the associated arrangements. Furthermore, there have been plans for a new intersection for access to main road 8 at Hanhikivi. A pedestrian and bicycle way running along the side of main road 8 between Parhalahti and Hurnasperä is under construction. *(Pohjois-Pohjanmaan elinkeino-, liikenne- ja ympäristökeskus 2013b)*

The distance from the Hanhikivi headland to the nearest railway station, located in Raahe, is approximately 25 kilometers by road. This railway section is only used for freight traffic. The nearest passenger train station is in Oulainen, located some 50 kilometers from Hanhikivi.

The nearest harbor of importance is located in Raahe, some 25 kilometers away. The nearest export ports are located in Lapaluoto, Raahe (approximately 25 kilometers away) and in Rahja, Kalajoki (approximately 50 kilometers away). The nearest airport is in Oulu, located some 100 kilometers from Pyhäjoki. The Bothnian Bay shipping channel runs by the Hanhikivi headland at a distance of approximately 15 kilometers from the shore areas. The local boat channel runs at a distance of approximately six kilometers from the shore.

7.8.2 Assessment methods

The assessment of the traffic impacts is based on the estimates of the volumes and routes of transportation and commuter traffic relating to the construction and operation of the nuclear power plant. The road improvements and new roads planned by the Finnish Road Administration were taken into account in the assessment. Traffic impacts were assessed for both the existing roads leading to the project site and the new road to be constructed. Possible impacts on air and sea traffic were also taken into account.

The impacts on living comforts and traffic safety caused by traffic were assessed on the basis of the traffic changes. The methods used to calculate the traffic volumes and the assumptions made are presented in Section 3.15.

The emissions from transportation and their impacts on the air quality are presented in Section 7.3, and the assessment of noise impacts is described in Section 7.9.

7.8.3 Construction phase impacts

The volume of traffic on weekdays during the construction of the nuclear power plant is estimated to be approximately 4,000 private vehicles per day, with a volume of heavy traffic of approximately 100 heavy vehicles per day. On weekdays, the volume of traffic on main road 8 north of the Hanhikivi headland will increase by some 2,460 vehicles per day, and south of the Hanhikivi headland, the increase will be some 1,640 vehicles per day.

The estimated traffic volume on main road 8 north of the Hanhikivi headland intersection in 2020–2025 is approximately 3,800 vehicles per day, and south of the intersection, approximately 4,200 vehicles per day. Taking into account the traffic volume increase estimate for 2020, the volume of traffic on main road 8 north of the Hanhikivi headland will increase by approximately 64 percent. On the south side, the increase will be slightly smaller, amounting to approximately 39 percent. The volume of heavy transportation traffic will increase by 40–60 vehicles by day, which equals 10 percent or less of the volume of heavy traffic on the main road in 2020. (Kuva 7-30) The availability of a passing lane south of Raahe during the construction of the nuclear power plant would improve the smoothness of the flow of traffic in comparison to the current situation.

The traffic volumes will increase significantly in the construction phase. The traffic will be particularly active during the fourth year of construction, which is when the greatest potential adverse traffic impacts will occur. High traffic volumes may impair traffic safety. Increasing traffic volumes may add to the noise, dust, and vibration impacts in the immediate vicinity of the traffic routes.

The adverse impacts of the construction-phase traffic can be mitigated by means of control and timing of traffic. When possible, traffic can be directed to routes bypassing the major residential centers. An effort will be made to schedule heavy traffic to run between 7 a.m. and 9 p.m. on weekdays and special transportation operations potentially slowing down traffic to take place outside the peak hours of normal traffic. Bus transportation will be arranged for employees in order to reduce the volume of private car traffic.

The increase in the traffic volumes may impair traffic safety on main road 8. Traffic safety can be improved by ensuring the safety of the intersection of main road 8 and the branch road leading to the nuclear power plant and the smoothness of the flow of traffic by means such as preselection lanes and speed limits. The safety of pedestrian and bicycle traffic can be improved by means of new pedestrian and bicycle ways and the installation of traffic lights in the intersection. The new road to be constructed from the main road to the nuclear power plant will be designed to be suitable for the traffic required for the construction and operation of the power plant.

In the construction phase, a flight obstacle permit will be required for structures such as large cranes in order to restrict air traffic over the area. No restrictions will be placed on ship traffic during the construction of the power plant. Some of the inbound transportation operations taking place during the construction of the nuclear power plant may be carried out by sea. In these cases, the wharf to be constructed in the power plant site will function as the port of delivery. The number of sea transportation operations will be fairly small, and they will have no significant impacts on other water traffic.

7.8.4 Operation phase impacts

The volume of traffic during the operation of the nuclear power plant is estimated to consist of approximately 600 private vehicles and approximately 30 heavy vehicles per day. Approximately 60 percent of the total volume of traffic to and from the nuclear power plant is estimated to come from the north, and 40 percent from the south of the plant, in accordance with the distribution of population in the Raahe economical area.

The estimated traffic volume on main road 8 north of the Hanhikivi headland intersection in 2020–2025 is 3,841 vehicles per day, and south of the intersection, 4,197 vehicles per day. Taking into account the traffic volume increase estimate, the total traffic volume on the main road in the vicinity of the intersection leading to the nuclear power plant will increase by approximately 15 percent. The volume of heavy traffic will increase by approximately six percent. During the operation of the nuclear power plant, the traffic volumes on the northbound section of main road 8 will increase by some ten percent, and on the southbound section, by some six percent. (Kuva 7-31)

The traffic to and from the nuclear power plant during the operational phase will add slightly to the traffic volumes on main road 8. However, most of the increase will consist of passenger traffic to and from the power plant. The increase in the volume of heavy traffic causing the majority of the environmental impacts (such as noise, dust, and vibration) will remain minor. The impacts of the operation of the power plant on the traffic volumes in the surrounding areas can be reduced by providing the plant personnel with free bus transportation to work. Traffic safety issues must also be taken into account when planning on the location, and designing structural solutions for, new traffic connections and improvements. Such solutions include, for example, widenings, deceleration and acceleration lanes at intersections, traffic lights, and pedestrian and bicycle ways.

The increase in the traffic volumes may to some extent impair traffic safety on main road 8. Traffic safety can be improved by ensuring the safety of the intersection of main road 8 and the branch road leading to the nuclear power plant and the smoothness of the flow of traffic by means such as preselection lanes and speed limits. The safety of pedestrian and bicycle traffic can be improved by means of new pedestrian and bicycle ways and the installation of traffic lights in the intersection. The new road to be constructed from the main road to the nuclear power plant will be designed to be suitable for the traffic required for the construction and operation of the power plant.

During the outage, the volume of passenger traffic to and from the power plant area will be approximately 1,150 vehicles per day, and the volume of maintenance and goods transport traffic will be approximately 10 vehicles per day. During the outage, the traffic volumes will be higher than normal, which will increase the volume of traffic on roads leading to the nuclear power plant. As the outage will normally last 1–2 months, any related adverse impacts on traffic will only occur during this limited period. Furthermore, the outage will usually take place in the summer, when the volume of other traffic on the main routes is lower than at other times of the year.

A flight obstacle permit will be required for the nuclear power plant. A no-fly zone will be set up over the nuclear power plant and its surroundings in order to restrict air traffic over the area.

No significant restrictions will be placed on shipping during the operation of the power plant. Only small water areas in the vicinity of the power plant will be enclosed

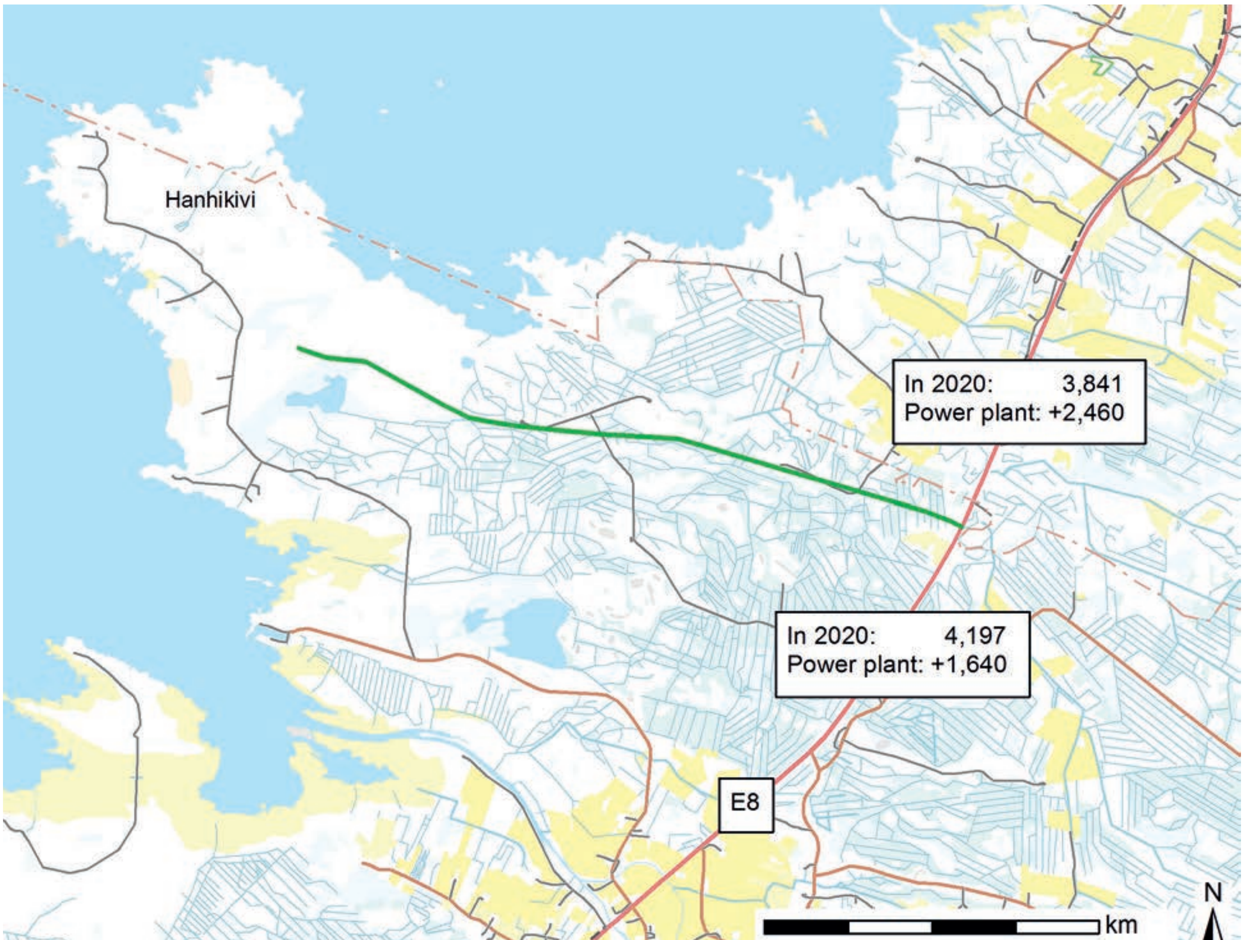


Figure 7-30. Traffic volumes in 2020 and the increase in the traffic volumes on main road 8 due to the construction of the nuclear power plant (vehicles per day) according to the Finnish Road Administration's traffic increase estimate.

within the nuclear power plant area. Movement in this area will be restricted. There will be no impact on water traffic running on waterways indicated in nautical charts.

7.9 Noise

7.9.1 Present state

No operations causing significant noise are currently taking place in the vicinity of the planned power plant location on the Hanhikivi headland. The location near the sea is rather favorable in terms of dispersion of noise. In particular, dispersion of noise along the water surface enables low-frequency noise to spread over considerable distances during calm weather.

Below is a brief presentation of general information concerning industrial noise, road traffic noise, and guideline values for noise.

7.9.1.1 Industrial noise

Industrial noise is mostly noise emanating from static noise sources, such as industrial plants. However, it is common to include all the noise caused by operations taking place in the industrial area, such as noise caused by forklift trucks and truck loaders, in the scope of industrial noise. Industrial noise often contains narrow-band sound components. In these components, the sound concentrates within a limited frequency range, and pure tones (i.e. sounds containing only one frequency) may clearly be distinguished from the noise. Transformers or fans and pumps operated at even rotation speeds and designed so that the air passing through them flows directly into the surrounding atmosphere often emit a narrow-band operating sound. In nuclear power plants, such components include transformers and ventilation-related fans. Various silencer solutions are commonly applied to decrease the sound level of air fans. In new power plants, the silencers are installed in the construction phase. Furthermore, impulse-like sounds may be heard locally during the construction of the plant. In these cases, the noise is caused by forceful impact-type events.

7.9.1.2 Road traffic noise

Factors affecting the level of noise generated by motor vehicle traffic include the speed of the vehicles, traffic volumes, the share of heavy vehicles, and the properties of the road. The

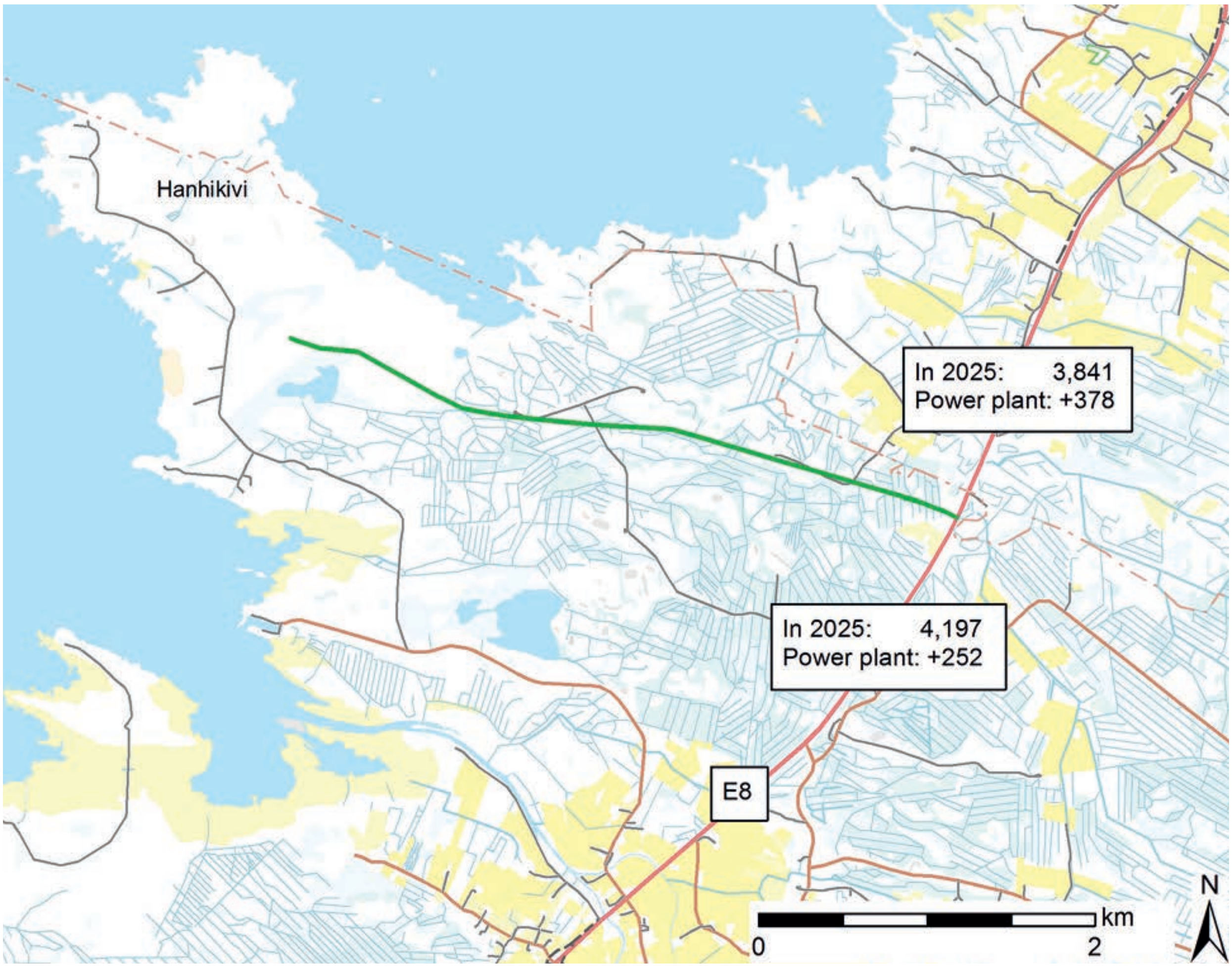


Figure 7-31. Traffic volumes in 2025 and the increase in traffic volumes due to the operation of the nuclear power plant according to the Finnish Road Administration’s traffic increase estimate.

noise generally occurs in the form of an even wide-band hum, from which the sound of individual vehicles may occasionally be distinguished. In addition to the noise output level, the factors affecting the noise level in a certain location include the distance between the location and the traffic route, buildings and other obstacles, the shape of the terrain, and water areas and other reflective surfaces. The doubling of traffic volume increases noise level by 3 dB. Correspondingly, the increase of speed level from 50 km/h to 80 km/h increases the noise level by 4–5 dB. Road traffic noise is commonly reduced by means of noise barriers and prevented through land use planning.

7.9.1.3 Guideline values for noise

The main objectives and measures of noise prevention are presented in the Environmental Protection Act and the Environmental Protection Decree, both of which entered into force on March 1, 2000. Guideline values for the A-weighted equivalent sound levels L_{Aeq} are presented in Government Decision (993/1992). The guideline for residential areas, recreational areas located within or in the immediate vicinity of populated areas, and areas accommodating care or educational institutes is that the ambient noise level may not exceed the daytime guideline value of 55 dB(A) (7 a.m. – 10 p.m.) or the night-time guideline value of 50 dB(A) (10 p.m. – 7 a.m.). In recreational residence areas and nature conservation areas, the corresponding guideline values are 45 dB(A) in the daytime and 40 dB(A) in the night time. The night-time guideline value is not applied in nature conservation areas that are not commonly used for recreational purposes or observation of nature at night.

The purpose of the guideline values for noise is to prevent the adverse impacts of noise on people. According to the explanatory memorandum for the Government Decision on the guideline values for noise *(Ympäristöministeriö 1992),* the purpose of the guideline values set for nature conservation areas is to guarantee an opportunity to enjoy the sounds of nature. Any marked access routes or paths must be taken into account when applying the guideline values in nature conservation areas. According to the explanatory memorandum, meeting the guideline values in all parts of a nature conservation area is not required *(Ympäristöministeriö 1992)*.

7.9.2 Assessment methods

In order to assess the noise impacts, the noise caused by the nuclear power plant, and the dispersion thereof, were modeled using a common Nordic industrial and road traffic noise model. The model considers the geometrical divergence loss, differences in the altitude of the terrain, buildings and other reflective surfaces, and the acoustic effects of ground surface and atmospheric noise.

The dispersion map included in the noise model calculates the average sound level contours at the interval of five decibels (dB) on the basis of the selected initial values. Water and road surfaces and the plant area were generally defined as hard ground surfaces. This, for its part, eliminated the contribution of ground attenuation to the sum of individual attenuations considered in the calculation. The dispersion of noise is calculated in accordance with the modeling algorithm. Furthermore, it is calculated conservatively, assuming that the environmental condition points are favorable for the dispersion of noise (including a light downwind from the noise source to each calculation point). The greater the distance from the noise source, the greater the effect of annual variation in weather and, in particular, the wind direction, on the actual noise level in the area will be. Thus, as the distance from the noise sources increases, the calculation uncertainty increases as well; at the distance of one kilometer, it is approximately ±3 dB.

Both estimated values and values measured from corresponding sound sources were utilized in the noise calculation to determine the initial values for the sound power levels of noise sources (overall level and spectral distribution). The sound power levels of noise sources located inside buildings were defined in terms of how much noise is carried from the inside to the outside, assuming that the wall materials have sound reduction capabilities in accordance with the properties of their component substances. As a rule, the entire wall area and roof of buildings were defined as surface sound sources. Furthermore, some of the sound sources were defined as directional sound sources. The estimation of the sound levels of fans located on roofs was based on the assumption that the fans are point sound sources. As detailed plant design or noise prevention planning has not yet been carried out, the current sound source descriptions are preliminary.

Construction-phase noise was modeled to represent the conditions during the first years of construction, when the noise levels are at their highest. At that point, the most significant noise sources will be the rock crushing plant, truck loaders, and traffic.

The noise caused during the construction of the reactor building, the turbine building, and the auxiliary buildings (offices, emergency power generators) was modeled using an area source covering the whole plant site. The overall sound power level of the noise L_{Aeq} was determined to be 107 dB(A) + 5 dB at the distance of one meter from the area source (including the impulsiveness correction). This corresponds well to the actual situation, although the sound level of the noise, and in particular, the maximum level, will be momentarily exceeded due to impact-type noise events, the occurrence of which is common during construction operations.

The rock crushing plant was modeled as an individual operation in the noise calculation. The overall sound power level of 120 dB(A) + 5 dB of rock crushing plant includes the operation of truck loaders. The sound power spectrum was estimated on the basis of available measurement results from a corresponding plant. As the sound emanating from the crushing plant will be rather loud and, due to the operation of truck loaders, occasionally impulsive in nature, rock piles higher than the plant itself have been included in the construction-phase calculation models. The purpose of the rock piles is to function as noise barriers directing the noise away from the most noise-sensitive areas.

Road traffic volumes during the construction phase and normal operation were estimated for noise calculation purposes using the method presented in Chapter 3. Vehicle speed on the road leading to the plant area was set to 60 km/h, and closer to the gate, to 20–30 km/h.

In the operational phase, the most significant sound sources at the nuclear power plant will be the transformers, the steam turbine, the generator, and the turbine hall ventilation system. While the transformers will generate a narrow-band, humming-type sound, they will generally not be very loud. For the calculation, the free-field sound level of the transformer noise source was assumed to be 80 dB(A) at the distance of one meter from the source. The narrow-band nature of the transformer sound source was taken into account in the noise model by adding +5 dB to the assumed sound power level value. The noise level of the turbine was assumed to be 85 dB(A). This assumption is based on a scenario in which the turbine is operated without separate acoustic lining inside a hall with walls made of sound-reflecting concrete elements. The noise level of the turbine hall fans and the ventilation openings was assumed to be 75 dB(A) including the effect of fan-specific silencers.

Noise modeling was carried out separately for industrial noise and road traffic noise in accordance with the Ministry of the Environment noise modeling guidelines *(Ympäristöministeriö 2007)* and the calculation results were compared with the guideline values for each noise source group.

7.9.3 Construction phase impacts

According to the results of noise modeling, the average daytime sound level L_{Aeq} in the recreational residence sites located outside the plant area on the Hanhikivi headland will be approximately 40 dB(A) during the noisiest phase of construction. This value falls well below the 45 dB(A) guideline value for recreational residence areas. The noise may occasionally be impulsive, in which case the noise level may momentarily exceed 40 dB(A). (Figure 7-32)

The noise level in the nearest nature conservation areas (the meadow in the northwestern part of the Hanhikivi headland and the Siikalahti seashore meadow) may, according to the modeling results, be approximately 50–53 dB(A). This value exceeds the 45 dB(A) daytime guideline value for nature conservation areas. Since these nature conservation areas are not regularly used for observation of nature or hiking, the guideline values are not considered to apply to these areas. The impacts on the nature conservation areas and the birdlife in the area are assessed in Section 7.6.6.

The areas affected by noise at 50 and 55 dB(A) generated by traffic during the most active period of construction period will be rather limited, and no residences will fall within their scope. The 45 dB(A) noise zone created by daytime (7 a.m. – 10 p.m.) traffic noise will extend to the distance of slightly under 250 meters from the road on both sides of the road (Figure 7-33). At the nearest residential

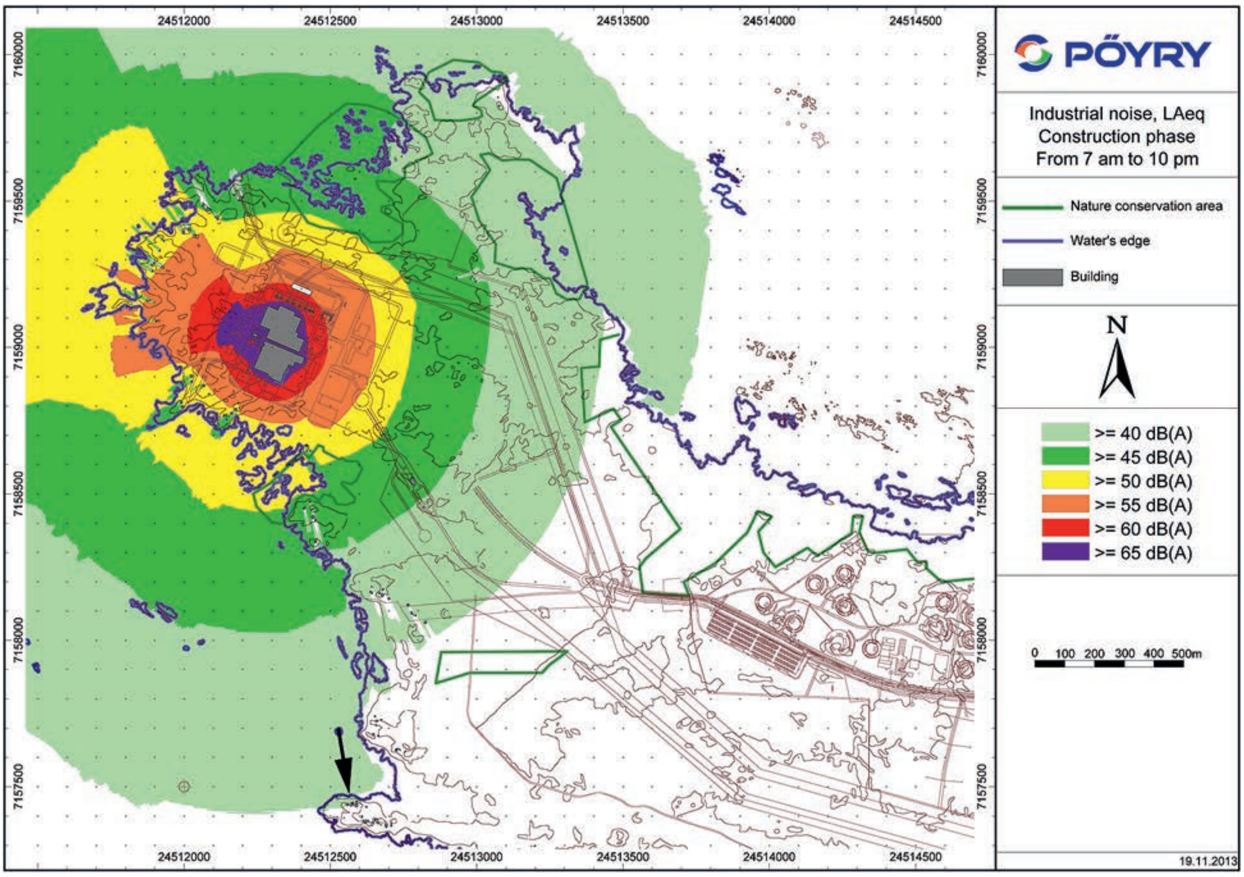


Figure 7-32. The industrial noise dispersion map for the most active period of construction. The black arrow indicates the nearest residence.

buildings, the noise level will fall well below the 55 dB(A) guideline value for residential areas.

The new road leading to the power plant will run through the Hietakarinlahti–Takaranta FINIBA area at its most narrow point. The Takaranta nature conservation area (the Takaranta seashore meadow and sand dune) will extend to the north from the road. The 45 dB(A) noise zone will extend a short distance inside these nature areas. The use of the areas for observation of nature or hiking is rather limited and mainly occurs close to the shoreline where the noise impact is not significant. The impacts on the nature conservation areas are assessed in Section 7.6.6.

According to the modeling results, the contributory impact of night-time road traffic noise will remain small during the construction phase (Figure 7-34). The 45 dB(A) noise zone will extend to the distance of approximately 65 meters from the centerline of the road. It will not extend to any residential site. Small parts of the nature conservation area and the important birdlife area will be enclosed within this noise zone.

7.9.4 Operation phase impacts

During the operation of the nuclear power plant, the direction of the most significant noise sources will be to the north as well as to the southeast and northwest. Consequently, the impact on the recreational residence sites located to the south of the plant will remain small. According to the results of noise modeling (Figure 7-35), the average noise level LAeq in recreational residence sites will be under 30 dB(A), which falls well below the daytime and night-time guideline values of 45 dB(A) and 40 dB(A), respectively. In the nearest nature conservation areas, the maximum noise level will be 35–40 dB(A).

The figures 7-36 and 7-37 show modeling results based on the daytime and night-time road traffic noise calculations for the operation phase. According to the modeling results, the 40 dB(A) noise zone caused by traffic to and from the plant will extend to the distance of approximately 100 meters from the road to both sides of the road in the daytime. Correspondingly, the 45 dB(A) zone will extend to the distance of approximately 60 meters. The noise level will be lower in the night time. In the night time, the 40 dB(A) zone will extend to the distance of approximately 50 meters from the road. At the nearest residential buildings, the noise level will fall below the daytime and night-time guideline values of 55 dB(A) and 50 dB(A), respectively.

In the daytime, the 45dB(A) noise zone will extend a short distance inside the nature conservation area (the Takaranta seashore meadow and sand dune), the boundary of which is located near the road, and the important birdlife area (Hietakarinlahti) located to the south of the road. In the night time, the noise zone will be smaller in size. The areas used for observation of nature or hiking is rather limited and mainly

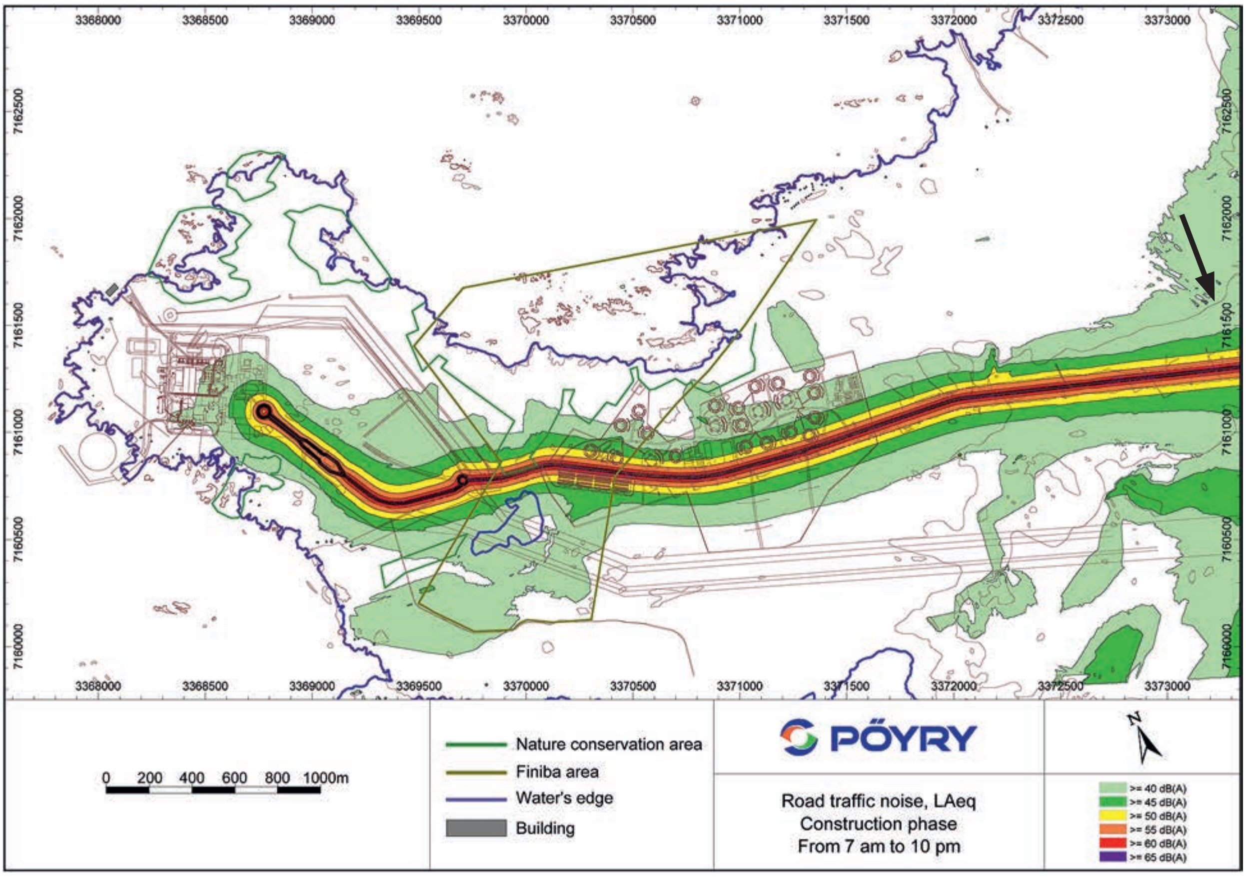


Figure 7-33. The road traffic noise dispersion map for hours between 7 a.m. and 10 p.m. during the construction phase. The black arrow indicates the nearest residence.

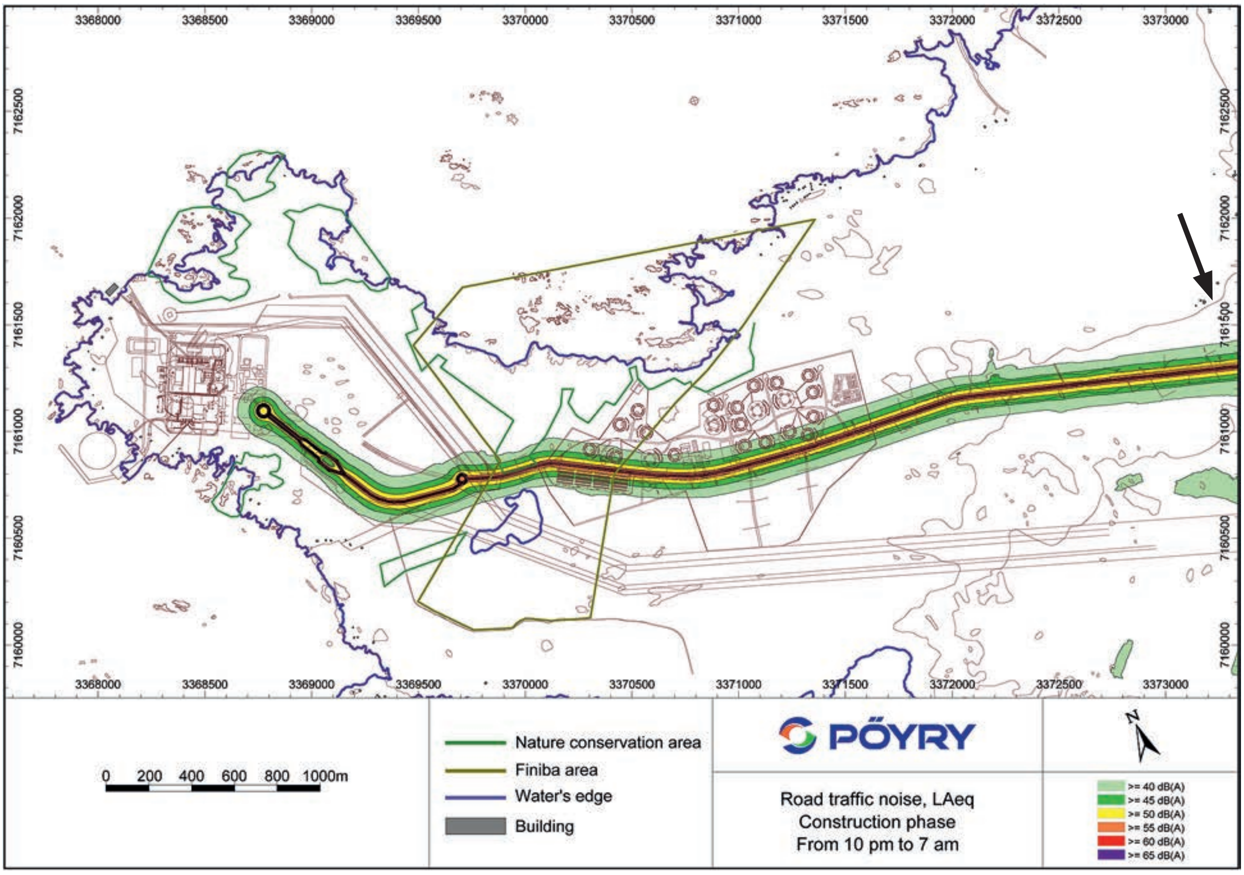


Figure 7-34. The road traffic noise dispersion map for hours between 10 p.m. and 7 a.m. during the construction phase. The black arrow indicates the nearest residence.

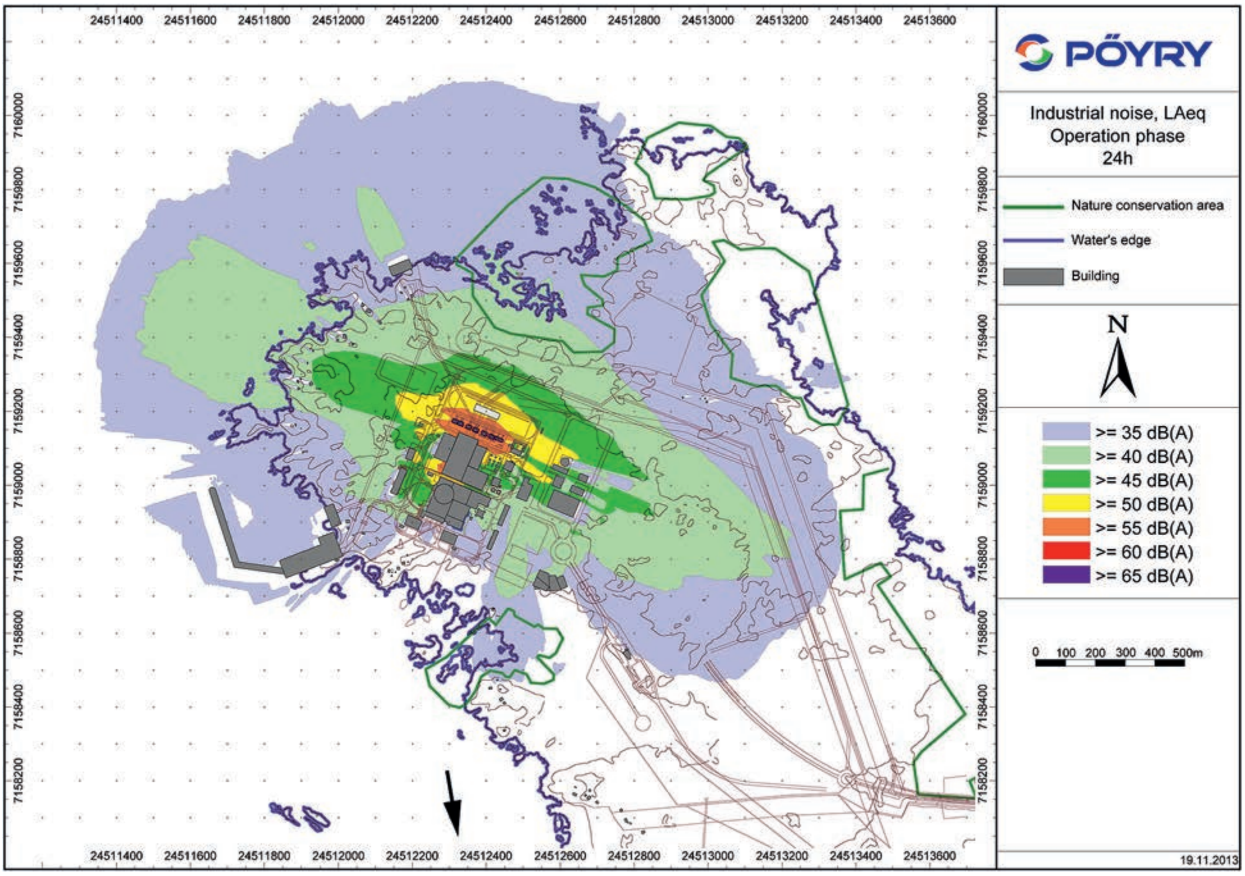


Figure 7-35. The industrial noise dispersion map for the operation phase. The black arrow indicates the nearest residence.

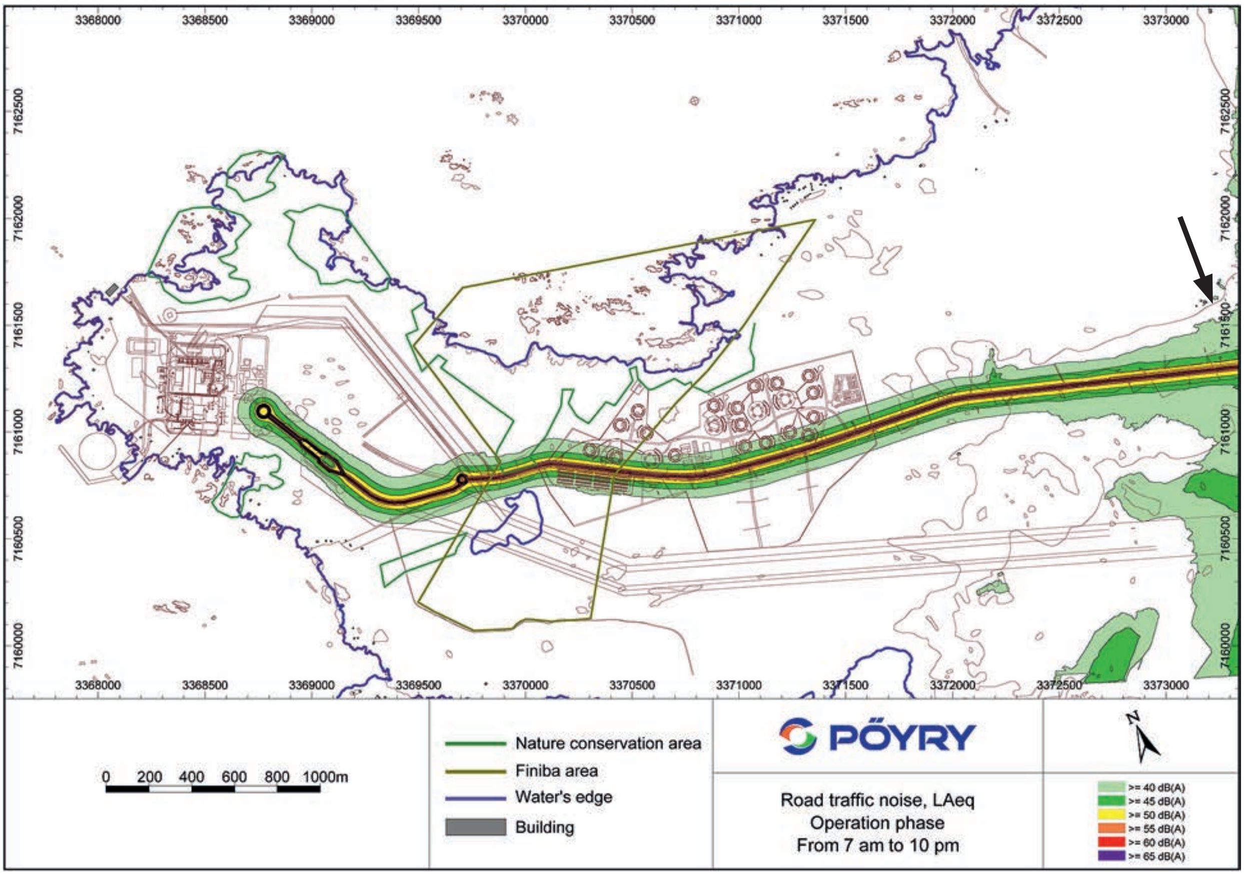


Figure 7-36. The road traffic noise dispersion map for hours between 7 a.m. and 10 p.m. during the operation phase. The black arrow indicates the nearest residence.

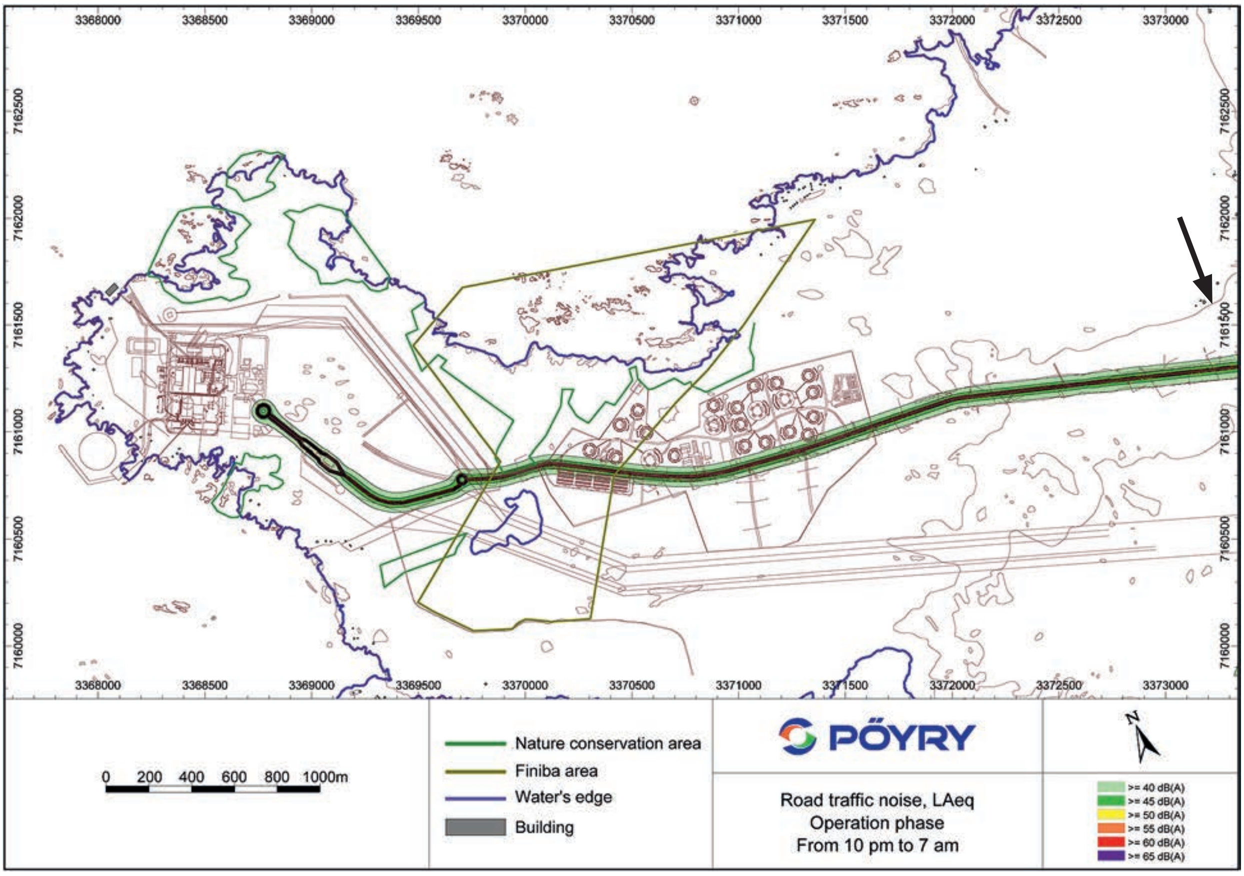


Figure 7-37. The road traffic noise dispersion map for hours between 10 p.m. and 7 a.m. during the operation phase. The black arrow indicates the nearest residence.

occurs close to the shoreline where the noise impact is not significant. The impacts on the nature conservation areas and the birdlife are assessed in Section 7.6.7.

7.9.5 Summary of the noise impacts

According to the results of noise modeling, the noise levels caused by the project will remain below the guideline noise values for residential areas and recreational residence areas both during the construction phase and the operation phase.

The average daytime sound level at the nearest recreational residences during the noisiest phase of construction will be approximately 40 dB(A). This value falls well below the 45 dB(A) guideline value for recreational residence areas. The noise level in the nearest nature conservation areas (the meadow in the northwestern part of the Hanhikivi headland and the Siikalahti seashore meadow) may, according to the modeling results, be approximately 50–53 dB(A).

The noise generated by traffic during the most active period of construction will remain below the guideline levels of 50 and 55 dB(A) and only affect rather limited areas. Furthermore, no residences will fall within their scope. The 45 dB(A) zone will extend a short distance inside the nature conservation area, the boundary of which runs near the road route, and the important avifauna area.

According to the calculations, the noise level carried from the nuclear power plant to residential areas and recreational residence areas during normal operation will be rather low. The average noise level at the closest recreational residence sites will remain below 30 dB(A). The noise level caused by traffic to and from the power plant will also be low, and it will remain well below the guideline noise values for residential areas.

As the designing of the plant progresses, a noise prevention plan will be prepared. The plan will include detailed descriptions of the layout of the construction-phase operations and noise prevention measures. During the construction phase, a great deal of variation may occur in traffic volumes, and the actual noise levels may deviate from the average sound levels determined through calculations. This variation will be taken into account in the noise prevention plan to be prepared later.

7.10 People and society

7.10.1 Present status

7.10.1.1 People and communities

The immediate surroundings of the Hanhikivi power plant site are sparsely populated. The village of Parhalahti, located a little over five kilometers from the nuclear power plant, is included in the plant's five-kilometer protective zone. Approximately 440 permanent residents live within the five-kilometer protective zone. There are 11,600 permanent residents within a twenty-kilometer radius of the site. The downtown area of the municipality of Pyhäjoki and downtown Raahe are both located within the twenty-kilometer zone (Figure 7-38, *Tilastokeskus 2013a*).

There are approximately 377,000 people living within a hundred kilometer radius from the power plant site *(Tilastokeskus 2013a)*. Of these, a significant number lives in the Oulu region. The largest population centers in the area are Oulu, Kokkola, Raahe, Ylivieska, Kiiminki, Haukipudas, Kempele, Nivala, Oulunsalo, and Kalajoki. There are a large number of holiday residences in the coastal area of Pyhäjoki. There are fewer holiday residences (approximately 20 in total) in the Hanhikivi headland area than in other coastal areas of Pyhäjoki. For a more detailed description of the areas land use, please see Section 7.3.

Most of the holiday residences are located on the western shores of the headland, while a nature conservation area covers most of the eastern shoreline. There are a few hundred holiday residences within a twenty-kilometer radius. There are four schools within a radius of approximately ten kilometer from Hanhikivi headland, the nearest of them being the village school of Parhalahti. The closest public beach is located in the western part of the headland (Figure 7-39).

The Hanhikivi area is used for recreational purposes to some extent. The project site is part of the important hunting grounds of the local hunting club (Parhalahden metsästäjät ry) where they hunt not only large game (elk) but also rabbits and waterfowls. The shores and the terrain of the Hanhikivi headland in general are excellent for

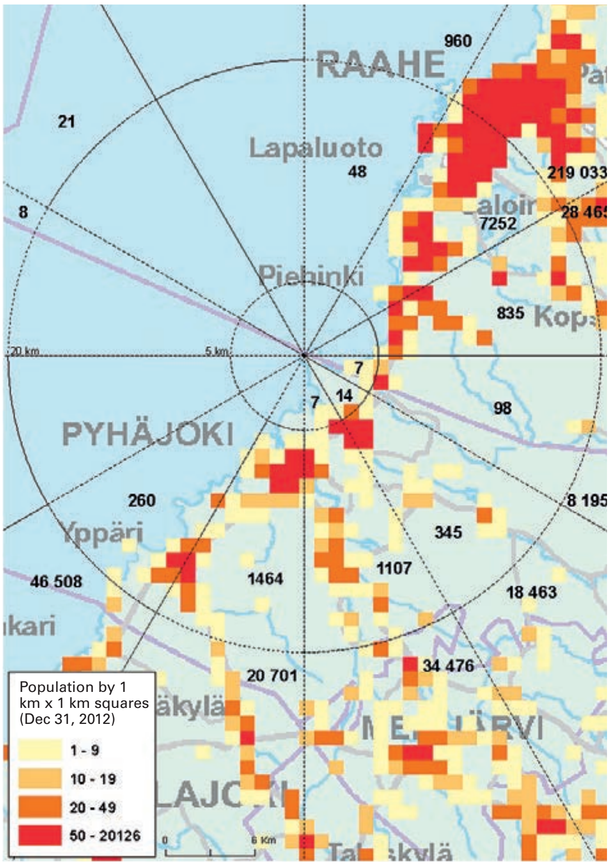


Figure 7-38. Distribution of population within the five- and twenty-kilometer zone of the power plant site in 2012 *(Tilastokeskus 2013a)*.

hunting waterfowls and rabbits. The area is actively used by hunters, and a major part of the hunting club's revenue comes from guest hunting permits sold for the area. Hunting dog tests are held in the Hanhikivi area for the local hunting club as well as other hunting clubs.

7.10.1.2 Population, regional economy, and employment

Population and population forecasts

The economic area of Raahe consists of seven municipalities (according to the latest municipal structure of January 1, 2013, at which time the municipalities of Vihanti and Raahe were merged), and approximately 59,000 people live in the area. The local population continued to grow from the early 1980s to the early 1990s, but the population trend in all the local municipalities has been decreasing since then (Figure 7-40). The population of Kalajoki has been growing since 2005.

According to the population forecasts of Statistics Finland, the population in the municipalities of the Raahe economic area will remain at around the same level until 2040 (Table 7-8). The population of the municipality of Pyhäjoki is expected to decrease by 261 people (8 %) between 2012 and 2040. The population of the town of Kalajoki is expected to increase by around 1,000 people by 2040.

Demography

The age distribution in the Raahe economic area was different from the age distribution for the whole of Finland in 2012 in that the relative share of people between the ages of 0 and 14 as well as the relative share of people aged 64 years or more was higher than for the whole of Finland. Correspondingly, the share of people of the working age (15–64-year-olds) in the Raahe economic area was lower than the national average. The share of people of the working age was highest in Raahe and Kalajoki (Table 7-9).

Employment and economic structure

The economic structure of the Raahe economic area is one of Finland's most highly specialized due to the fact that industry is very important for the area. The number of the jobs in the industrial sector has decreased in the area in the past few years, however. Approximately 600 jobs were lost

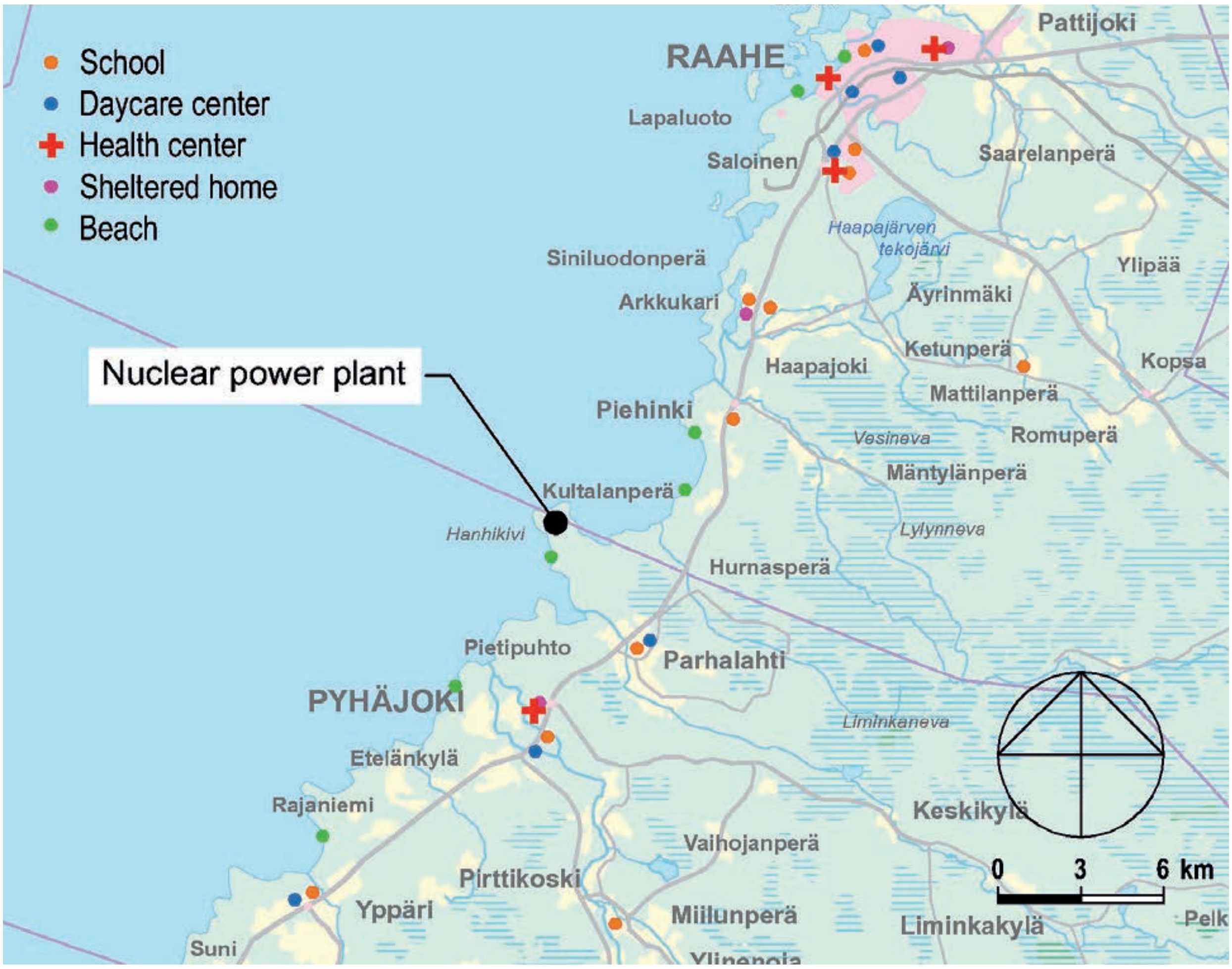


Figure 7-39. Daycare centers, schools, health centers, sheltered homes, and public beaches close to the project site.

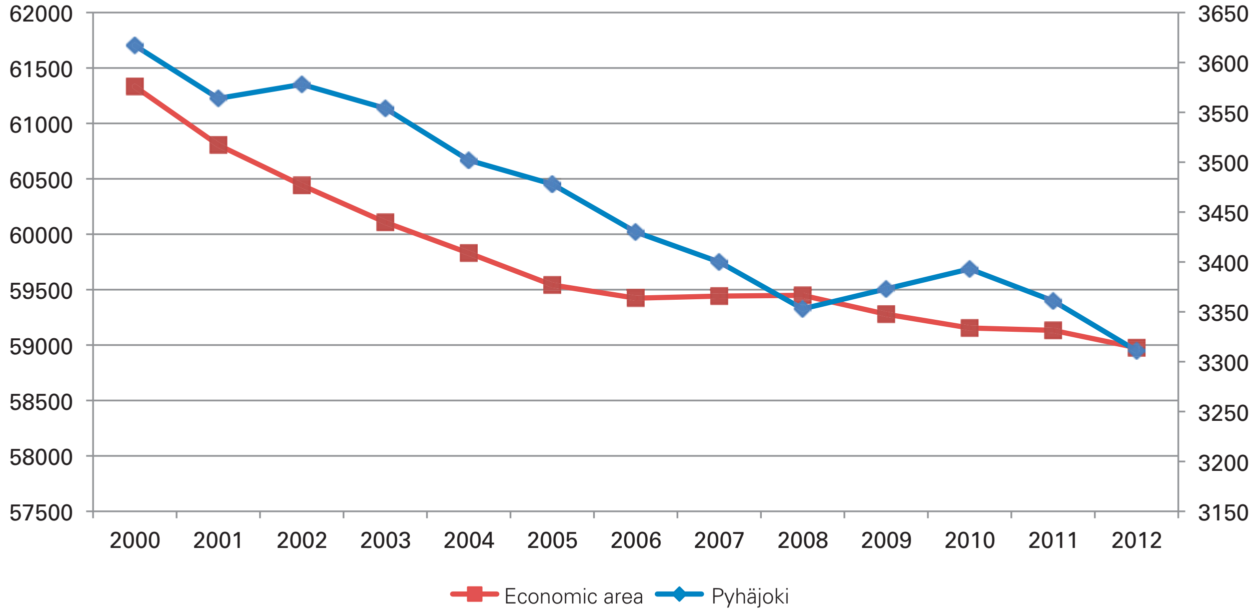


Figure 7-40. Development of the population of the municipality of Raahe and the Raahe economic area from 2000 to 2013 *(Tilastokeskus 2013b).*

Table 7-8. Population forecast for the Raahe economic area for 2015–2040 *(Tilastokeskus2013b).*

	2012	2015	2030	2030	2040
Pyhäjoki	3,340	3,292	3,253	3,183	3,079
Alavieska	2,737	2,707	2,692	2,680	2,669
Kalajoki	12,667	12,821	13,101	13,507	13,655
Merijärvi	1,192	1,173	1,148	1,122	1,106
Oulainen	7,864	7,735	7,580	7,394	7,224
Raahe	22,618	22,718	22,832	22,786	22,396
Siikajoki	5,614	5,554	5,500	5,436	5,376
Total	**56,032**	**56,000**	**56,106**	**56,108**	**55,505**

from industry between 2007 and 2011 alone (Table 7-10). The most important employer of the economic area, Rautaruukki, has decreased the number of its employees in the 21st century. The number of jobs has increased in mining and quarrying (Laivakangas mine) and in healthcare and social welfare, for example.

There were a total of 3,646 private companies in the Raahe economic area in 2011. More than half of these (59 %) were located in Raahe or Kalajoki (Table 7-11). More than half of the employees worked in Raahe, and more than half of the total net sales were made by companies located in Raahe. Rautaruukki's share is significant.

Unemployment rate in the Raahe economic area decreased in 2009–2011 and increased in 2012 due to the economic recession. The share of the unemployed was, on average, 10.2 % of the labor force in 2011. The area's most important municipality of employment was Raahe whose regional self-sufficiency regarding employment was approximately 117 % in 2011 (Table 7-12). As many as 40 % of those employed in Raahe, worked in the industrial sector.

Municipal economy

The per resident tax revenue of the municipalities in the Raahe economic area has increased in the 21st century at a rate higher than the average growth rate in Finland. Theper resident tax revenue of the local municipalities still remains lower than the average in Finland, except for Raahe (Table 7-13). The annual contribution margin per resident of municipalities is a key performance indicator when assessing the sufficiency of municipalities' cash flow financing. The annual contribution margin of the municipalities in the Raahe economic area was positive, except for Siikajoki. Siikajoki's margin was still €494 per resident in 2010, however. The annual contribution margins per resident of the town of Kalajoki and the municipality of Merijärvi were higher than the average for all Finnish municipalities. The loan capital per resident in the Raahe economic area was higher than the average in Finland. Raahe had the highest loan capital of the local municipalities. The loan capital of Raahe has continued to grow ever since the turn of the century. The loan capital of Alavieska has also grown strongly in the past few years.

Table 7-9. Age distribution of the Raahe economic area in 2012 *(Tilastokeskus 2013b).*

2012	0–14 years, %	15–64 years, %	64+ years, %
Pyhäjoki	18.2	59.1	22.7
Alavieska	20.2	59.8	20.1
Kalajoki	19.2	60.6	20.2
Merijärvi	22.9	58.1	19.0
Oulainen	19.8	59.3	20.9
Raahe	19.4	62.5	18.1
Siikajoki	22.7	59.9	17.5
Raahe economic area	**19.8**	**61.0**	**19.2**
Whole of Finland	**16.4**	**64.8**	**18.8**

Table 7-10. Distribution of jobs in the Raahe economic area (according to Statistics Finland's classification system TOL 2008) in 2007 and 2011. *(Tilastokeskus 2013b).*

Branch of industry	2007	2011
A Agriculture, forestry, and fishery	2,328	2,126
B Mining and quarrying	97	236
C Industry	6,698	6,088
D Electricity, gas, and heat supply, refrigeration business	69	49
E Water supply, plumbing and sewerage, waste management, and other public sanitation sectors	118	115
F Construction	1,718	1,718
G Wholesale trade, retail trade, motor vehicle and motorcycle repair	1,826	1,852
H Transport and storage	1,291	1,245
I Accomodation and catering	456	553
J Information and communications	287	238
K Insurance and financial services	246	254
L Real estate business	120	131
M Vocational, scientific, and technical activities	637	744
N Administration and supporting services	837	858
O Public administration and national defense; mandatory social insurance	716	664
P Education	1,515	1,514
Q Health and social welfare	3,448	3,711
R Arts, entertainment, and recreation	145	148
S Other services	563	603
T Households as employers; other activities taken by private households to produce goods and services for private use	0	0
U Global organizations and bodies	0	0
X Branch of industry unknown	270	324
Total	**23,385**	**23,171**

Table 7-11. Number of companies, net sales, and personnel in themunicipalities of the Raahe economic area in 2011 *(Tilastokeskus 2013b).*

2011	Locations	Net sales, M€	Personnel
Pyhäjoki	222	49	424
Alavieska	230	51	499
Kalajoki	1,136	517	3,334
Merijärvi	91	7	120
Oulainen	490	228	1,560
Raahe	1,000	1,257	7,762
Siikajoki	477	101	992
Total	**3,646**	**2,210**	**14,691**

2011	Employed	Unemployed	Jobs	Self-sufficiency, %	Unemployed, % of labor force
Pyhäjoki	1,290	132	808	62.6	9.3
Alavieska	1,059	125	807	76.2	10.6
Kalajoki	5,235	518	4,828	92.2	9.0
Merijärvi	418	56	242	57.9	11.8
Oulainen	2,940	402	2,928	99.6	12.0
Raahe	10,117	1,142	11,821	116.8	10.1
Siikajoki	2,111	243	1,737	82.3	10.3
Total	**23,170**	**2,618**	**23,171**		

Table 7-12. Number of the employed and jobs, self-sufficiency regarding employment and the unemployment rate in the Raahe economic area in 2011 (*Tilastokeskus 2013b).*

7.10.2 Assessment methods

This section assesses the impacts of the nuclear power plant project on people and society. In addition to social impacts, the assessment covers the project's impacts on economy and employment from the viewpoint of both regional and national economy. The social impact assessment is an interactive process. The process is all about identifying and anticipating any impacts on individuals, communities, or society that could change people's living conditions, comfort, wellbeing, or distribution of wellbeing (*Sosiaali- ja terveysministeriö 1999, Terveyden ja hyvinvoinnin laitos 2013*). The assessment also takes into account the impact on recreational use of the area. One objective of the social impact assessment is to promote communication and interaction between the various parties. The social impact assessment provides valuable information about the needs of the different stakeholders during the assessment process and during the latter stages of the project. Furthermore, it can be used as a channel for sharing information.

The social impacts of a project must always be interpreted in relation to the community affected, the prevailing conditions, and the social situation in general. People's attitudes towards the impacts also reflect the status of the local economy and employment, and their susceptibility to change. Social impacts can be direct, such as reduction of the comfort of the local residents or hindering of current land use because the areas under assessment will be transferred to the use of the project. The social impacts can also be indirect, such as impacts on the appeal of the area or changed operational preconditions due to the changed environment. The way people experience social impacts is individual and depends on what they do in the area and which values they consider important in their living environment. The impacts can also affect the region's intangible values alone, such as a landscape with emotional value to people, the peace and quiet of nature, or the image of the region.

The current assessment focused on the issues raised by the stakeholders during the environmental impact assessment of 2008 and during the current EIA procedure. The residents' attitudes towards the project have been assessed based on the opinions about the EIA program they have voiced, the resident survey, feedback provided during the EIA procedure, and discussions in the media.

The assessment studied the project's impacts during both construction and operation. Information about the project area, such as the location of residential and recreational areas in relation to the project area, was used as the assessment background data. The assessment surveyed vulnerable sites in the immediate surroundings of the project site, i.e. sites that are more susceptible to potential adverse impacts. Both, the analysis of empirical or subjective data and expert assessments were utilized in the impact assessment.

The project's impacts on people's comfort and living conditions were identified and evaluated with the help of quantitative and qualitative assessments from the other parts of

2011	Tax revenue, €/resident	Annual contribution margin, €/resident	Loan capital, €/resident
Pyhäjoki	2,686	266	2,692
Alavieska	2,428	157	2,762
Kalajoki	2,647	518	2,413
Merijärvi	2,074	410	2,684
Oulainen	2,791	65	2,831
Raahe	3,639	160	4,803
Siikajoki	2,577	-151	1,958
Economic area (on average)	2,692	203	2,878
Whole of Finland	**3,530**	**384**	**2,037**

Table 7-13. Financial KPIs of the municipalities in the Raahe economic area in 2011 *(Tilastokeskus 2013b).*

the environmental impact assessment. The assessed impacts included changes in land use, impact on the landscape, water systems, traffic and traffic safety, impact on employment, and noise. Perceived impacts, meaning how the local residents and other parties in the area experience the above-mentioned impacts, were also assessed. The perceived impacts are mainly discussed in connection with the results of the resident survey.

The project's impacts on people and society have been studied by assessing the project's impact on the regional economy, taking into account the impacts during construction and operation of the nuclear power plant. Data of the social impact assessment was obtained from the resident survey and the small group interviews, for example. A guidebook *Ihmisiin kohdistuvat terveydelliset ja sosiaaliset vaikutukset* ("Impacts on people's health and society") by the Ministry of Social Affairs and Health (*1999*) and a guidebook on the assessment of impacts on people by the National Institute for Health and Welfare (*2013*) were used to support the impact assessment.

7.10.2.1 Resident survey

The resident survey was sent by post to permanent residents and holiday home owners of the area influenced by the power plant project (homes within a twenty kilometer zone from the power plant site) in October and November 2013. The questionnaire was sent to a total of 693 households.

The survey respondents were chosen using the same sampling method as in the resident survey implemented in 2008 to ensure that a comparison of how the respondents' views have possibly changed in the past five years would be possible. All the permanent residents and holiday home owners within the five-kilometer zone from the power plant site were included in the sample. This zone is located in the area of the town of Raahe and the municipality of Pyhäjoki. The survey was also sent to a random sample of 10 % of the households located within a 5-20 kilometer radius of the power plant site. This zone is located in the municipality of Pyhäjoki, the town of Raahe, and the municipality of Merijärvi. One questionnaire per household was sent in both zones. By focusing on the two zones and using the sampling methods described above, it was possible to survey the opinions of permanent and holiday residents comprehensively over a wide area. Furthermore, the survey offered an opportunity to communicate information about the project to permanent and holiday residents living in the immediate vicinity of the project site (less than five kilometers from the site) (Table 7-14).

Address data from the Population Register Centre was used in identifying the survey respondents and in posting the survey. The survey could not be sent to any residents with a currently valid direct marketing ban or ban on giving their address data to such purposes.

In order to be able to compare the results with those of the previous survey, the content and formulation of the survey questions were kept as similar as possible to those in the previous survey. The questionnaire comprised 21 questions. A summary of the environmental impact assessment program, which included a description of the project, was enclosed with the resident survey.

7.10.2.2 Small group interviews

The small group interviews on social impacts of the Fennovoima project were arranged on November 21–22, 2013. Three small group meetings were arranged. Two of the groups comprised local residents and the third group comprised officials of the municipality of Pyhäjoki and the consolidation of municipalities. Participants of the resident groups were selected by representatives of Pöyry contacting the Pro Hanhikivi association and the Parhalahti village association, both of whom invited representatives to attend the interviews. Two representatives of the EIA consultant, Pöyry, acted as the interview hosts.

The plan with the group interviews was to discuss the Fennovoima nuclear power plant project and its positive and negative social impacts, particularly those that have arisen since the drafting of the previous EIA.

The participants in the group interviews were able to voice their own opinions, argue their case, and voice any opinions by other people they considered important. The objective of the discussions was to find out the underlying reasons for any conflicts and how these conflicts came into being. The participants were informed that their names would not be published. The discussions took 1.5–2 hours. The most important issues discussed in the group interviews are listed below.

The in the group interview questions were drafted in advance to keep the discussion properly organized. The questions were reviewed at the beginning of the interview. The questions included:

- What is your general idea or image of Fennovoima and its actions in Pyhäjoki?
- What has been done well and what has been done poorly during the various stages of the nuclear power plant project? What should the company have done during the various stages of the nuclear power plant project?
- As a private person and/or association, how have you reacted at the different stages of the nuclear power plant project?
- The political decision regarding nuclear power has already been made. How should the decision about the location of the new nuclear power plant have been resolved?
- If the project is realized, what should be done next?

Table 7-14. Resident survey sampling area and sample size.

Sampling area	Sample size (number of questionnaires sent)
Less than five kilometers from the project site	142
5–20 km from the project site	551
Total	**693**

    - Which parties should be heard and included in the discussion, and how should they be included?
    - What kind of mitigation/compensation methods should be used?
- If the project is not realized, what should be done next?
    - How should any follow-up actions be realized?
- What kind of positive impacts has the nuclear power plant project had?
    - What are your concrete expectations on positive impacts?
- What kind of negative impacts has the nuclear power plant project had?
    - Have these been fears, or have you experienced some concrete disadvantages?
- Who will benefit from the project if it is realized?
    - Employees, entrepreneurs?
    - Municipal economy?
- Who or what will be negatively affected if the project is realized?
    - Nature sites in the immediate vicinity of the project area, such as the Hanhikivi headland?
    - Fishery or other local activities?
    - Local hunting?
- Other themes:
    - Impacts related to the entry of the Russian actor into the project
    - Other positive or negative impacts

7.10.2.3 Regional economy and employment

The starting point of the assessment of the impacts on employment and the regional economy is that the nuclear power plant project is a major construction project, and when realized, it will be a significant regional employer. The construction, operation, and annual maintenance of the nuclear power plant will have diverse impacts on businesses, services, and the labor market in Pyhäjoki and the surrounding Raahe economic area, as well as the whole of Finland.

The project's employment impact assessment is based on a background survey on the project's impact on the regional economy that was drafted in 2008 (*Pöyry Energy Oy 2008*), since the studied nuclear power plant's impacts on the economy and employment are not expected to be very different from the impacts of the 1,800 MW plant studied in the EIA of 2008. The figures used in the previous assessment, such as the data on the economic area, work input coefficients, and investment size, have been updated to correspond to the current situation. This environmental impact assessment studies the impacts of an investment of approximately €4,000–6,000 million.

The project's employment impacts have been separately evaluated for the construction phase and the operation phase. Both direct and indirect employment impacts have been studied for both phases. The term 'direct employment impact' refers to design and construction work required by the investment and implemented directly by the developer, contractors, subcontractors, and service providers. In addition to direct impacts, the investment will create a long supply chain consisting of intermediate product inputs.

In addition to the actual power plant investment, this assessment also studies the employment impacts of connected projects (such as the harbor). The assessment of the project's direct and indirect employment impacts has been implemented utilizing data about work inputs in 2010 published by Statistics Finland (*Tilastokeskus 2013b*). The amount of property tax and municipal tax has been assessed based on the investment data and the employment impact assessments.

7.10.2.4 Uncertainties related to the assessment

People's experiences and opinions about the nuclear power plant project, which have been described in the social impact assessment, may change as the project proceeds. The social impact assessment has been implemented utilizing the results of the other parts of the environmental impact assessment, which means that uncertainties related to the other assessments will also influence the results of the social impact assessment. The project's perceived impacts have been studied using resident survey results, for example. Since the response rate of the survey was only approximately 25%, the results of the survey are not fully representative of the opinions and views of all the permanent and holiday residents in the area.

The initial data and assumptions used in the environmental impact assessment are based on previously implemented projects and other studies where the data has been proven reliable. The assessment of the project's economic impacts involves some uncertainties. The project's estimated employment impact is based on the size of the total investment, which may be revised as the project proceeds.

The project's impacts on the regional economy and employment will in the end depend on, for instance, the current economic cycle and availability of local workforce. Municipalities and different actors in the project's impact area may influence by their actions how significant the local benefits are (such as improved employment) and they are regionally distributed. The significance and regional distribution of the project's impacts on employment and on the regional economy will also depend, to some extent, on decisions to be made by Fennovoima and the plant supplier regarding recruitment, contract supply chains, etc. Regional distribution of the impacts will also depend on how large a share of the project employees are from Finland and in which town they live.

7.10.3 Results of the resident survey and summary of the group interviews

7.10.3.1 Results of the resident survey

Respondent data

The questionnaire was sent to a total of 693 households. 173 questionnaires were returned, i.e. the response rate was approximately 25 %. The response rate is moderate when compared to other similar surveys. The response rate is low when compared to the resident survey of 2008, however. The response rate of the 2008 survey was approximately 53 %. The graphs illustrating the results include, for comparison purposes, also the results of the 2008 survey in cases where the same questions were posed.

The respondents were asked to estimate how far away from the power plant site their home or holiday home is located. A total of 36 % of all the respondents estimated that they live less than five kilometers from the power plant site and 64 % stated that they live 5–20 km from the power plant site. Based on the estimates given, it can be assumed that the response rate within the five-kilometer zone was more than 42 % and the response rate within the 5–20 km zone was more than 19 %. Of the respondents, 38 % (62 people) were female and 62 % (103 people) were male. Three percent of the respondents belonged to the age group from 18 to 25 years, 5 % were 26 to 35 years old, 13 % were 36 to 45 years old, 47 % were 46 to 64 years old, and 32 % were 65+ years old. Thus, almost 80 % of the respondents were more than 45 years of age.

Of the group, 83 % (142 people) stated that they are permanent residents of the area and 17 % (30 people) stated that they own a holiday home in the area. The share of permanent residents was slightly higher (89 %) in the resident survey of 2008. The relative share of holiday residents among those respondents living less than five kilometers from the power plant site was higher (30 %) than among those living 5–20 km from the power plant site (10 %). A total of 95 % of the respondents had been living in the area for more than five years and only one respondent had been living in the area for less than 12 months. This corresponds to the results of the 2008 survey.

Respondents view about the project impacts

The respondents were asked to assess how the project would influence their own income or the income of their family, their recreational activities or spare time in general, and the traffic routes they use (Figure 7-41). Approximately half of the respondents were of the opinion that the project will not influence the above-mentioned issues. Around one third of the respondents stated that the project will have a positive or highly positive impact on their income or the income of their family and their opportunity to obtain income. Of the group, 13 % of the respondents were of the opinion that the impact on their income would be fairly or highly negative. Of these three issues being assessed, the respondents considered recreational activities or spare time to be the most susceptible to negative impacts. The assessments of the people living less than five kilometers from the plant site were more negative than the assessments of the people living 5–20 km from the plant site.

The respondents were asked to assess how the project will influence the value of their home or holiday home. The respondents' views on the impact of the project on the value of real estate were very strongly polarized (Figure 7-42). Compared to the resident survey of 2008, the share of respondents who believed that the value of real estate will rise had increased from 19 % to 35 %.

The respondents were also asked to assess how the project will influence different aspects of their living environment. The questions were divided into four sections, depending on the impacts. The respondents' assessments on the project's impact on living comfort, living conditions, and recreational activities are illustrated in Figure 7-43. About half of the respondents (42–64 % depending on the question) were of the opinion that the project will not influence any of the issues being assessed. The respondents believed that the project will have negative impacts particularly on fishing opportunities, safety, picking of natural products, and on the stillness and peace of their living environment.

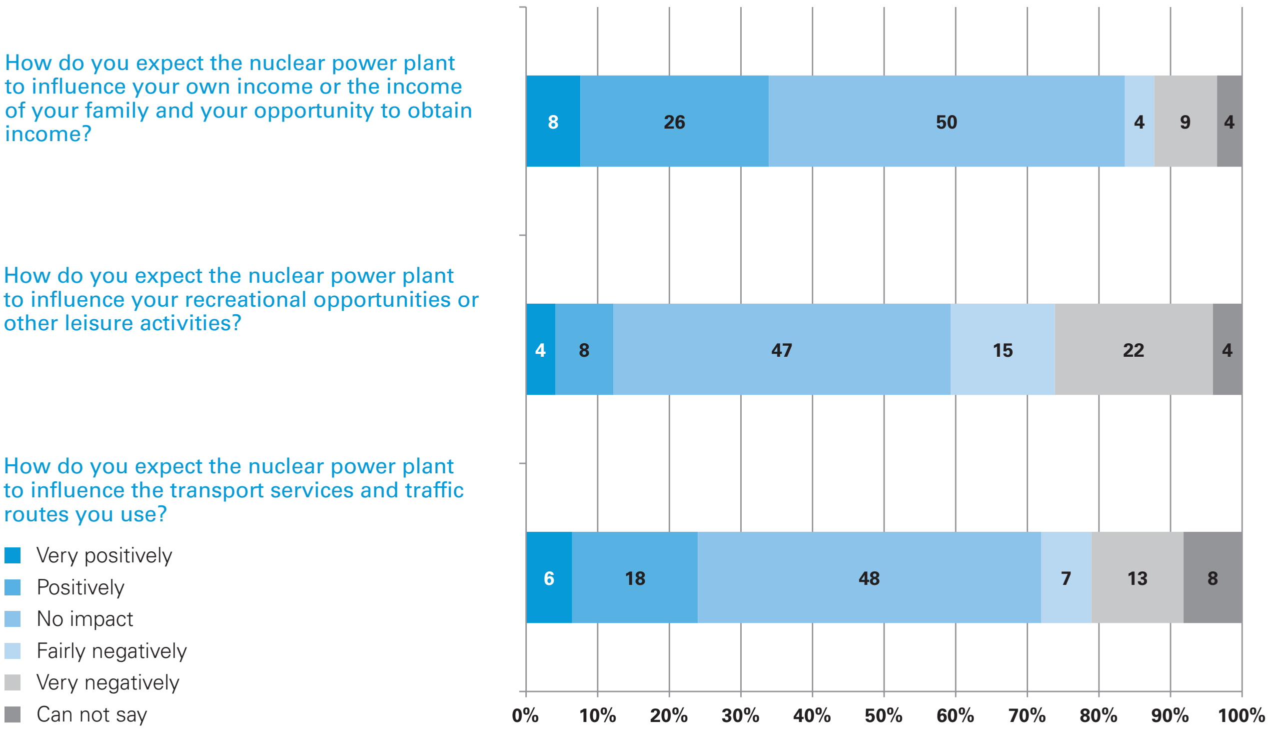


Figure 7-41. Respondents' assessments on the project's impact on their income, recreational activities, and traffic connections (n = 171–172).

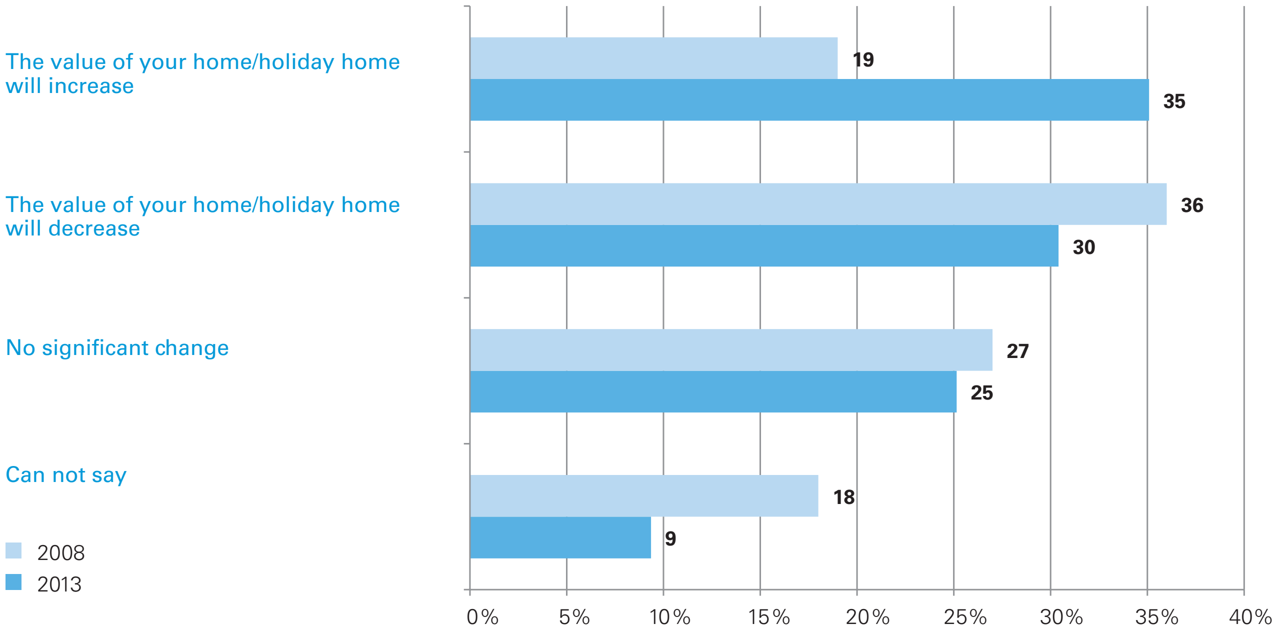


Figure 7-42. Respondents' assessments on the project's impact on the value of real estate (n = 171).

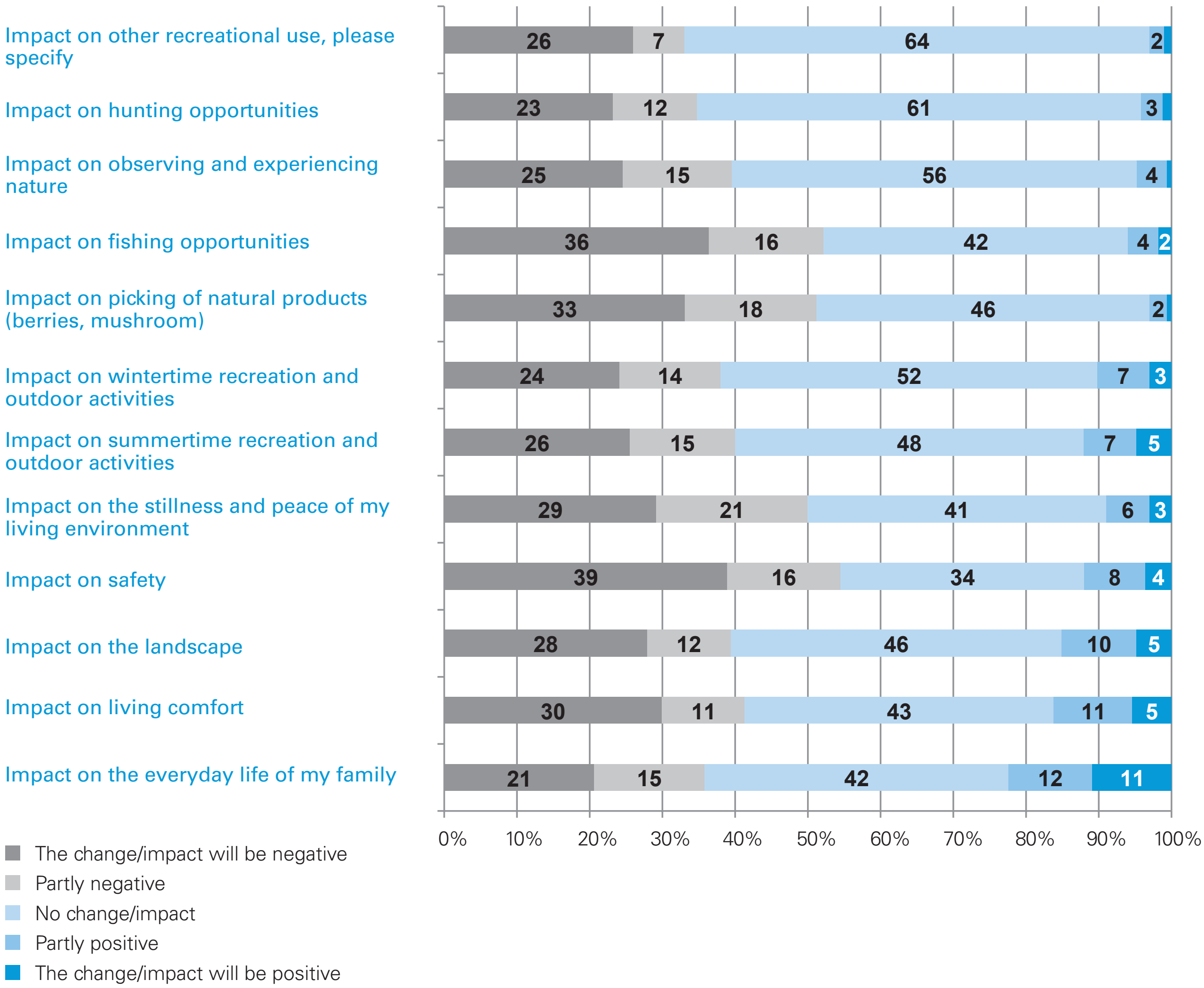


Figure 7-43. Respondents' assessments on the project's impact on living comfort, living conditions, and recreational activities (n = 100–168).

The respondents' views on the project's impacts on employment, businesses, and the environment are illustrated in Figure 7-44. Most of the respondents were of the opinion that the project will have a negative impact or no impact at all on the environment. The respondents believed that the project's impact on the state of the marine area would be the most negative. On the other hand, the respondents were of the opinion that the project would have positive impacts on employment and businesses, excluding the impacts on fishery, agriculture, and forestry. According to the results, the project would have a positive impact on employment, municipal services, municipal economy, and the business life of the region in general.

In several responses, the perceived threats of the project concerned safety, health, or changes caused by employees coming from outside the area. Furthermore, the respondents considered the decrease of the area's recreational and environmental value to be a significant disadvantage.

"Foreigners will make the village more restless. It is impossible to predict the future; you never know what kind of natural catastrophes the future will bring."

"I'm worried about how radiation/pollution will affect people's health."

"The peaceful living environment will be disturbed, the nature will be polluted, the public right of access to the area will be lost. The habitats of rare plants and animals will be destroyed."

"I will not be able to hunt, fish, or spend time at my summer cottage."

Some of the respondents, in turn, emphasized their trust in Fennovoima and considered that the project's positive impacts on the economy will be influential in securing vitality of the region.

"The positive impacts outweigh the negative: more people will move to the area, the area will become more vital, the economy of the local municipalities will experience a significant boost…"

"I trust that Finnish authorities will properly supervise the construction and operation of the plant."

"The area's economic structure will become more diverse. The municipality will get more tax revenue. The municipal tax rate may even be reduced."

The respondents' assessment of the significance of the impacts during the construction phase and operational phase

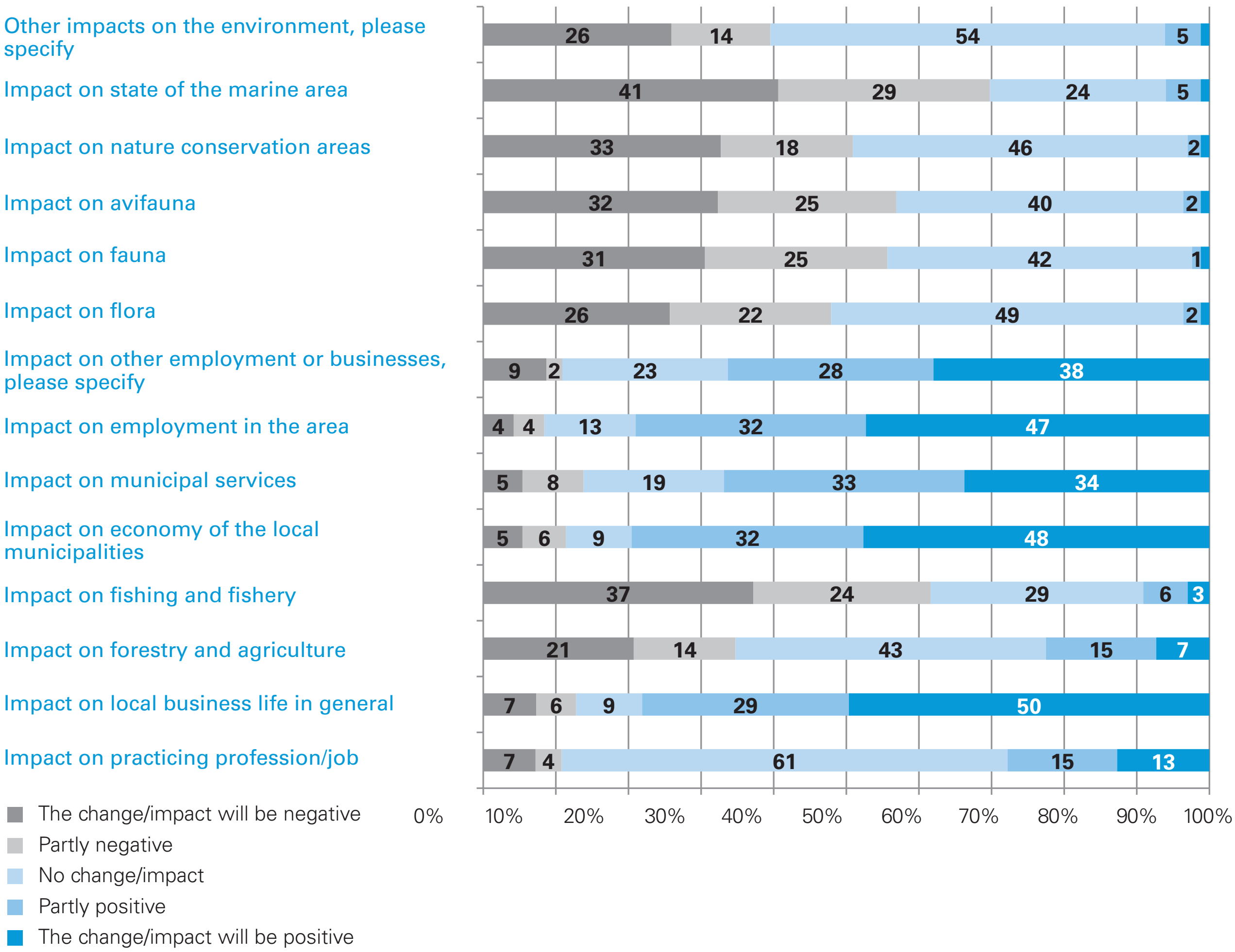


Figure 7-44. Respondents' assessments on the project's impact on employment, businesses, and the environment (n = 81–167).

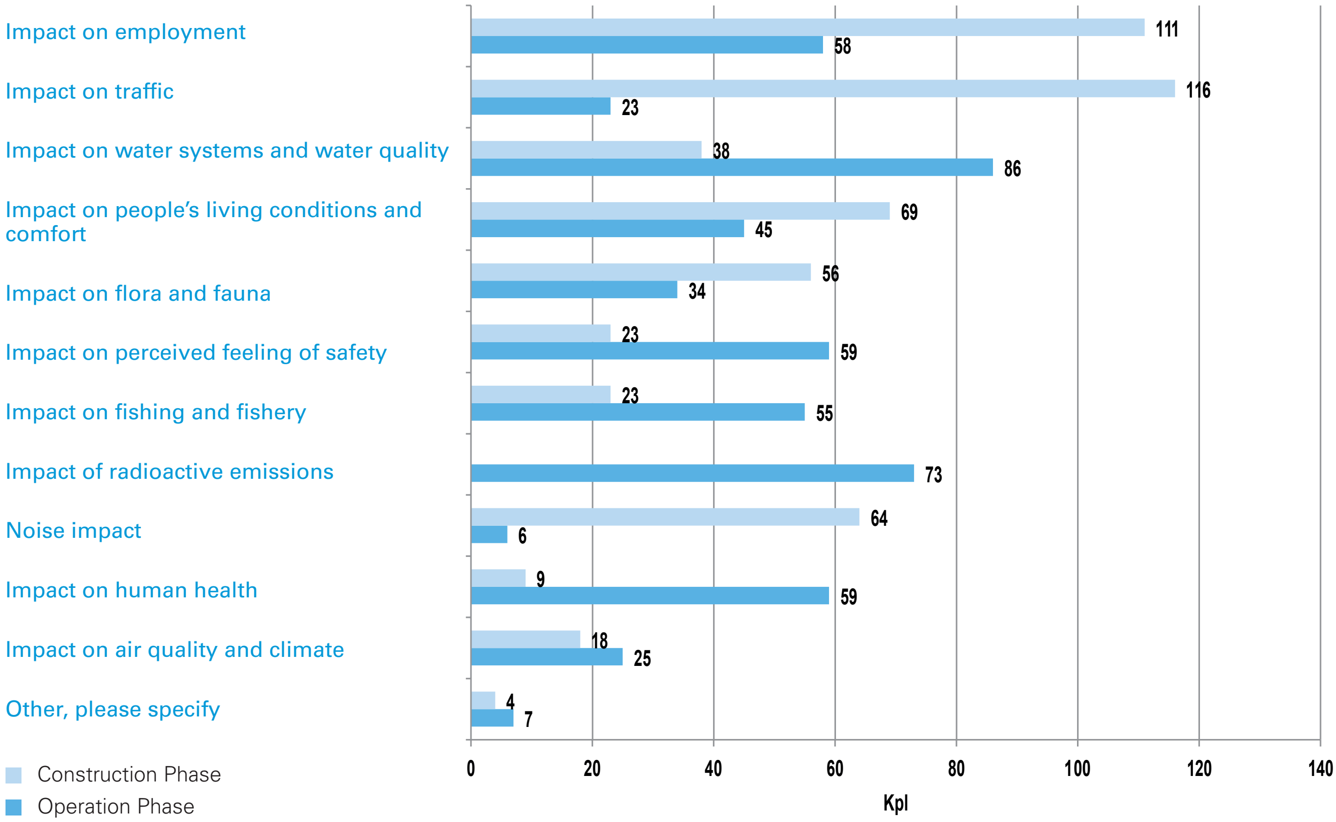


Figure 7-45. Respondents' assessments on the project's most important impacts during the construction phase and operational phase.

of the nuclear power plant were studied with a question where the respondents were asked to select the three most important impacts during both construction and operation (Figure 7-45). The respondents were of the opinion that the most important impacts during the construction phase would be the impact on employment (111 responses), impact on traffic (116 responses), impact on people's living conditions and comfort (69 responses), and noise impacts (64 responses). The same issues were considered the most important in the 2008 resident survey. Other impacts mentioned included the impact on nature conservation areas, the impact on fishing waters, multinationality, and the use of foreign labor. Holiday residents considered the impact on the environment to be more important than the permanent residents.

The respondents were of the opinion that the most important impacts during the operation phase would be the impact on water systems and water quality (86 responses), the impact of radioactive emissions (73 responses), the impact on people's perceived feeling of safety (59 responses), and the impact on people's health (59 responses). Most of these issues considered important during the operation phase were also considered important in the 2008 resident survey. Other impacts mentioned included the impact from the spent nuclear fuel and the impact on tax revenue.

The respondents were shown several statements on the project and its environmental impacts with three response alternatives ("I agree", "I disagree" and "I cannot say") (Figure 7-46).

Approximately 53 % of the respondents stated that they are in favor of constructing the Fennovoima nuclear power plant and 39 % stated that their attitude towards the project is negative. There was no similar question in the survey of 2008. The attitudes of the holiday residents were slightly more negative than those of the permanent residents. The attitudes of women and men were clearly different from each other. About 64 % of the men were in favor of the project while 28 % opposed the nuclear power plant. Of women, 38 % were in favor and 56 % opposed the project. The attitude towards the project also depended on the respondent's place of residence. Around 38 % of those living less than five kilometers from the plant site were in favor and 55 % opposed the project. The attitudes of people living 5–20 km from the plant site were clearly more positive, 61 % of them were in favor and 32 % opposed the project.

Almost two in every three respondents (60 %) were of the opinion that the nuclear power plant would benefit the region. In 2008 47 % of the respondents were of this opinion. More than half of the respondents (58 %) believed that the nuclear power plant will be safe once completed, while a little over a quarter (28 %) suspected the project's safety. A significant share of the respondents (46 %) believed that they are unable to influence the project's environmental impact assessment procedure. This distribution of responses is almost exactly the same as the distribution of responses for this statement in the 2008 resident survey. However, more than half of the respondents believed that the environmental impacts will be thoroughly studied.

The respondents were asked whether there are any particularly susceptible areas, sites, or activities close to the project site which the respondents believe the construction and oper-

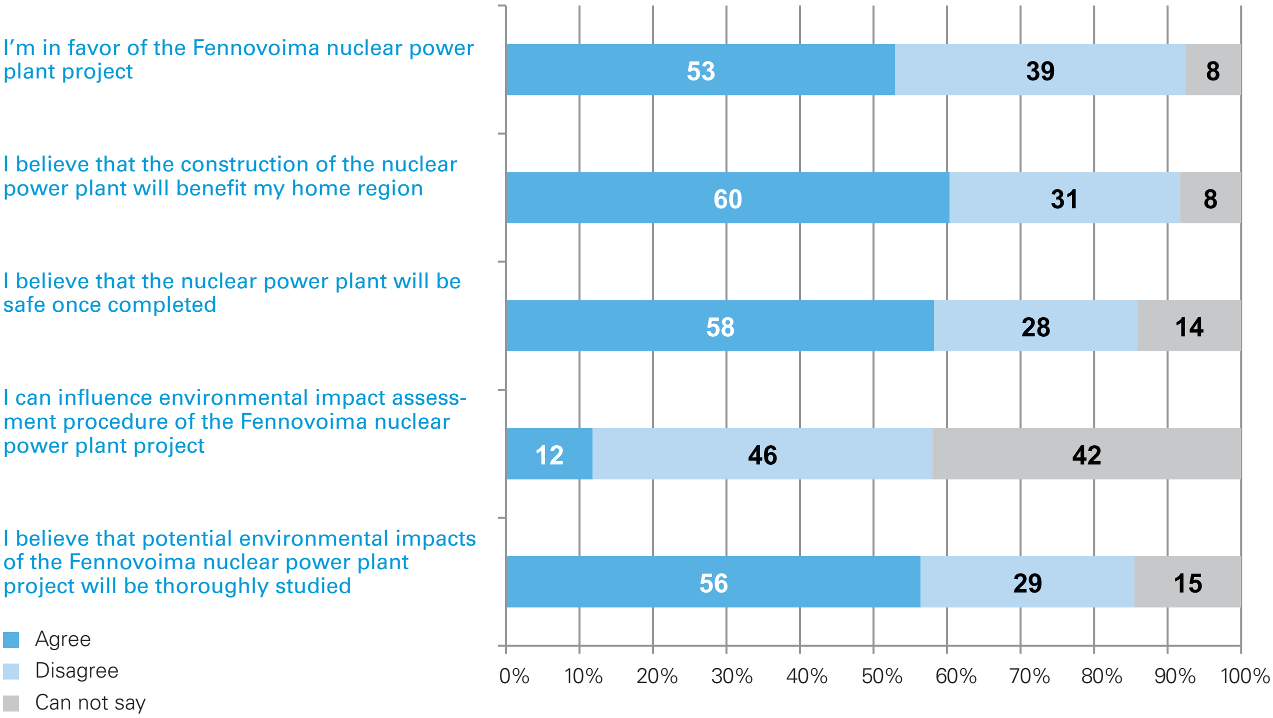


Figure 7-46. Respondents' responses to the statements about the project (n = 169–172).

ation of the nuclear power plant would influence. Most of the responses referred to the area's nature and recreation values. The respondents were concerned whether the recreational opportunities, such as fishing and hunting, would remain. The land and sea area of Hanhikivi headland was considered an especially vulnerable recreation area which is currently in its natural state and which is valuable for both people and animals. Other vulnerable items mentioned included the white-tailed eagle, monuments of antiquity, fishing waters, species protected by the Habitats Directive, seawater, avifauna, local agriculture, people's holiday homes, and the moor frog.

The respondents were asked to state means that could be used to prevent and mitigate possible adverse impacts or risks. The respondents considered active communication with different stakeholders during the different phases of the project to be an important means of mitigation. They also wished that communication about problems, if any occurred, would be open. They presented a wish that the traffic routes and safety arrangements in the area would be functional and good. They hoped that the project would be optimally planned and supervised. They hoped that the construction workers would be competent and that proper working conditions would be arranged for migrant labor. Some of the respondents proposed using as many Finnish employees and the services of as many Finnish companies as possible. The respondents proposed that dredging should take place in the wintertime and traffic arrangements improving the traffic routes would be made on main road 8. Measures proposed to minimize the impacts on the water systems included careful processing of service water and building a protective breakwater on the cooling water intake. Most of the respondents who stated that they oppose the project proposed refraining from building the nuclear power plant or transferring the project to another location as the mitigation means.

Communications and other issues

The respondents were of the opinion that they had received enough information about the project (Figure 7-47). A small number of respondents even stated that there had been too much information about the project. The distribution of opinions is very similar to that of the survey implemented in 2008. The respondents were especially interested in the project's safety, issues pertaining to the final disposal of spent nuclear fuel, the project's environmental impacts, employment opportunities, and the project's impacts on people. Other issues mentioned by the respondents included the project's impact on agriculture and on the value of real estate as well as changes in people's living environment during construction. The respondents wanted more information about the nationality of employees participating in the project and any adverse impacts caused by the large-scale construction project, such as adverse impacts on the sense of community and a variety of side effects. They hoped that information about the project be communicated via a wide range of communication channels. They wished to obtain information about the project online, from newspapers, and from interactive events. They hoped that visits to the project site would be arranged.

Key issues in which the respondents wished the project organization to pay attention to during project planning were related to safety factors. Safety issues were mentioned in many of the answers to the open-ended questions, and the respondents proposed several means that could be used to promote safety of the project. In addition, they hoped that

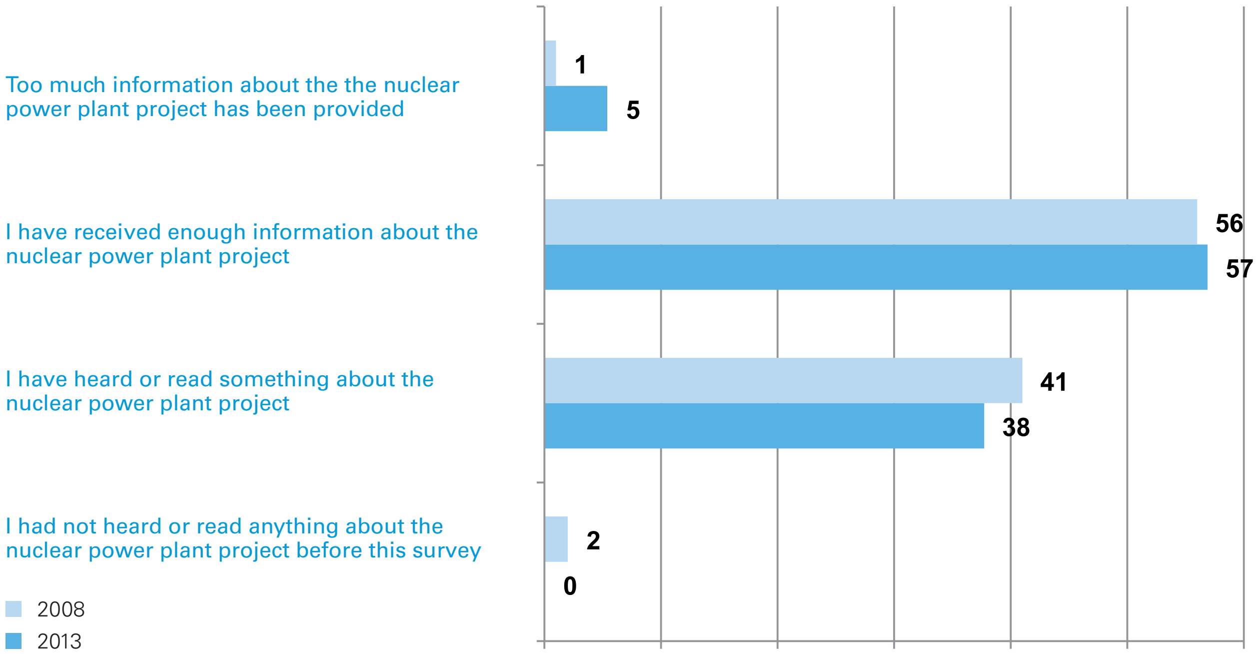


Figure 7-47. Respondents' assessment on sufficiency of communications (n = 167). The results in 2008 are shown for comparison purposes.

attention would be paid to the project's potential impacts. The respondents presented a wish that as much Finnish workforce as possible would be utilized during the project's construction phase and operational phase to maximize the project's positive impacts on the national and local economy. They wished that the environmental impact assessment would take into account the project's impacts on the natural environment, safety, and people. The respondents highlighted the importance of a safe living environment and valuable natural environment for the local residents.

Women, holiday home owners, and people living close to the project site were somewhat more critical towards the project than the other respondents in average. Groups opposing the project have been established in Pyhäjoki, and there have been some conflicts between the parties opposing the project and the parties supporting it. The opponents of the project consider the project unsuitable due to the environmental values and the safety issues associated with the operation of nuclear power plants. The respondents' opinions on the project's impact on the value of real estate had become more positive.

To a large extent the results of the survey were similar to the results of the resident survey in 2008. However, the response rate was very low when compared to that of the resident survey in 2008.

7.10.3.2 Summary of the group interviews

The group interview of the representatives of Parhalahti village association

The representatives of Parhalahti village association participated in a group interview on November 21, 2013 at Pyhäjoki Town Hall. Based on the group discussion, the general perception of Fennovoima as a company and its activities so far is fairly positive . A local office that was opened at an early stage of the project has been an excellent means to provide information. The atmosphere at the office has been moderate and fair as comes to the project, and many people have visited the office.

The participants of the group interview stated that relations between some of the residents of Parhalahti village have become more tense due to the project. However, there were some old disputes about redistribution, for instance, among the local residents already before the nuclear power plant project. The participants were of the opinion that it is unlikely that Fennovoima as a company could have acted in a manner that would have prevented the local disputes about the location of the power plant site. Fennovoima has participated in local leisure activities, such as the Parhalahti Day, by donating money, which has made the image of the company more positive. The Parhalahti Day has been arranged twice so far. People opposing the project also participated in the event.

Attitudes of the participants of the group interview towards the entry of the Russian company into the project were still expectant, and they stated that the project will be a showcase project for Rosatom. They were also optimistic because a partner with good financial standing had committed to the project. Rosatom becoming a partner was a surprise to the local residents, but they trust Rosatom more than the prospective plant suppliers studied previously. Cooperation with Russians has been going on for thirty years, during which Rautaruukki was built.

According to the Parhalahti village association, it is clear that the current confrontation started with the local ownership of the lands and issues pertaining to losing land. People stressed the importance of the sentimental value pertaining to land areas in the discussions conducted at the group interview.

> *"It all boils down to the difficulty of letting go. Not more than 5 % of the residents of Pyhäjoki had even visited Hanhikivi before the project started."*

> *"Now they say that nature values outweigh all of the project's benefits. The sentimental values are clearly much more real, but they have been left in the background while people only talk about the nature values."*

The participants stated that the loudest confrontation has ceased and the atmosphere in the area has improved. Everybody still sticks to the position they took at the very beginning of the project, however. In addition, the deadlock of the municipality versus the people opposing the project seems to still continue.

> *"Information and counterarguments are useless: nobody will change their mind."*

The locals considered it very important to reach a decision about the project as soon as possible. The time spent waiting for a decision has caused local services to wither and has taken the opportunities to benefit from the project in the future. The project would give rise to an opportunity to restore the service level in Pyhäjoki in a controlled manner.

> *"Raahe will benefit a great deal. The same will happen as in Rauma: new people will come to the region and bring new life with them. A larger town with better services will benefit the most. The benefits will spread to a wider area than just Pyhäjoki."*

A wind farm is being planned in Parhalahti,which would prevent hunting in the area. This is one of the reasons why the participants did not consider wind power to be a better alternative for producing energy than nuclear power. People also hunt in the Hanhikivi headland area, and this is why the participants hoped that the municipality would dedicate other substitutive areas to hunting. That would be considered a gesture of good will from the municipality.

If the project is realized, those that will lose the most will be the holiday home owners who no longer can use the area. Furthermore, hunters will no longer be able to hunt on the Hanhikivi headland. The participants were of the opinion that the project's impact on fishing would not be major because only a few people practice net fishing in the area, there are no professional fishermen, and there are other fishing grounds to the south of the project site. People go duck shooting a little farther away from the project area, at the mouth of Liminkajoki river.

The participants expect Fennovoima to keep in close contact with the local residents in the future. Communication will be necessary, particularly when the large-scale construction project starts. Other important issues mentioned included arranging regular public events and village evenings to tell the people what has been and will be done. If the project were not realized, the participants would expect Fennovoima to assist them in utilizing the already made investments in the new situation.

The group interview of the representatives of Pyhäjoki municipality

Representatives of the social and welfare services, educational services, and local parish of Pyhäjoki participated in a group interview on November 22, 2013 at Pyhäjoki Town Hall. The participants were of the opinion that the attitude towards Fennovoima among the residents of Pyhäjoki is quite good. All of the information that has been needed has also been provided. It seems based on the discussions that there are only few arguments or conflicts among the local residents about the project. Based on their experiences at work, the participants were of the opinion that the attitude of people towards the project is fairly neutral and conflicts have occurred only among a small group of people.

There have been single cases where people have voiced concerns or distress about the nuclear power plant project. Hanhikivi headland is an important childhood location and an important recreational area for some people. They feel distressed when thinking about losing the area. Most of the local residents have never visited Hanhikivi headland, but now the area has gained a greater reputation than ever before.

> *"People have maybe gone to Parhalahti to swim at some point in the past, and that is all. The villagers will not lose anything. Hanhikivi headland was a forgotten place. Not all of the people in Parhalahti village are aware of the disputes among landowners."*

> *"The villagers have not sought outside help. Not even schoolchildren have talked about the project or any related conflicts. People do not like to disparage outsiders. These are disputes between few individuals."*

In the future, the participants want open and honest communications, a separate communication channel, and communication on the company's website and in the media. The municipality will carry a large share of the responsibility for communications also in the future.

> *"Fennovoima should come from Helsinki to Pyhäjoki to show that they are committed to the area instead of just wanting to benefit from it. Just the office is not enough. Social responsibility."*

The participants were of the opinion that the project is a more significant issue for those who oppose it. In the participants' opinion, those that will lose the most if the project is realized are single residents in the Hanhikivi headland area.

> *"It would also be a bad situation for those who oppose the project if the project is not realized: they would be blamed."*

The participants stated that information about the location of the final disposal of spent nuclear fuel should be communicated as soon as possible, since this information would make the situation more clear to everyone concerned.

The group interview of the representatives of Pro Hanhikivi ry

Representatives of Pro Hanhikivi ry association participated in a group interview on November 22, 2013 at Iikkala Daycare Center in Parhalahti. The participants were of the opinion that communications by Fennovoima have seemed more like an advertising campaign, in which the potential drawbacks have not been discussed to a sufficient extent. The participants noted, however, that Fennovoima has not prevented people's access to information or prevented them talking about the issues. Pro Hanhikivi ry has arranged seminars and other events about the power plant project at its own expense. The actions of the association are based on a specific set of values, not based on emotions. Up until 2010, the members of the association wished to reach an understanding with the municipality, but such an understanding was never reached and now the actions of the association have drifted farther away from those of the municipality.

> *"Everybody is weary of the project. People do not return the resident survey, for example. They feel that they cannot influence the issue."*

The participants were of the opinion that the municipality has been blinded by speed. The project has been promoted by any means necessary, eliminating all barriers, such as opposition views.

> *"Behavior of the municipality has been inappropriate: they have intimidated and blackmailed people. It's great that businesses are being developed, but the local residents should not be forgotten."*

The members of the association are of the opinion that staying in Pyhäjoki would be difficult.

> *"If the project is realized, we will leave because we will lose the area, the power plant will be close to our homes, and the neighborhood will become restless. There are no guarantees that the power plant will stick to the promised emission limits during its operation. The municipality cannot be trusted. The area will become an industrial area; it will no longer be a rural area but a village consisting of bunkhouses. All parts of our lives will be broken and upside down. Those players, who know how to benefit from everything, will win."*

> *"If the nuclear power plant is not built, we will be able to continue our lives from where we left them in 2007. Staying in the municipality may be difficult even if the nuclear power plant project is not realized, because people have labeled us."*

7.10.4 Construction phase impacts

7.10.4.1 Impacts on living conditions, wellbeing and recreational use

Construction of the nuclear power plant is a large project in terms of the comfort and living conditions of people in a very extensive area. The construction period, which will take approximately ten years, will have a significant social impact on the municipality of the plant location and in its immediate surroundings. The project will require a large number of employees, and new people will move into the area, particularly during the construction phase. Some of the employees will come to Finland from abroad.

The plan is to construct the nuclear power plant in the middle and north parts of the Hanhikivi headland. Most of the area is currently owned by Fennovoima. Fennovoima currently owns around 366 hectares of land and sea areas. Fennovoima manages these land areas either directly by owning them, or by having signed preliminary property transaction agreements or leases. The areas, which have been leased, include a binding letter of intent on the right to purchase the areas. Fennovoima will continue purchasing more areas on the Hanhikivi headland with the goal of owning all of the areas reserved for the nuclear power plant and its supporting functions in the land use plans. The areas will primarily be obtained by signing voluntary agreements, but Fennovoima also submitted in May 2012 an application to the Government for a redemption permit based on the Act on the Redemption of Immoveable Property and Special Rights (603/1977).

Demand for services and homes in the area will quickly increase at the construction phase. On the other hand, the supply of services both in the municipal sector and in the private sector will also increase. Availability of services may be compromised for a short period of time if the necessary preparations are not made and the required resources are not obtained in due time. Ensuring the availability of the required housing, healthcare, and education services will be especially important.

The project will cause impacts that influence comfort and health during the construction phase, such as noise, dust, and traffic. According to the noise modeling results, the noise caused by the construction work and traffic will remain minor in the areas including permanent and holiday homes. The activities during construction are not estimated to have any significant impact on air quality. The traffic volumes of the current roads leading to the power plant site will clearly increase. One of the key mitigation measures mentioned in the resident survey responses was ensuring the functionality of roads and access routes. The road to be built on the Hanhikivi headland will be designed taking into account safety of the intersection and fluency of traffic at the intersection.

Hydraulic construction work will cause some temporary turbidity of the water, which may reduce comfort at a nearby beach and the shores of holiday homes. The construction site and its new traffic routes will be clearly distinguishable in the local landscape.

The variety of cultures and languages that will be brought to the area by foreign employees at the construction phase will provide the region's municipalities, entrepreneurs, and residents an opportunity of globalization. Any cultural clashes and disturbances can be prevented by, for instance, familiarizing foreign employees with Finnish culture and practices, and by organizing sufficient leisure-time activities.

The respondents to the resident survey mentioned the employment impacts, the impact on traffic, the impact on people's living conditions and comfort, and the noise impact as the project's most important impacts during construction. The participants in the group interviews brought up basic services required during the construction phase, such as accommodation and healthcare services, and the disadvantage caused by the construction site to the local residents.

7.10.4.2 Impacts on health

As mentioned above, the health impacts during construction, such as noise, dust, traffic, and exhaust gas emissions, will not cause any significant impacts on people's health.

No radioactive emissions will occur during construction since no radioactive spent nuclear fuel will be present at the plant site before the start-up of the nuclear reactor. Since nuclear fuel does not contain significant levels of radioactivity, no radiation protection measures are required for its storage or handling before commissioning of the nuclear power plant and the start-up of the nuclear reactor.

7.10.4.3 Impacts on the regional economy

Due to the large-scale of the project, it will influence the demographic structure, municipal economy, migration, and for example the housing market. The municipality of Pyhäjoki will receive property tax for the nuclear power plant starting from the construction phase. The project will improve employment and the income level in the area. The improved income level will increase consumption. These impacts will also extend to the neighboring economic areas. (*Pöyry Energy Oy 2008*)

The nuclear power plant project is a significant construction project the total investment of which will be around €4,000–6,000 million. This sum also includes the costs from the construction of the harbor basin, the breakwaters, and the navigation channel. Additional investments will also be necessary when constructing the road, for instance. The project will employ a large number of people both directly and indirectly during the construction phase. The project's employment impact will not affect just Pyhäjoki and the economic area, but the whole of Finland. In addition to the employment impact, the project will influence business life in Finland, the demographic structure of the local municipalities, availability of services, the housing market, and migration.

Employment impacts in Finland and the economic area during construction

It has been estimated that the construction phase of the nuclear power plant will be ten years. How the investment is distributed into smaller parts and the degree of domestic origin of each part will depend on the delivery method, among other issues. Approximately half of the total investment value is estimated to be suitable for Finnish suppliers. The investment's impact on the regional economy has been studied based on the assumption that the degree of domestic origin will be 45% (*Pöyry Energy Oy 2008*). Depending on the degree of domestic origin, the investment in Finland will be €1,800–2,700 million.

The economic impact in Finland will consist of construction engineering work (42%), machinery and equipment (31%), and project-related and other services (27%) (Table 7-15).

According to an estimate by FinNuclear ry association, the Fennovoima nuclear power plant project will provide significant business potential for Finnish companies. According to Rosatom, acquisitions – excluding the reactor – will make up approximately 80% of the total acquisition value. These will be deliveries involving components of lower safety classes which many Finnish companies will be able to deliver, provided they obtain the qualifications needed to become a nuclear sector supplier in due time and are able to deliver the large entities or the special expertise that is usually favored in acquisitions of this type. (*FinNuclear ry 2013*)

If the degree of domestic origin is 45%, the project's estimated employment impact during construction is approximately 24,000–36,000 man-years, depending on the investment size (Table 7-16). When divided evenly among the ten-year construction phase, the project's employment impact will be 2,400–3,600 man-years. The number of employees working at the power plant site will be at its highest four to five years after the start of the construction phase. Approximately 3,500 employees will be working onsite at that point.

Table 7-15. Distribution of the economic impact in Finland if the degree of domestic origin is 45%.

	Share of total investment, %	Degree of domestic origin, %	Domestic share of investment, %	Domestic share of investment, M€
Machinery and equipment	55	26	14	560–840
Construction work	30	64	19	760–1,140
Project-related and other services	15	77	12	480–720
Total	**100**		**45**	**1,800–2,700**

Table 7-16. Employment impacts of the project during the construction phase with a 45% degree of domestic origin.

	Direct impact, man-years	Indirect impact, man-years	Total impact, man-years
Machinery and equipment	2,240–3,360	2,800–4,200	5,040–7,560
Construction work	5,320–7,980	4,560–6,840	9,880–14,820
Project-related and other services	6,240–9,360	2,880–4,320	9,120–13,680
Total	**13,800–20,700**	**10,240–15,360**	**24,040–36,060**

Indirect employment impacts will occur through companies providing intermediate inputs and services. Such indirect employment impacts include subcontracting, supply of building materials and supplies, and transport services. (*Pöyry Energy Oy 2008*)

Jobs will also be created in Finland indirectly during construction of the power plant as private and public consumer demand increases. The demand is expected to increase at the location of the power plant and in the economic area. These impacts will also extend to a wider area because most of the products required by the project will be manufactured outside of the economic area. Thus, the project's employment impacts will also be targeted to the locations where the products are manufactured.

The foreign employees of the project will also spend at least part of their wages in Finland. It has been estimated, based on previous projects, that some of the foreign employees will bring their families to Finland with them. Some of the increased demand for public services, such as social welfare and healthcare services, and the consequent employment impact will be targeted to the whole economic area in addition to the project location. The increased demand for services may temporarily impair the availability of public services.

The employment impact on the economic area has been assessed based on the assumption that the share of the total employment impact influencing the economic area will be approximately 20–25% (*Pöyry Energy Oy 2008*). In this assessment, it is assumed that the employment impact will only involve construction and services required by the construction site. The total employment impact on the economic area would be, depending on the investment size, approximately 4,800–9,000 man-years during the ten-year construction period, or an average of 480–900 man-years per year.

Most of the employees needed from the economic area during the early stages of construction would be construction workers and service employees, while most of the employees needed during the latter stages of construction would be mechanics to install machinery and equipment. The share of Finnish workforce will be lower in these positions.

The significance of the impact will depend on, for instance, how many competent employees and competent companies there are in the area to participate in contracting and subcontracting. Companies operating in the area can influence the regional allocation of the employment impacts by training competent employees for the needs of the construction phase. Furthermore, the companies can form partnerships to improve their opportunities to make contracts. The project could have an adverse impact on some of the local companies as the demand for workforce increases if the cost of workforce for example in the construction sector were to increase.

7.10.5 Operation phase impacts

7.10.5.1 Living conditions, wellbeing and recreational use

The nuclear power plant project will influence for example living conditions in the surrounding areas, land use, the landscape, and to some extent fishing in the area. These impacts are discussed in more detail in Sections 7.2, 7.4, and 7.5.

Living conditions and wellbeing

The grounds of the nuclear power plant extend approximately one kilometer from the plant (Chapter 3). Some holiday homes will have to be removed from the southwestern shore of the Hanhikivi headland, and the shore in the area can no longer be used for recreational purposes. Land use on the northeastern and northern shores, which are important areas for nature conservation and recreation, will mainly remain unchanged.

The protective zone of the nuclear power plant will extend approximately five kilometers from the plant, restricting land use in the area to some extent. Densely populated areas, hospitals, or institutions in which a large number of people will visit or reside, or important production activities which could be affected by an accident at the nuclear power plant, may not be placed inside the protective zone. The nuclear power plant operator must be able to control all operations at the plant site, and moving around the area will be prohibited or restricted. Otherwise, the normal operation of the nuclear power plant will not restrict movement or recreational activities in the area surrounding the plant, except for the unfrozen water areas and areas with weaker ice.

A significant environmental impact of the nuclear power plant will be the thermal load caused by the cooling water. This will be visible particularly in the wintertime when unfrozen water areas and areas with weak ice cover will restrict recreational activities that take place on ice. In Pyhäjoki, the cooling water will keep the water unfrozen and the ice cover weak mainly to the north and east of Hanhikivi headland. There are no ice roads or official snowmobile routes that people would no longer be able to use. On cold winter mornings, a fog will form over the unfrozen water areas. The fog will not disturb maritime or road traffic, however.

As illustrated by the responses of the resident survey, those who are in favor of the project are of the opinion that the significant economic impacts of the project will increase wellbeing in the area, and these impacts will also influence the whole country in addition to the economic area. The project is expected to improve employment in the area and the nuclear power plant is expected to create significant annual property tax revenues for the municipality of the plant location as well as income tax revenue for the entire region created by the new jobs. Some of those opposing the nuclear power plant oppose electricity generated by nuclear power as such, while others do not oppose nuclear power itself but do not wish to have a nuclear power plant in their own town.

The project will change the landscape and thus the living environment of local residents, holiday residents, and recreational users. Impacts on the landscape in the vicinity of the power plant construction area will be significant: the current forested nature area will become a large-scale constructed environment. The landscape impacts from other activities related to the project will also change the living environment of the area. The most significant changes in the landscape from the viewpoint of holiday residents will be the changing of the view from the sea. These changed views can be seen from the areaof Maunus and Syölätti, for example.

Traffic volumes in the immediate vicinity of the project area and along the transport routes will increase, particularly to the north of the Hanhikivi headland. The increased traffic volume can be considered significant, and it may cause some sporadic disadvantages to those moving in the area. Traffic safety may also decrease. During the operation phase, the traffic volume will increase when there is an annual outage at the nuclear power plant. The noise impact on people will be at its highest during the construction phase. The noise impact during the operational phase will be minor.

Recreational use

The project's greatest impacts on recreational use involve fishing and hunting. The sea area in front of the Hanhikivi headland is significant both in terms of the fish stock and in terms of fishery. The degree of professional fishing is low: three of the professional fishermen in the area are classified as professional fisherman of the category 1, three of the category 2, and the rest are of the category 3. Most of the fishermen, around 80% of them, are category 3 fishermen, who receive less than 15% of their total income from fishing. The project will reduce the opportunity of professional fishermen to obtain their income from the area.

The unfrozen water areas during winter will make ice-fishing more difficult but it will extend the open water fishing season. Potential disadvantages to recreational fishing may include difficulties in catching whitefish and excessive build-up of slime in nets.

Due to the project, most of the Hanhikivi headland area will no longer be available for hunting use. According to a representative of Parhalahti hunting club, an important hunting area of the club will become inaccessible. Areas suitable for hunting waterfowl on the northern and northeastern shores of the headland will not be affected. If the wind farm currently planned for the Parhalahti area is built, it temporarily reduces hunting opportunities in the area.

People may be less willing to fish, gather berries and mushroom, or use the area for recreation purposes in the surroundings of the power plant. The area will change from an area in its natural state to a constructed industrial area. Different activities, and for example noise and lighting will reduce the area's recreational value.

Continuously taking samples from water and land areas is part of the radiation control procedure of a nuclear power plant (Chapter 10). Samples taken from land areas include samples of natural plants, potable water, naturally growing produce (berries and mushroom), game, agricultural products, and horticultural products. Nuclear power plants must quarterly report the results of their radiation control activities to the Radiation and Nuclear Safety Authority. Radioactive substances originating from Finnish power plants have been observed very rarely in samples taken from land areas. Radioactive substances are found a couple of times per year in continuously taken air and fallout samples. The contents observed in the samples have been very low and can only be detected using very sensitive measurement methods. No radioactivity originating from Finnish power plants has ever been observed in milk, grain, meat, mushrooms, berries, apples, or the grass cattle grazes on. Moving in the vicinity of a nuclear power plant and picking natural products can be done as before. Eating berries and mushroom gathered or fish caught from the area is safe (*Säteilyturvakeskus 2013*).

Should a severe accident occur, civil defense measures would be implemented in the immediate vicinity of the nuclear power plant, and the use of food products would be restricted. A severe accident is highly unlikely, however. The impacts of a severe accident are discussed in more detail in Section 7.13. During the normal operation of the nuclear power plant, the protective zone (approximately 5 kilometers) and the emergency planning zone (5–20 km) around the plant will not influence the everyday life of the local residents.

7.10.5.2 Impacts on health

Impacts of radiation

Radiation dose of local residents

During operation of the power plant small amounts of radioactive substances will be released both into the air (Section 7.3) and into the sea (Section 7.4) in a controlled manner after being filtered and delayed to decrease the radioactivity. These nuclear power plant emissions will be effectively diluted by the air and sea water surrounding the power plant. Consequently, the concentrations of radioactive substances accumulating in the surroundings of the power plant will be very low and can only be detected using sensitive measurement methods. The emissions during normal operation will be so low that the consequent radiation dose to the population will be impossible to measure. This is why the radiation dose of local residents is estimated by calculation.

A person representing the group of people that will be subject to the most emissions, i.e. a person whose radiation dose will likely be the highest due to their place of residence and lifestyle, has been specified when calculating the radiation dose to the general public. The calculation was done using a hypothetical person living in the immediate vicinity of the power plant. This person mainly eats natural produce gathered from the surroundings of the power plant – such as local berries, mushroom, fish, and drinks milk from a local farm and eats local grain and meat products. In addition, the person spends a lot of time on the beaches close to the nuclear power plant and swims in the sea. The result is very conservative – in practice, the calculated radiation dose is the highest possible dose a person could get living in the immediate vicinity of the nuclear power plant. The local residents will actually receive doses that are much lower than the calculated conservative dose. *(STUK 2013l)*

According to a Government Decision (395/1991), the normal operation of a nuclear power plant can cause a maximum annual radiation dose of 0.1 mSv to an individual living in the vicinity of the power plant location. This limit value is specific to the nuclear plant location and concerns all the plant units and operations at the location. This limit value forms the basis for determining the nuclide-specific limits for the nuclear power plant's radioactive emissions into the air and sea. The radiation exposure of people living in the immediate vicinity of the existing Finnish nuclear power plants is assessed annually on the basis of the plants' emission data, environmental samples, and meteorological measurements. The calculated radiation dose for the most exposed (critical) group of the population living in the surroundings of the Loviisa and Olkiluoto nuclear power plants amounted to less than 0000.1 mSv in 2012. This dose is less than 0.1% of the limit value (0.1 mSv) laid down in the Government resolution and only a fraction of the annual dose an average person living in Finland receives from other sources (3.7 mSv). (*STUK 2013l*). No increased risk of cancer has been observed in the immediate surroundings of nuclear power plants in Finland *(Heinävaara et al. 2009)*.

The yearly radiation dose caused by the emissions from the operation of the Fennovoima nuclear power plant for the most exposed resident in the immediate vicinity has been estimated, at maximum, to be as high as the dose caused by the existing nuclear power plants, which is less than 0.0001 mSv. The radiation dose from the power plant will be less than one hundredth of the annual radiation limit of 0.1 mSv laid down for the nuclear power plant (in Government resolution 395/1991) and less than one thousandth of the average radiation dose of a person living in Finland (which is approximately 3.7 mSv). The radiation dose is so low that it will not have any direct impacts on human health. The radiation doses caused by a severe nuclear accident and the resulting impacts are discussed in Section 7.13.

Radiation dose to nuclear power plant employees

The radiation doses of nuclear power plant employees are mainly accumulated during outages when the employees work close to active components and open systems. The radiation dose of an employee depends on the duration of outages and their job tasks relevant from the radiation protection perspective. (*STUK 2013f*)

According to the Radiation Decree (1512/1991), the radiation dose incurred by an employee through radiation work may not exceed the average of 20 mSv per year over a period of five years and the value of 50 mSv during any single year (cf. the maximum limit of 0.1 mSv for the most exposed resident). To limit the personal radiation exposure of employees in compliance with the ALARA (As Low As Reasonably Achievable) principle, a nuclear power plant must always have more strict dose limitations in place than those laid down in the Radiation Decree *(STUK 2013p)*. The Radiation and Nuclear Safety Authority monitors the personal radiation doses of nuclear power plant employees working in Finland and compliance with the dose limits. The largest radiation dose received by a nuclear power plant employee in Finland was 14.3 mSv in 2012, which was clearly below the limit value. In addition to the radiation doses of individual employees, the Radiation and Nuclear Safety Authority monitors the combined total dose of all nuclear power plant employees, i.e. the collective dose. The collective doses provide information about how successful the radiation protection of employees as a whole at the nuclear power plant has been.

The power plant will be designed in so that the radiation doses of employees will remain lower than the radiation dose limit values, both during operation and during outages. All work that will subject the employees to radiation will be planned and supervised in compliance with the radiation protection guidelines.

Other health impacts

In addition to radiation effects, health impacts during operation of the nuclear power plant have been assessed with the help of a noise impact assessment (Section 7.9). The health impacts of the project have been assessed by comparing the results of the noise modeling with the guideline values for noise. Very loud noise may have an adverse impact on the health and wellbeing of people exposed to it for example by disturbing their work, rest, and sleep. According to the noise modeling results, the noise guideline values will not be exceeded in the areas with permanent and holiday residences, and therefore the noise is not expected to cause any significant health impacts. It is possible, however, that noise impacts will make the area less comfortable at times. The threat perceived from a nuclear power plant and people's fears regarding the project may cause stress, which may – if prolonged – have adverse impacts on their health.

7.10.5.3 Regional structure, regional economy, and employment

Employment impacts in Finland and the economic area during operation

It has been estimated that the direct annual employment impact in Finland during operation will be around 400–500 man-years. Of these, around 100 man-years will be connected to services outside the nuclear power plant, such as rescue, catering, security, cleaning, and transport services. Furthermore, commissioning personnel will work onsite during the project start-up phase. Each annual outage will employ around 500 people for one to three weeks, meaning approximately 10–30 man-years annually. Most of the employees participating in the annual outages will come from outside the economic area.

During the operation phase, the project will create – in addition to the direct employment impacts – indirect employment through intermediate input chains and increased consumption. A variety of supplies and materials will be needed for the operation, maintenance, and outages of the power plant. The manufacture of these supplies and materials will also have an employment impact. Some of the supplies and materials will be manufactured in Finland and others abroad. Also in the construction phase, as the employment situation and people's purchasing power will improve, the demand for private services will increase, which in turn will create new jobs. (*Pöyry Energy Oy 2008*)

The demand for private services will distributed within the economic area according to where people live, but the employment impacts will be carried via the intermediate input chains to the whole of Finland and abroad. Investments to infrastructure will create new jobs. The municipalities in the affected area will have to construct the buildings needed for municipal infrastructure and services for the new residents. New jobs will created in housing production, especially at the beginning of the operation phase when some of the new residents moving into the area either build a house or have one built. Many of these impacts will influence the economic area, but as a whole the employment impact from construction will influence the whole of Finland extensively. If the project is realized, it may have a significant impact on employment also through investments made by the owners of Fennovoima.

The employment impacts on the economic area have been assessed based on the assumption that approximately 85 % of the permanent employees and outside service providers will live permanently in the municipalities of the economic area. For example, around 85 % of the permanent employees of the Loviisa Nuclear Power Plant live in the local economic area. The direct annual employment impacts would be approximately 340–425 man-years with the 85 % assumption.

Jobs will be created indirectly in the economic area through the increased consumption level and the increased economic vitality during the operation phase. The employees and their families, who will move to the area, will use both public and private services. The public services they require will mostly be municipal social welfare, healthcare, and education services. The employment impacts arising from the intermediate input chain during operation has been estimated to occur mainly outside the economic area.

In addition to the permanent employees, employees participating in annual outages will create seasonal demand for accommodation and catering services. This means that some of the companies in the area may have to hire temporary employees. The project could have an adverse impact on some of the local companies as the demand for workforce increases if the cost of workforce were to increase for example in the construction sector.

Impact on tax revenue

The most significant impacts on the economy of the municipality of Pyhäjoki will occur in the form of property and income tax revenue. The municipality of Pyhäjoki will collect property tax from the nuclear power plant starting from the construction phase. The property tax revenue will be at its highest at the time when the plant is completed. According to the revised Property Tax Act (654/1992), the maximum property tax rate for nuclear power plants is 2.85 %. The property tax rate determined for power plants by the municipal council of Pyhäjoki in 2013 is 2.85 % (*Pyhäjoki 2013*). The taxable value of a nuclear power plant building is its replacement value less 2.50 % annual age deduction. However, the taxable value will always be at least 40 % of the replacement value. The property tax revenue has been estimated based on the assumption that the value of the plant would be approximately €150 million when completed. The real property tax revenue, if calculated with the property tax rate of 2013, would be approximately €4.2 million at the time of completion. After the power plant is completed, the property tax revenue will depend on development of the property's replacement value. The municipalities in the commuting area will also receive property tax revenue from new housing being built. Furthermore, the construction of new commercial properties will increase the tax revenue.

In a regional economy impact assessment drafted in 2008, during the construction phase of the power plant the cumulative income tax revenue of the economic area was estimated at approximately €17–27 million, depending on the degree of domestic origin. During the operation phase, the estimated annual municipal tax revenues was estimated at around €1.9–2.4 million. The tax revenues will depend on, for instance, the municipal tax rates, the share of employees living in the economic area, the wage rate, and the number of employed people. The municipalities in the economic area will also receive tax revenue from indirect jobs.

Fennovoima Oy operates on the Mankala principle, i.e. it is a non-profit operation. This is why Fennovoima is not liable to pay any corporation tax. The project will, however, increase the corporation tax revenue as the taxable income of the company's owners and that of other companies' increases.

Real estate market and housing

Construction phase

At the construction phase, there will be a demand for short-term temporary housing near the construction site and accommodation further away in the regional population centers. Up to some 3,500 people will be working at the nuclear power plant construction site. This is such a large number of employees that accommodation available nearby, bunkhouses to be erected at residential centers, rented apartments in the surrounding area of the plant site, and accommodation further away in the nearest larger cities will have to be used.

Most of the demand for rented apartments would be in the Raahe region. There were around 5,200 rented apartments in the Raahe economic area in 2012. Of these apartments, 200 were in Pyhäjoki and a little less than 3,000 were in Raahe (*Tilastokeskus 2013b*). Some of the employees could live in Oulu with joint transport arranged to the construction site.

The increased demand in the rental market could be reflected as an increase in the local rental rates. The construction phase, on the other hand, may lower the prices of the nearby holiday homes and prolong the time for the sale of properties.

Operation phase

During the operation phase, 400–500 full-time employees would be operating the plant and providing external services for the plant. Of these employees, 340–425 (85 %) are expected to settle permanently in the economic area. If all these employees were to move in from elsewhere, it would mean new demand for approximately 400 new apartments or houses in the economic area. Not all of these need to be new homes if there are vacant homes already available in the area, but the municipalities could attract new residents by offering them detached houses and the seashore plots. In practice, at least a part of the employees of the plant will be original residents who are already living in the economic area. Then also the demand for housing would be lower. During the start-up phase of the power plant, there will also be a demand for rented housing. The employees and their families may first move to the area and only start looking for a place of their own once they are there. The real estate market will probably revive to some extent due to the project. The increased demand for plots of land and housing may even cause the real estate prices to increase slightly.

Population and demography

The nuclear power plant will influence the population and demography at the municipality of power plant site and in the surrounding economic area because of the new jobs and the change in the employment rate. The permanent jobs available during the operation phase of the plant will attract new residents to settle permanently to the area. The number of new jobs and migration are interlinked, and how they affect each other depends on a variety of factors, such as availability of workforce and age structure of the local population.

In addition to employment opportunities offered by the nuclear power plant, there are other factors that will influence the volume of migration and population growth. These factors include, for example, comfort of the living environment, traffic connections, prices of property and housing, standard of service, and employment opportunities. Especially families with children may consider the availability and quality of healthcare, daycare, and educational services very significant.

If all of the 400–500 employees required at the operation phase moved in from outside the economic area and 85% of them remained in the area, around 700–900 new residents in total would move to the area based on the average family size of 2.1 persons. In practice, at least some of the employees of the power plant will be original residents who are currently unemployed or not part of the active workforce.

The people moving into the region would be better educated and younger than the present population in average. The plant would offer employment opportunities also for those graduating from universities located in the neighboring regions, enabling them to remain in the area. The population of Pyhäjoki and Raahe would expand and the average age of the residents would decrease.

7.10.6 Summary of the project impacts on people and society

The project is large in scale and it will influence the region's social and cultural environment. The nature and significance of the impacts will, however, depend on from where the employees come to the area, how many local services they use, and how they participate in the local social activities. Local actors in the area, such as the public and the third sector, can allocate and mitigate the positive and negative impacts by being proactive.

The project's social impacts can be divided into three main categories based on the project schedule (design, construction, and operation phase; Figure 7-48). The key adverse impacts at the design phase include perceived psychosocial impacts, such as concerns, fears, and doubts of the local residents. Some of the residents and other actors in the vicinity of the nuclear power plant consider the project to be a threat to their health. A severe nuclear power plant accident is highly unlikely, but even the minute prospect of an accident can cause feelings of fear and uncertainty.

Fennovoima will acquire control of the properties at the power plant site prior to the project's construction phase, which means that some people will lose their land areas or holiday homes. Based on the interviews with stakeholders, some people losing land areas and holiday homes combined with the current uncertainty about the realization of the project have already caused anxiety and fear among a group of local residents. Furthermore, some of the residents are concerned about the plant's health impacts. The project has caused concern and uncertainty for some people at the Parhalahti village, which is located approximately five kilometers from the planned power plant location. These people are concerned for example about investments related to their homes or their lands.

Impacts during the design phase

- Creation of conflicts between people opposing and people supporting the project
- Expectations on increased vitality of the area
- Fears and doubts in the immediate vicinity of the project site
- Limitations on land use and loss of properties
- Perceived psychosocial impacts (due to the prolonged processing)

Impacts during the construction phase

- Extensive impacts on employment and economy in the region
- Changes in the vicinity of the power plant site
- Environmental impacts during the construction phase
- Limitations of recreational activities
- Changes in the social and cultural environment

Impacts during the operation phase

- Significant, permanent impacts on the regional economy
- Changed identity and character of the area in the vicinity of the power plant site
- Changes in the immediate vicinity of the power plant site
- Limitations of recreational activities in the immediate vicinity of the power plant site
- Perceived psychosocial threats (such as the feeling of insecurity)

Figure 7-48. Summary of social impacts at different project phases *(based on Fennovoima Oy 2008).*

It became apparent during the small group interviews that some of the disputes among those opposing and those supporting the project have escalated and have come to a deadlock, which can be considered to be an issue that impairs people's living conditions. On the other hand, based on experiences of the employees of the municipal social and welfare services, educational services, and local parish, the attitude of most of the residents towards the project is neutral and there have been conflicts only among a fairly small number of people.

Approximately 53 % of the people who responded to the resident survey were in favor of the nuclear power plant while 39 % of the respondents opposed the project. The attitudes of the holiday residents were slightly more negative than those of the permanent residents. More men than women were in favor of the project, and the attitude of those living in the immediate vicinity of the power plant location was more negative than that of the other respondents. Most of the project's negative impacts involve lost land areas, adverse environmental impacts, or perceived insecurity and fear. People emphasized the project's impact on the regional economy and how these reflect to the vitality of the area and future opportunities as the project's positive impacts.

During the construction phase a large number of employees will work in the area. In addition to the project's employment impacts on the economic area it will influence the whole of Finland. Significant changes will occur in the immediate vicinity of the project site due to the changed landscape and increased traffic volume. The project's most significant impacts on recreational use involve fishing and hunting. The sea area of the Hanhikivi headland is significant both in terms of the fish stock and in terms of fishery. There are also professional fishermen in the area, and the project will decrease their opportunities to make a living in the area. Due to the project, the area will no longer be available for hunting. People may be less willing to fish, gather berries and mushroom, or use the area for recreation purposes in the surroundings of the power plant. A large number of employees will move to the area, which will make the social and cultural environment more diverse.

New employees and their families will also settle permanently to the Pyhäjoki region during the project's operation phase. This will have a favorable impact on the age structure and dependency ratio. The project's financial impacts include, for instance, property tax revenue. It has been estimated that several hundred direct jobs will be created in the area during the project's operation phase. The number of employees working at the power plant site will be at its highest four to five years after the start of the construction phase. Approximately 3,500 employees will be working onsite at that point. The financial impacts will have a very significant positive influence on the region's vitality, and they will strengthen both the public and the private sector. The building of a nuclear power plant, the threats associated with the production of nuclear power, and the negative image associated with spent nuclear fuel have all contributed to the strong opposition to the project. The opposition has been strongest in the immediate vicinity of the nuclear power plant.

7.10.7 Prevention and mitigation of adverse impacts

7.10.7.1 Construction phase

During the construction of the nuclear power plant, a large number of people taking part in the construction work will come to stay from other parts of Finland. The social impacts caused by the construction phase can be mitigated by decentralizing the accommodation of the employees to the adjacent municipalities as well as at the power plant site and Pyhäjoki. Adequate leisure activities for the employees participating in the construction work will be arranged in cooperation with various stakeholders. To ensure the availability of services, the parties active in the project area must prepare for the increased demand of services as early on as possible. Some of the construction employees will come to the area from abroad. Adverse social impacts due to cultural differences can be mitigated by arranging training regarding Finnish culture and customs for foreign employees. Training about adapting to the changed situation and promoting ethnic diversity could also be arranged for the local residents.

The respondents to the resident survey and the participants of the small group interviews hoped that the organization responsible for the project will actively communicate with the stakeholders and that an open communication between the organization responsible for the project and the stakeholders would continue all through the project period. They wished that several channels of communications would be utilized.

7.10.7.2 Operation phase

Various fears and threats are associated with nuclear power. This is why it is important to offer information about the operation of the nuclear power plant and the risks and impacts inherent to nuclear power and communicate this in an active, appropriate, and comprehensible manner. The fears related to nuclear power plants may also be alleviated by providing information in plain language on how safety will be ensured in all nuclear power plant operations, how extremely unlikely a nuclear power plant accident is, and what kind of concrete consequences the most severe accident would have.

The operation of the nuclear power plant will be presented to the general public at a visitor center, which Fennovoima will build in connection with the nuclear power plant. Regular and open reports about the results of the radioactive measurements and other measurements taken in the surroundings of the plant will be offered.

7.11 Waste and waste management

7.11.1 Assessment methods

The assessment of the quality and quantity of the waste generated during the operation of the nuclear power plant and their processing methods was based on available initial data and the waste management plans prepared by the project owner. Publicly available reports on matters such as transportation and final disposal of spent nuclear fuel were also utilized in the assessment.

Legislation regulating the waste management and the quantity, type, and processing methods of the waste generated are described in more detail in Sections 3.11, 3.12, and 3.13.

7.11.2 Construction phase impacts

In the construction phase, management of conventional waste will be arranged in accordance with the environmental guidelines so that the impacts of the waste and its treatment on the environment are minimized. The primary objective is to reduce the amount of waste generated. The secondary option is to utilize waste in new applications and in the production of materials or energy. The last option is to appropriately dispose of the waste in a landfill site.

Waste management in the construction phase is based on efficient sorting of waste at the site of its generation as well as on uniform and efficient instruction of the various parties and companies operating at the site on appropriate waste management procedures. Waste generated during construction will be appropriately sorted and recycled or utilized in energy production as far as possible. The earth-moving, excavation, and dredging masses generated during the construction phase will be utilized, as far as possible, in various on-site filling and leveling operations. The handling, storage, and transportation of hazardous waste will be arranged in accordance with the regulations.

The impacts of waste water generated at the construction site and its processing are discussed in Section 7.4.3.

No radioactive waste will be generated during the construction phase.

7.11.3 Operation phase impacts

7.11.3.1 Conventional waste

Conventional waste generated at the nuclear power plant will include iron and sheet metal scrap, wood, paper, and cardboard waste, as well as biowaste and energy waste. Most of the waste generated can be utilized through recycling or use in energy production. Sorted waste will be delivered for treatment, utilization, and final disposal in accordance with the requirements of waste legislation and environmental permit decisions.

Waste management at the plant will not cause any environmental impacts. The amount of waste generated will be kept as small as possible, and the waste to be utilized as large as possible. The fulfillment of the targets will be monitored by keeping records of the amounts of sorted waste fractions and utilization of the waste fractions. For example, paper and cardboard, metal, wood, biowaste, glass, and energy waste will be separated from municipal waste. Solid matter carried to the nuclear power plant along with the cooling water, such as algae, refuse, and fish, will be removed using screens and filters, dried, and baled. Then it will be delivered for processing according to its type.

7.11.3.1 Hazardous waste

Non-radioactive hazardous waste generated at the nuclear power plant will be processed in accordance with the requirements of waste legislation and environmental permit decisions in the same manner as at other industrial plants. Hazardous waste generated at the nuclear power plant will include batteries, fluorescent tubes, light bulbs, oil-contaminated filters, waste oil, solvent and chemical waste, and waste electric and electronic equipment.

Hazardous waste will be stored in appropriately labeled, covered, and water-tight vessels or containers. Different types of hazardous waste will be kept separate from one another. The release of hazardous waste into the soil, groundwater, or surface water and sewers will be prevented.

Hazardous waste will be delivered to a hazardous waste treatment plant, and the delivery will be recorded in the transfer document in which the required information on the waste fractions will be entered. The amount of hazardous waste generated will mainly depend on the extent of the outage operations. Hazardous waste will not cause any impacts on the environment due to its small quantity and the appropriate processing methods utilized.

7.11.3.3 Operating waste

During the operation of the nuclear power plant, operating waste will be generated in operations such as processing of radioactive liquids and gases and maintenance and repair work performed in controlled areas. Operating waste include protective clothing, insulation materials and cleaning materials. Liquid operating waste includes radioactive concentrates and masses generated as a result of the plant's water treatment processes. Operating waste will be classified as low or intermediate level waste on the basis its radioactivity. Furthermore, legislation allows the separation of the fraction of very low level waste from other low level waste and the final disposal of this lowest level waste in a surface repository.

An estimate of the volumes of operating waste generated in the nuclear power plant is presented in Section 3.12 (Table 3-5). The estimated volume of solid waste generated over the entire operation phase of the plant (after treatment and packing) is approximately 2,500 m^3, while the estimated volume of liquid waste is approximately 2,100 m^3. An effort will be made to minimize the generation of operating waste through careful planning and implementation of maintenance operations, choosing the right work methods, efficient sorting of waste, and favoring re-usable tools as far as possible.

Operating waste will be collected and removed from the plant premises without delay. For storage or final disposal, waste will be packed in vessels (typically, 200-liter drums) which facilitate the transfer of the waste, prevent the dispersion of radioactive substances, and reduce the risk of fire. Low level waste packages can be handled without any radiation shielding. The handling and transportation of intermediate level waste require the use of radiation shielding, and the packages often function as technical release barriers in the final disposal.

A more detailed description of the treatment and management of operating waste is presented in Section 3.12.

Adequate facilities will be built at the nuclear power plant for the treatment and storage of operating waste. The facilities will contain systems enabling the safe handling and transportation of waste and the monitoring of the quantities and types of radioactive substances. Prior to final disposal, packed waste will be stored under supervision in a storage building located immediately adjacent to the solid waste treatment facilities in the plant site. According to the plan, enough storage capacity for 10 years will be built for operating waste. The principle behind the final disposal of operating waste is to isolate the radioactive substances contained in the waste from the environment so that the safety of the environment is not endangered at any stage.

Two different techniques can be applied for the final disposal of operating waste; surface repository or underground repository. Presented below is an assessment of the environmental impacts of both alternatives. A more detailed description of the repositories and operating waste treatment and management methods is presented in Section 3.12.

Underground repository

The underground repository for operating waste will be designed in accordance with the requirements of Government Decree (736/2008). The Decree states that the maximum limit of the annual dose to any individual of the population from the operation of the nuclear power plant as a whole, including the operation of the final disposal repository, at any given time is 0.1 mSv. The annual dose to any individual in the population from possible accidents caused by natural phenomena or human activity will remain below 5 mSv.

Furthermore, the repository will be designed so that the annual dose to any individual from accidents with expected frequencies of occurrence higher than once in a thousand years will remain below 1 mSv. The average annual radiation dose of Finnish people from background radiation is 3.7 mSv *(STUK 2011c).* The design objective set for any repository constructed in bedrock will be that the annual radiation dose to individuals may only exceed 0.01 mSv in the case of a limited critical group, i.e. the plant's workers.

The emissions of radioactive substances from the underground repository into the atmosphere will normally be insignificant. The impacts of accidents are described in Section 7.13.

The waste packages transported into the repository must be undamaged and in good condition, and there must not be any loose contamination on their surface. Thus, no radioactive substances will be released from the waste packages during the operation phase, and the water accumulating in the repository cannot be contaminated by radioactive substances.

After the sealing of the repository, flows caused by temperature differences (convection) or the shifting of molecules from regions of higher concentration to regions of lower concentration (diffusion) will, over long periods, carry small quantities of radionuclides contained in the waste into the environment. Technical and natural release barriers will prevent and slow down the migration of radionuclides. The release barriers utilized in final disposal will be designed to effectively prevent the release of radioactive substances for at least hundreds of years in the case of short-lived waste or thousands of years in the case of long-lived waste. After this time, the radioactivity inside the repository will have decreased to an insignificant level.

No factors unfavorable to long-term safety (Government Decree 736/2008) must be present at the final disposal repository. Such factors include groundwater resources of local significance, the utilization or quality of which the construction of a final disposal facility for operating waste would endanger. There are no classified groundwater catchment areas within the area affected by the planned construction of a final disposal facility at the power plant site. The nearest classified groundwater catchment area is located some 10 kilometers from the future location of the power plant. The groundwater resources of the surrounding areas will not be contaminated with radioactive substances due to the final disposal of operating waste.

Surface repository

In the case that a repository located on or immediately below the ground surface is constructed at the power plant site, it will only be used for the final disposal of very low level waste in accordance with Section 22 Government Decree (736/2008). The total volume of waste disposed of in the surface repository will be kept at such a level that the activity of radioactive substances falls below the limit values set for large-scale final disposal in Section 5, subsection 1 of the Nuclear Energy Decree.

The radioactivity concentration of the very low level waste disposed of in this repository will be so low that the waste packages to be disposed of can be handled without implementing any special radiation protection arrangements.

As the total radioactivity of the waste to be disposed of will be low and the waste will be packed tightly and isolated from the environment by covering it with a compact sealing layer, no radioactivity will be released into the atmosphere or migrate into the soil. Technical and natural release barriers will also prevent and slow down the migration of radionuclides. No waste containing radioactivity bound to readily volatile or dust-forming substances will be disposed of in the repository.

Emissions could only take place in the case of a fire, and even then, the impacts of radiation would remain insignificant due to the low activity level of the waste. The possibility of fires will be taken into account by ensuring the availability of firefighting equipment in the vicinity of the repository during deposit campaigns. The possibility of a fire will also be taken into account during the sorting and packing of waste.

The filling of the repository for very low level waste with water will not be possible because the repository will be located on the ground surface and because flooding will have been taken into account in its design. The base slab of the repository will isolate the waste from the soil, and any seepage water permeating the surface layers covering the repository will be collected and analyzed in order to determine the concentrations of radioactive substances. If necessary, the seepage water can be cleaned in an appropriate manner at the power plant's liquid waste treatment plant before it is released into the water system. This will guarantee that no significant quantities of radioactive substances are released from the repository.

7.11.3.4 Spent nuclear fuel

Interim storage of spent nuclear fuel

Some 20–30 tons of uranium will be removed as spent fuel from the reactor of the nuclear power plant each year. An approximate total of 1,200–1,800 tons of spent nuclear fuel will be generated over the course of the 60 years of operation of the nuclear power plant.

The level of radioactivity of spent nuclear fuel will be at its highest immediately after removal from the reactor, but it will decrease to approximately one-hundredth of the original value in only one year. After interim storage of some fifty years, the level of radioactivity of the spent nuclear fuel removed from the reactor will be one-thousandth of the original value. The radioactivity of disposed spent nuclear fuel will decrease to a level corresponding to that of natural uranium in approximately 100,000 years. *(STUK 2004, SKB 2008b)*

Fennovoima will construct an interim storage facility for the spent nuclear fuel at the power plant site. A more detailed description of the interim storage facility is presented in Section 3.13.

In all phases of spent nuclear fuel management, it is important to ensure that the possibility of an uncontrolled fission chain reaction is excluded, i.e. the nuclear fuel remains subcritical. The transport containers, storage facilities and handling equipment of the spent nuclear fuel will be designed and constructed so that the subcriticality of the fuel can be ensured. The spent nuclear fuel handling and storage facilities will be equipped with ventilation and filtration systems that will remove any radioactive substances released in the air during possible emergency situations. Thus, the interim storage facility will not pose a danger to its surroundings, and no statutory limit values will be exceeded.

The nuclear and radiation safety principles applied to the operation of the nuclear power plant will also be applied to the handling and storage of spent nuclear fuel when applicable. The limit value for the annual dose to any individual of the population from the operation of the nuclear power plant as a whole, including the handling and storage of spent nuclear fuel, is 0.1 mSv. The annual radiation dose may only exceed 0.01 mSv in the case of a limited critical group, i.e. the plant's workers.

As regards handling and storage of spent nuclear fuel, the main safety factors are as follows:

- Ensuring the preservation of the integrity of the nuclear fuel elements and the leak tightness of the nuclear fuel rods
- Implementation of efficient radiation protection arrangements
- Ensuring sufficient cooling of the nuclear fuel
- Prevention of the occurrence of spontaneous fission chain reactions in the storage.

During normal operation, the handling and storage of spent nuclear fuel will have no impacts on the environment. There are no significant differences between the environmental impacts of the two interim storage options; a water-pool-type storage or the dry storage. Radiation impacts are assessed in Section 7.10. The impacts of abnormal and accident situations are assessed in Section 7.13.

Transportation of spent nuclear fuel

The amount of spent nuclear fuel generated annually as a result of the operation of the nuclear power plant will be 20–30 tons. One transport container typically holds approximately 10 tons of spent nuclear fuel. Assuming that the final disposal facility will have sufficient capacity to process the whole 10-ton batch at one time, there will be an average of 2–3 spent nuclear fuel transportation operations each year from the start of the final disposal activities until all spent fuel has been delivered for final disposal. The final disposal operations are not estimated to begin before 2070. Based on the above assumption, a total of 120–180 transportation operations will be required to transfer all the spent fuel generated during the operation time of the plant out of the plant site.

At this point, the transportation routes from the plant area to the final disposal site cannot be assessed in their entirety because, according to Fennovoima's delineation of the project, the spent nuclear fuel transportation operations fall within the scope of final disposal activities, and the environmental impacts and safety of the transportation operations will be assessed separately as the project progresses.

The transportation container used in the transportation of spent nuclear fuel will very effectively attenuate the radiation emitted by the fuel. According to the safety regulations, the dose rate of the radiation emanating from the transportation container shall not exceed 0.1 mSv/h. The dose rate of the radiation will decrease rapidly as the distance from the transportation container increases, and it will reach the level of natural background radiation (0.1 μSv/h) at the distance of approximately 30 meters. According to previous studies, the dose rate of the radiation at the distance of one meter from the surface of the transportation container will be 0.03 mSv/h. This value was used as an assumed initial value for radiation level in the following calculations (*Suolanen 2004, Posiva 2012a*).

The passing of one spent nuclear fuel container at the distance of 10 meters will cause an individual a dose of 6×10^{-7} mSv, and at the distance of two meters, a dose of 3×10^{-6} mSv. The latter value equals less than one-millionth of the annual radiation dose from background radiation (3.7 mSv/year/person). In the case that the transportation convoy stops near a residential area and the container remains in a stationary position for two hours, the radiation dose to an individual staying at the distance of 10 meters will be 0.0009 mSv. This dose equals approximately one four-thousandth of the annual dose to that individual from background radiation.

Under normal circumstances, then, the level of radiation exposure from the transportation of spent nuclear fuel to people and the environment will be insignificant, and distinguishing between the additional exposure and the exposure caused by environmental background radiation will be practically impossible. In the case of sea transportation, the level of radiation exposure from normal transportation operations to the population will be even lower since the distances between shipping routes and residential areas are greater than the distances between residential areas and railroads or main roads and since the population density along the transportation routes is lower (*Suolanen et al. 2004, Posiva 2012a*).

Under normal conditions, the surface contamination of the transportation container shall not exceed the limit value of 4 Bq/cm^2. This surface contamination level has no adverse health impacts on people or other organisms.

The individual doses of the spent nuclear fuel transportation personnel and the personnel handling the transportation container will be higher than the doses of other members of the population because they will stay closer to the container during the transportation operations. However, their radiation doses will be very small, and the consequent risk of serious late impacts will be indistinguishable from the impacts caused by exposure to environmental background radiation. (*Suolanen et al. 2004, Posiva 2012a*)

According to previous studies, the transportation of spent fuel from the Loviisa nuclear power plant to Olkiluoto would have to continue for tens of thousands of years for the radiation from the transportation operations to cause one additional case of cancer in the population (according to statistical estimation) (*Suolanen et al. 2004*). Thus, under normal circumstances, the spent nuclear fuel transportation operations will, for all practical purposes, not cause a health risk to people.

The abnormal and accident situations relating to the transportation of nuclear fuel are discussed in Section 7.13.

Final disposal of spent nuclear fuel

This EIA report outlines the environmental impact of the final disposal phase of spent nuclear fuel on a general level. The reason for this is that the associated operations will be subjected to a separate EIA procedure at a later time. The description of the environmental impacts is based on sources such as the investigations carried out by Posiva Ltd (Posiva) for its construction permit application.

According to Posiva's investigations *(Posiva Oy 2012c)*, the nearly oxygen-free groundwater moves very slowly at the depth of hundreds of meters, and its corroding effect on the copper canisters and the spent nuclear fuel will be very small. If, however, spent fuel should be released from the disposal canisters and come into contact with groundwater due to cracking of the bedrock or some unforeseeable reason, the dissolved substances would in large part remain in the surrounding bentonite barrier and the bedrock. Even in such an event, the maximum radiation dose to people living above the repository would be equal to that currently caused by natural background radiation, and the number of individuals exposed would be low as the exposure would be limited to the surrounding areas. The bedrock effectively attenuates radiation; two meters of solid bedrock is sufficient to attenuate the radiation to the level of natural background radiation.

The long-term safety of the disposal of spent nuclear fuel will be assessed through safety analyses investigating likely developments and unlikely incidents undermining safety. The possible consequences to people and nature are assessed in each case. The safety analyses enable the determination of the consequences of the failure of one or more release barriers. The underlying purpose is to ensure the safety of the final disposal even in the case that the conditions change.

7.12 Decommissioning of the power plant

A separate EIA procedure will be carried out at a later time to assess the environmental impacts of the decommissioning of the nuclear power plant. However, a decommissioning plan will be prepared during the early stages of the operation of the plant. The Radiation and Nuclear Safety Authority (STUK) will approve the plan and the updates to be implemented every six years. One of the primary objectives of the plan is to ensure that dismantled radioactive plant components will not cause any danger to the environment. In order to provide a comprehensive picture of the lifecycle of the nuclear power plant project, Section 3.14 of this EIA report presents a general description of the various decommissioning phases and their duration, as well as the types of waste generated and their processing methods.

In accordance with the Nuclear Energy Decree, STUK will control the measures relating to the management of waste generated in conjunction with the decommissioning of the plant and the associated preparations to ensure that they are performed in compliance with the relevant regulations and degrees pursuant to the Nuclear Energy Act. STUK will also confirm the procedure according to which the party under the waste management obligation should record the radioactive waste generated during the decommissioning of the plant.

A preliminary estimate of the total volume of nuclear power plant decommissioning waste generated is 10,000–15,000 cubic meters. The volumes of decommissioning waste will depend on the plant's structure, the dismantling strategy, and the decommissioning waste handling, packaging, and disposal methods. Thus, the estimate given is purely indicative.

Waste generated in the dismantling phase will be similar to waste generated during the operation of the plant, and it can be processed in a similar manner as operating waste. The majority of waste generated during the nuclear power plant's dismantling operations is not radioactive, and it can be treated in the same way as conventional waste. The treatment of operating waste and the associated environmental impacts are described in Section 7.11. The safety requirements set for low and intermediate level waste generated during decommissioning with regard to handling and final disposal will be similar to those set for operating waste.

Decommissioning waste generated in the controlled area will be tested in several stages using different methods. After testing and the possible cleaning measures, the waste will be classified into specific further processing groups according to its properties and activity (e.g. restricted or free utilization, or disposal at an ordinary landfill site or in a final disposal repository for operation waste). The testing methods and results will be reported to STUK.

Contaminated plant components and pieces of equipment will be cleaned as far as possible so that they can be cleared by STUK and either recycled or disposed of at a public landfill site. The plant's systems will be sealed so that radioactive substances cannot spread into the environment.

Radioactive waste that cannot be cleaned for recycling or disposal at landfill sites will be treated and disposed of as low or intermediate level waste. Intermediate level decommissioning waste will consist of waste generated as a result of the dismantling of the process system, such as pumps and valves. Low level decommissioning waste will include certain concrete and steel structures.

Low and intermediate level decommissioning waste will be disposed of in the operating waste repository located in the Hanhikivi headland in the dismantling phase. The repository will be expanded as necessary. Decommissioning waste will be transported to the repository inside a radiation shield.

The impacts caused during the dismantling operations will be minor, provided that the radiation protection regulations applied to the personnel performing the work will be similar to those applied to the relevant personnel during the operation of the plant. The tools and working methods will be selected so that the radiation exposure of the workers remains as small as possible. Certain work phases will be performed inside isolated spaces equipped with separate ventilation systems. The air will be separated and filtered in order to prevent radioactive emissions to other parts of the plant or into the environment. The plant components will be dismantled into parts that are as small as possible. If required, the parts will be reprocessed mechanically or chemically in order to clean them before the final inspection tests.

The environmental impacts caused by the dismantling, processing, and transportation of the nuclear power plant's non-radioactive structures and systems in the plant area and in the vicinity of the roads include dust, noise, and vibration impacts. The increase in the number of heavy vehicles in the traffic during the dismantling of the power plant and the associated transportation operations may impair road safety particularly in the vicinity of residential areas. Furthermore, on roads to and from the plant site the emissions of the increasing traffic will have an impact on the air quality.

7.13 Impacts of abnormal situations and accidents

7.13.1 Nuclear accident

7.13.1.1 Assessment methods

The occurrence of a severe nuclear accident in a nuclear power plant utilizing modern technology is extremely unlikely, since this would require several different, mutually independent failures and mistakes to take place simultaneously. The safety of the nuclear plant will be ensured using successive and mutually independent protective measures in accordance with the defense in depth principle. Furthermore, provisions will be made for operational transients, accidents, and severe accidents in the plant design. The purpose of this is to minimize the consequences of these events. Nuclear safety is discussed in more detail in Chapter 4.

The assessment of the impacts of a nuclear power plant accident was based on a postulated severe accident scenario. A dispersion model for the radioactive release, as well as the consequent fallout and the radiation dose to the population, was prepared on the basis of the postulated scenario. The modeling results are indicative only, and they are based on assumptions in which the radiation doses were overestimated. More detailed analyses on nuclear safety, accidents, and their consequences required by the nuclear energy regulations will be prepared as the project progresses. In the construction and operating license application phases, dose calculations will be performed for an area extending a minimum of 100 kilometers from the plant. These calculations will utilize plant type-specific accident scenarios based on the detailed analyses presented in the safety report, as well as the associated source terms. The dispersion of radioactive substances in water systems and the related impacts will be assessed at this time.

Limits set by authorities

The Government Decree on the Safety of Nuclear Power Plants (717/2013) stipulates that the release of radioactive substances resulting from a severe accident shall not cause a need for extensive civil protection measures. In terms of authority regulations, this means that no need shall arise for evacuations outside the protective zone (extending to the distance of some 5 kilometers from the plant) or for taking shelter indoors outside the emergency planning zone (extending to the distance of some 20 kilometers from the plant). An evacuation will be performed in the case that the radiation dose is estimated to exceed 20 mSv over a period of one week. Taking shelter indoors will be necessary in the case that the dose is estimated to exceed 10 mSv over a period of two days. Table 7-17 shows the limits set by authorities for the initiation of civil defense measures.

According to Government Decree 717/2013, a severe accident shall not lead to a cesium-137 release exceeding 100 TBq. If the release falls below the limit value, no need for long-term restrictions on the use of large land or water areas will arise.

Table 7-17. Limits set by the authorities for the initiation of main protection measures.

Protection measure	Dose limit	Maximum distance from the plant within which a need for the measure is allowed
Taking shelter indoors	10 mSv*/2 days	20 km
Ingestion of iodine tablets	For children 10 mGy**, for adults 100 mGy (thyroid dose)	Not specified
Evacuation	20 mSv/week	5 km

* The unit of radiation dose is the sievert (Sv)

** When referring to the effects of radiation on a single organ, the unit of radiation dose is the gray (Gy)

The magnitude and timing of the release

The analysis utilized a postulated release corresponding to the severe accident limit value of a cesium-137 release of 100 TBq laid down in Government Decree 717/2013. The initiation of a release of this magnitude would require a failure of the reactor cooling systems and the evaporation of the reactor coolant through boiling, resulting in the uncovering and melting of the reactor core. AES-2006 plants have several active and passive reactor cooling systems as described in Chapter 3. Because of these systems, the probability of a severe accident such as the one analyzed here is very small. However, to make provision for a severe accident, the plant will be equipped with a core catcher as well as a passive containment cooling system and a hydrogen removal system. These systems will enable the maintenance of the integrity of the containment even in the case of a severe accident. In the case of a severe accident, the release would be primarily caused by containment design leakage through the inner and outer containment shell or via the filtered exhaust through the vent stack. The release routes would contain the radioactive substances and significantly decrease the amounts released into the environment. Furthermore, the core melt caught in the core catcher would be sprayed with water, which prevents the dispersion of radioactive substances.

The release was postulated to commence six hours after the beginning of the accident. Considering the technical design solutions utilized at the plant, this is a very conservative assumption for a radioactive release of this magnitude. The safety solutions would keep the release rate low. Due to the low release rate, reaching a total release of 100 TBq of Cs-137 would require the postulated releases to continue for up to several weeks. However, for the purposes of this assessment, a release rate that overestimates the doses was used, and the entire release was assumed to occur within 72 hours. Furthermore, a sensitivity analysis was performed for the release rate. This was done to ensure that a change into an even more unfavorable direction will not immediately cause the exceeding of the limits set by the authorities. The sensitivity analysis examined a release occurring at a triple rate, meaning that the entire release was assumed to occur within 24 hours. Table 7-18 shows the assumptions made for the modeling.

In addition to cesium-137, the release was assumed to contain other nuclides in the proportion in which they are released from the reactor in relation to cesium. The burnup of the fuel has an effect on the composition of the source term. High-burnup fuel contains more radionuclides with long half-lives. The amounts of radionuclides released in addition to the 100 TBq of cesium-137 used to define a major release were determined according to the reactor core inventory, which the burnup influences. According to Fennovoima's plans, the maximum burnup per fuel assembly will be 60 MWd/kgU. The average burnup across the reactor will be lower.

The most significant radioactive substances – a total of 44 different nuclides – were considered in the calculations. According to the estimate, some 1,560 TBq of radioactive iodine-131 would be released. For the purposes of the modeling, it was assumed that 100 percent of the noble gases contained in the reactor would be released into the environment. As regards the most significant radionuclides, the source term determined in accordance with the NUREG-1465 report (*NRC 1995*) is conservative in comparison to the source term determined on the basis of the burnup value specified in Fennovoima's plans.

Using the International Nuclear Event Scale (INES scale) illustrating the severity of nuclear facility events, nuclear power plant events and accidents can be rated into different categories (levels 0–7). These are described in more detail in Chapter 4. Levels 1–3 represent incidents (events that compromised safety), and levels 4–7 represent accidents. The major release examined in this modeling effort corresponds to an INES level 6 accident because the magnitude of the release is approximately 10,000 TBq of iodine-131equivalents. If the release were five times larger than the one resulting from the accident analyzed here, the accident would be rated at INES level 7. The consequences of an INES level 7 accident are assessed in conjunction with the presentation of the analysis results.

Dispersion calculation model

The dispersion of radioactive substances, and the consequent fallout and radiation dose to population, was calculated on the basis of the release data. For the purposes of dose calculation, it was assumed that there are people permanently occupying or living in the area immediately outside the plant area.

The calculation of the dispersion of the radioactive release was based on the Gauss dispersion model used commonly around the world (e.g. *Sriram et al. 2006*). The modeling utilized dispersion and fallout parameters complying with the German authority guidelines *(SSK 2003)*. The Finnish authority guidelines do not include regulations on calculation parameters. The release was assumed to travel in the release height at the speed and in the direction of the prevailing wind and to disperse in vertical and horizontal directions according to the normal distribution (Gauss distribution). For distances exceeding 20 kilometers, a long-range model was used, and for distances exceeding 150 kilometers, the results were extrapolated using a fitted value that overestimates the doses.

A term representing the wind direction and speed, rainfall, and mixing of air currents determined on the basis of weather observation documentation (Pasquill stability class) was applied in the dispersion calculations. As regards the weather observations, measurement data from the Finnish Meteorological Institute weather observation stations best representing Hanhikivi, Pyhäjoki were used. The weather observations were recorded over a period of three years between October 2010 and October 2013. The wind data was recorded at the Lapaluoto weather station in Raahe because there is no other wind data measuring station in the vicinity that is equally representative with regard to the location of Hanhikivi. The rainfall and cloudiness data, which was used in the calculation of the Pasquill stability class, was recorded at the Pellonpää weather observation station in Oulu. The solar radiation data was recorded in Kuolaniemi, Sotkamo. This was the nearest weather station measuring sunshine that could provide a complete set of data for the whole period analyzed. The sounding data was recorded at the sounding station of the Jokioinen Observatory.

The impact of rain on the fallout was taken into account in the modeling. The radioactive cloud generated as a result of the release may travel long distances in dry weather. During the travel, some of the radioactive substances fall to the ground as a result of gravity (dry fallout). When it is raining, radioactive substances are washed to the ground with clearly higher efficiency depending on the magnitude and intensity of the rain (wet fallout). The dry and wet fallout rates were determined on the basis of wind direction and stability and rain magnitude.

The release is expected to occur at a height of 100 meters. This height would be reached, for example, in cases in which the release occurs through the vent stack or the release occurs as a result of the leakage of the containment and the heat contained in the release lifts the release plume to height of 100 meters.

Dose calculation

External radiation, i.e. radiation from the release plume and the fallout, as well as activity entering the body through respiration and consumption of nutrition, were considered in the estimation of the radiation dose from the release. The calculation parameters used in the dose calculation were selected considering the prevailing conditions in the vicinity of the plant site. However, the differences between individual people and their living habits cannot be fully taken into account in the calculation models used to assess the radiation doses to the people living in the surroundings of the nuclear power plant. It is thus necessary to define so-called representative individuals whose age and living habits best correspond to those found in the small population group that will be most exposed *(ICRP 2006)*. The radiation dose from the radioactive release was calculated separately for children aged 1–2 years and adults because the generation mechanisms and impacts of radiation exposure are different for each of these population groups. In the analysis, the two age groups were assumed to have different eating habits. As regards eating habits, the typical Finnish diet was taken into account. Furthermore, the difference between the breathing capacity of children and adults was considered. The doses were calculated using dose factors determined by the International Commission on Radiological Protection (ICRP) *(ICRP 2012)*.

For the purposes of the modeling, it was assumed that no civil defense measures would be implemented. For example, people were assumed to stay outdoors around the clock as the radioactive plume travels over the area. At a later stage, they were assumed to be exposed to the radiation from the fallout without any protection. As this would not be the case in reality, this method of examination led to the overestimation of the radiation doses.

For the purposes of the calculation of the radiation dose from consumption of nutrition, it was assumed that the people consume ample quantities of plants and milk produced in the vicinity of the plant, natural products harvested from nature, and fish caught in the surrounding area. As a scenario in which only locally produced foodstuffs are used is not realistic, this assumption also caused the method used to overestimate the radiation doses. The contamination of plants used directly as food (including contamination from the fallout and the radioactive substances migrating to the plant from contaminated soil through its roots), as well as the radiation dose to people from radioactive substances received through various food chains, were taken into account in the calculation. An example of the exposure pathways considered is the one in which radioactive substances fall on pasture land. The grazing cattle ingest the grass, and the activity then ends up in people who eat the meat of the cattle. The dose pathway leading from lichen to reindeer to humans, which has significance for the population of Lapland, was examined separately.

The dose to an individual of the population corresponding to the 95 percent upper fractile was calculated on the basis of weather observations. This means that in 95 percent of the weather conditions, the dose is smaller than the calculated value. The dose distribution function was calculated by separately calculating the maximum radiation values for each combination of weather conditions at each distance from the plant examined. This maximum dose value, then, indicates the maximum dose that an individual can receive at the given distance in the given weather conditions. While the direction in which this dose is reached may vary, no possible maximum dose was excluded in this modeling, even in the case the dose would only be reached at the sea. Separate distribution functions were formed for each distance on the basis of these maximum doses, and the 95 percent upper fractiles were determined. This method of examination overestimates doses in comparison to methods such as the one in which the doses are calculated according to the actual location of residential areas in the vicinity of the plant. This method of examination will be used later in, for example, construction license phase analyses.

Table 7-18 shows a comparison between the modeling assumptions made for this EIA and the ones made for the 2008 EIA.

7.13.1.2 Radiation doses from severe accidents

In order to assess the need for civil defense measures, the radiation dose from radioactive substances entering the body was calculated for three different periods of time:

- the first two days,
- the first seven days, and
- the entire lifetime.

The radiation doses from the release are presented in table 7-19. It should be noted that the radiation doses from the release would only be received in the direction of travel of the release.

During the first two and seven days following the accident, the radiation dose would be mainly caused by radioactivity entering the body through respiration and by external radiation, i.e. radiation from the release plume carried by atmospheric currents and the fallout on the ground. The radioactive substances entering the body through consumption of nutrition were not taken into account in these calculations. In the longer term, the fallout on the ground would

Table 7-18. A comparison between the assumptions made for the accident modeling carried out for the 2008 EIA and the one carried out for this one.

Variable/ assumption	The 2008 EIA	The 2014 EIA	Justification
Definition of the composition of the source term	SSK 2002	NRC 1995, NRC 1988, NRC 1975	The source term definition reports by the US Nuclear Regulatory Commission (NRC) are globally accepted.
The amount of cesium-137 in the release	100 TBq	100 TBq	The maximum release laid down in the Government Decree.
The amount of iodine-131 in the release	960 TBq	1,560 TBq	Based on the reference "NRC 1995"
The amount of xenon-135 in the release	1,570 TBq	180,000 TBq	Based on the reference "NRC 1995"
Weather conditions	Average and adverse weather conditions determined by expert judgement based on weather observations made in 2004–2006.	Dilution factors calculated based on the weather observations made between October 2010 and October 2013 (corresponding to the 95% fractile).	Distributions calculated directly based on the weather conditions offer more accurate radiation dose values.
Start of release from the start of the accident	6 hours and 24 hours	6 hours	Only the more unfavorable release, i.e. the one that starts earlier, has been studied in this EIA.
Duration of the release	1 hour and 6 hours	72 hours	The durations of release used in this EIA have been selected in order to assure overestimation of the doses. However, the duration selected more realistically than in the EIA of 2008.

Table 7-19. Radiation doses to adults and children from a severe accident (the 95 percent fractile) 1–5 kilometers from the plant site.

	Radiation dose for a child (mSv)			Radiation dose for an adult (mSv)		
Distance (km)	In 2 days	In 7 days	Over lifetime (70 years)	In 2 days	In 7 days	Over lifetime (50 years)
1	22.8	29.3	690	14.8	19.0	336
2	12.3	15.7	386	7.9	10.4	189
3	7.7	9.9	253	5.2	6.5	126
4	5.7	7.3	189	3.8	4.8	96
5	4.3	5.6	149	2.8	3.7	76
10	1.9	2.4	71	1.2	1.6	37
15	1.2	1.5	48	0.7	1.0	25
20	0.8	1.1	36	0.6	0.7	19
50	0.4	0.5	15	0.2	0.3	7.4
100	0.2	0.3	10	0.1	0.2	4.8
150	0.2	0.2	8	0.1	0.2	3.8
500	<0.1	<0.1	<3	<0.1	<0.1	<2
1,000	<0.1	<0.1	<2	<0.1	<0.1	<1

partially migrate to plants and subsequently to foodstuffs. Due to this, the radiation dose from foodstuffs produced in the fallout area would be a significant one. However, it is likely that the use of contaminated foodstuffs would be avoided, which in turn would help to at least partially prevent the reception of a radiation dose through consumption of nutrition. For comparison, Finnish people receive an average radiation dose of approximately 184 mSv from other sources, mainly natural background radiation, over a period of 50 years (*STUK 2013f*). Furthermore, people who are exposed to large amounts of radon at their homes through drinking water or indoor air can receive a radiation dose of over 1,500 mSv over a period of 50 years *(STUK 2013u)*.

In the case of the modeled severe accident, all the people living at a distance of two kilometers or less from the plant would have to be evacuated. The reason for the need of evacuation would be the radiation dose to children. It is estimated that there would be no radiation dose to adults requiring evacuation beyond the distance of one kilometer from the plant, i.e. on the mainland, the dose limit would not be exceeded outside the plant area boundary. In practice, however, the protective zone of the nuclear power plant (extending to a distance of approximately five kilometers from the plant) will always be evacuated if there is a risk of a substantial release of radioactive substances into the environment. A need to take shelter indoors would not arise beyond the distance of three kilometers from the plant. Table 7-20 lists the civil defense measures required at the distance of 1–5 kilometers from the plant.

Table 7-21 shows the thyroid doses from the release in the direction of travel of the release. The doses are given for different distances and periods of time. Children living at a distance of five kilometers or less from the plant should take an iodine tablet. However, there would be no need for adults to take an iodine tablet.

The results of the modeling show that the doses fall below the limits set by the authorities for the commencement of civil defense measures (Table 7-17). The results are compared with the limits set by the authorities (Table 7-20). The table also presents the results of the sensitivity analysis for the duration of the release (24 hour release). While the postulated release occurring at a triple rate would cause a need for civil defense measures farther away from the plant site, the results of this sensitivity analysis also fall below the limits set by the authorities.

In the case of a release of five-fold magnitude occurring over a period of 72 hours (corresponding to an accident of INES level 7), evacuation would be required within a radius of five kilometers and taking shelter indoors within a radius of ten kilometers from the plant. As regards noble gases, a release of this magnitude is theoretically impossible, since the amount of noble gases released would be five times higher than the amount of noble gases contained in the reactor.

The shares of different nuclides and exposure routes

The shares of different exposure routes and nuclides in the radiation doses were also examined for each dose calculation performed. The shares of the exposure routes and nuclides depend on factors such as the weather conditions, the distance from the plant, and the length of the period of examination from the commencement of the release. A dose received in seven days at the distance of two kilometers from the plant was examined in order to determine the exposure routes. The results are presented in Figure 7-49. Doses from consumption of nutrition over the period of seven days are not taken into account. Fifty-seven percent of the dose comes from direct gamma radiation received from the release plume.

Figure 7-50 shows the shares of the exposure routes in lifetime doses received at the distance of two kilometers from the plant. Unlike in the case of the dose received over the first seven days, the shares of radiation received directly from the plume and the inhaled air in the total dose are small. The reason for this is that following the accidental release, the plume passes over quickly and the activity level of the air returns to its former level. In the case of lifetime doses, the most significant exposure routes include the dose received from nutrition and the gamma radiation from the fallout. Together, these account for 97 percent of the dose.

Radiation doses for people who eat reindeer meat has been separately examined, because the infertile and nutrient-poor nature of Lapland promotes contamination of food chains by the radioactive elements in the fallout, and consequently the lichen-reindeer food chain accumulates cesium effectively. Finns eat an average of 0.6 kg of reindeer each year. On the other hand, people who practice reindeer farming in the remote regions of Lapland have been reported to eat up to 0.5 kg of reindeer meat per day. Assuming this is done every day of the year, the total annual consumption of reindeer meat would be approximately 180 kg. The Hanhikivi headland is located approximately 100 km from the nearest reindeer herding area as defined in the Reindeer Husbandry Act (848/1990). According to the simulation, a typical Finn would get a maximum additional dose of 0.05 mSv from reindeer meat. If no restrictions of use or protection measures for the reindeer are implemented, a person who eats plenty of reindeer meat may get a radiation dose of 14 mSv through the meat, if the reindeer comes from the worst fallout area.

7.13.1.3 Impacts of a severe accident

Impacts of radiation exposure

The severe reactor accident being studied does not cause any direct or immediate health impacts in the vicinity of the facility, because even without any protection measures, the radiation dose in the first two days is no more than 23 mSv, which is considerably below the limit for showing changes in the blood count, which is 500 mSv.

Delayed random impacts from radiation exposure may only be estimated statistically. Statistical assessment is based on the assumption that a large population of people is exposed to equal radiation doses. The risk of the radiation dose to an individual can be used to calculate an expected value for the incidence of radiation-incurred health impacts in a large population – that is, the number of probable health impacts in the population. Due to reasons described in section 4.6, it is practi-

Table 7-20. Required civil defense measures and the radii within which the measures must be implemented. Results are shown for both the 72-hour release examined in the actual analysis and the release examined in the sensitivity analysis (defined on the basis of the 95 percent fractile).

	Dose limit	Distance within which the protection measure is necessary		Maximum distance within which the protection measures may be necessary according to the Decree
		72-hour release	Sensitivity analysis 24-hour release	
Evacuation	20 mSv/week, children	2 km	3 km	Approx. 5 km (the protective zone)
	20 mSv/week, adults	1 km	3 km	Approx. 5 km (the protective zone)
Taking shelter indoors	10 mSv/2 days, children	3 km	5 km	Approx. 20 km (the emergency planning zone)
	10 mSv/2 days, adults	2 km	4 km	Approx. 20 km (the emergency planning zone)
Ingestion of iodine tablets	10 mGy/2 days, thyroid dose to children	5 km	15 km	Not specified
	100 mGy/2 days, thyroid dose to adults	No need	1 km	Not specified

Table 7-21. Thyroid doses to children and adults at distances of 1–150 kilometers from the plant (95 percent fractile).

	Thyroid dose for a child (mGy)			Thyroid dose for an adult (mGy)		
Distance (km)	In 2 days	In 7 days	Over lifetime (70 years)	In 2 days	In 7 days	Over lifetime (50 years)
1	112	136	8,579	53	66	1,501
2	63	78	4,985	31	38	859
3	40	48	3,158	19	24	563
4	29	35	2,364	14	16	396
5	21	25	1,844	10	12	309
10	9	11	816	4	5	146
15	6	7	546	3	3	95
20	4	5	394	2	2	72
50	3	3	199	1	1	34
100	2	2	132	1	1	23
150	1	2	106	1	1	18

cally impossible to link an individual delayed health impact with radiation exposure caused by an accident.

The International Commission on Radiological Protection (ICRP) has estimated that exposure to a radiation dose of 1,000 mSv at small doses and dose rates increases the risk of cancer by 5.5% (*ICRP 2007*). Without the additional impact of an accident, the risk of getting cancer before the age of 70 is 15 % to 20% in Finnish males, and about 15% in Finnish females (*Pukkala et al. 2006*). These cases of cancer arising from reasons other than the radiation dose from an accident are so probable that the additional risk of cancer caused by the accident is statistically insignificant at all distances.

The radiation dose caused by the release would be approximately 150 mSv for a child (over the course of 70 years) and approximately 76 mSv for an adult (over the course of 50 years) at a distance of five kilometers from the plant. Theses doses are lower than the dose received by the average Finn from natural sources during the same period. If the child is one or two years old when the accident happens, the radiation dose can be estimated to increase his or her risk of getting cancer before the age of 70 by approximately 0.8%. For an adult who is 20 years old at the time of the accident, the corresponding additional risk of cancer before the age of 70 is approximately 0.4%.

Radiation damage to the fetus occurs only at rather large doses (*Paile 2002*). Impacts of radiation on pregnancies have only been shown in the survivors of the Hiroshima and Nagasaki nuclear explosions (*Auvinen 2004*). For example, a pregnant woman who lives at a distance of five kilometers gets a 5.6 mSv dose as a result of the accident during one week. The dose caused by the accident is not large as natural radiation alone will cause a total radiation dose of approximately 1 mSv to the developing fetus during the full course of pregnancy (*Paile 2002*).

The methods used for calculating radiation doses include a substantial number of assumptions that overestimate the

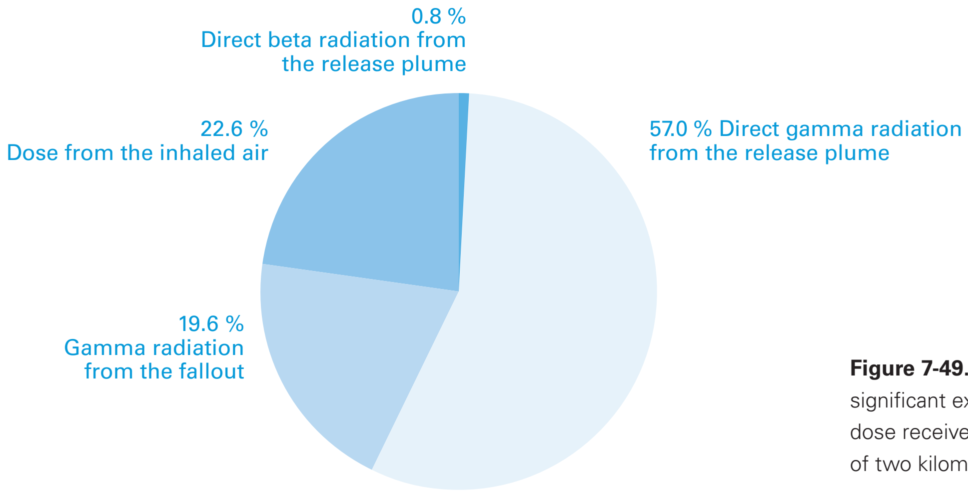


Figure 7-49. Average shares of the most significant exposure routes in the radiation dose received in seven days at the distance of two kilometers from the plant.

fallout and the radiation doses. For example, the impact of civil protection measures on doses has not been included. It is highly probable that the radiation doses in an actual situation will be clearly below the doses presented. Contingency planning for exceptional situations and accidents at a nuclear power plant is based on detailed accident modeling of the particular nuclear power plant type, as well as careful consideration of the specific weather conditions at the location.

Impacts of a radioactive fallout

A fallout refers to particles that originate from a release caused by an accident and that fall onto earth, vegetation and water under the influence of gravity and rain. The radioactive substances in the fallout may be accumulated in vegetation and carried to berries, mushroom and further to other populations.

To demonstrate radioactive contamination of areas of land and water and of foodstuffs, a fallout of radioactive iodine (I-131), cesium-137 (Cs-137) and strontium-90 (Sr-90) at various distances from the nuclear power plant is examined. These are the radionuclides most significant to radiation exposure. The half-life of iodine-131 is about eight days, so it causes a significantly shorter contamination period than cesium-137 or strontium-90, whose half-lives are about 30 years. Cesium-134 has a half-life of approximately two years. The radiation dose of short-lived iodine-131 may be of significance at the initial stages of the fallout, especially if the fallout takes place during a growth period. Iodine-131 is stored in the thyroid gland and causes a thyroid radiation dose. Cesium-137 and strontium-90 are important especially with a view to long-term radiation exposure.

Noble gases are rapidly released from a damaged reactor, but their relative impact is lower than that of other radioactive substances in the release. Noble gases are effectively diluted when they spread in the atmosphere, and they do not cause a fallout that would contaminate the environment. Noble gases also do not bind to organs through breathing or digestion, but mainly cause an external radiation dose. Their impact also remains relatively brief at any case (hours or days) due to their short half-life (*STUK 2004b*). For these reasons, the radiation exposure from noble gases is not significant at longer distances from the nuclear power plant (more than 20 km) and does not cause immediate danger outside the plant area even in worst cases.

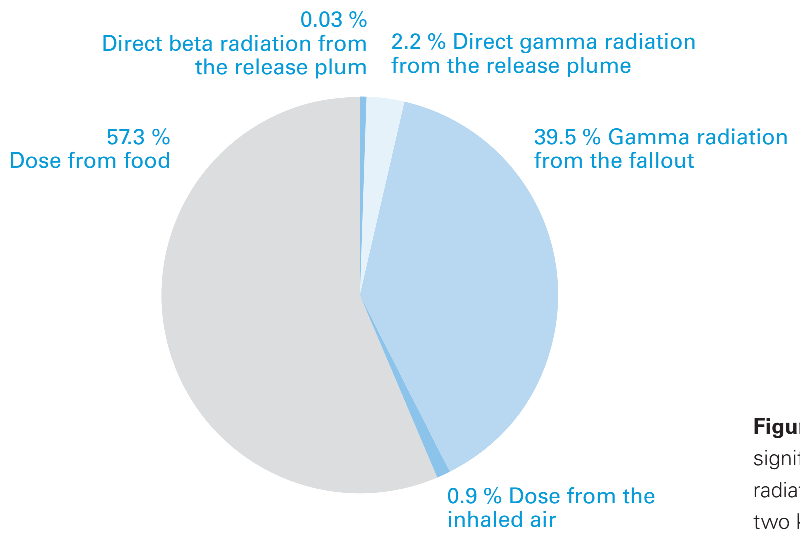


Figure 7-50. Average shares of the most significant exposure routes in the lifetime radiation dose received at the distance of two kilometers from the plant.

Table 7-22 presents the fallout of the most important nuclides in the spreading direction of the release at various distances from the power plant.

Table 7-23 presents the radioactivity of various foods resulting from the release that is being examined. Extensive long-term restrictions on the use of agricultural foodstuffs such as vegetables, milk and meat will not be necessary. If domestic animals or food production are not subjected to any protection measures, restrictions of use may be necessary within 40 kilometers of the plant in the spreading direction of the release until cesium concentrations have fallen low enough.

In case of an accident, restrictions on the use of various kinds of natural products will have to be issued in areas affected by the greatest fallout. Long-term restrictions on the consumption of some mushrooms, for example, may be required in areas at a distance of 50 km in the spreading direction of the release. The radioactivity in mushrooms will depend particularly on cesium-137, which is the most important radioactive substance found in the woods with regard to radiation doses. The accumulation of cesium varies greatly between mushroom species. The activity in edible mushrooms may vary even a hundred-fold (*Pöllänen 2003*).

The cesium-137 concentration in forest berries varies depending on how nutrient-rich the habitat is. Accumulation reaches its peak on infertile or humid habitats (*Pöllänen 2003*). In cervids and other game animals, the level of accumulated radioactivity depends on the amount of radioactive substances in their food plants. The concentration of cesium-137 in mountain hare meat may be two or three times that of a fully grown elk inhabiting the same area, whereas the concentration is significantly lower in brown hare, waterfowl, and pheasants (*Pöllänen 2003*).

Radioactive fallout also contaminates surface water, which leads to increased activity in freshwater fish. The average cesium concentration in consumable Finnish freshwater fish is approximately 0.20 kBq/kg (*STUK 2004b*). With regard to radiation exposure from fish, cesium-137 is the most noteworthy radioactive component in the fallout because it is localized in the edible parts of the fish. Strontium-90, on the other hand, is localized in fish bones, which are generally not consumed. Fish species feeding on plankton, such as vendace or carp, reach maximum activity concentration of cesium-137 in a few months after the fallout. After that time their concentration begins to decrease, because the regeneration speed of plankton is high. Due to long food chains, predatory fish, such as northern pike or pike-perch, do not reach their maximum activity concentration until later.

In nutrient-poor lakes, the cesium concentration in fish is higher than in nutrient-rich lakes even if the amount of fallout in both lakes is equally large per volumetric unit. The cesium concentration in fish decreases more slowly in small, nutrient-poor lakes where the rate of water exchange is low. It has been estimated that after the Chernobyl disaster, it took over 20 years before the concentration of cesium-137 in fish fell to the pre-fallout level in areas with the highest cesium-137 fallout. (*Pöllänen 2003.*) In Finland, the highest fallout from Chernobyl was approximately 45 to 80 kBq/m^2 (*STUK 2013j*). The areas with highest fallout include southern lake Päijänne, for example (*STUK 2013v*). In southern lake Päijänne, the activity content in northern pike decreased below the maximum permitted level established in the European Union in approximately six years, whereas the corresponding time in vendace was about one year (*Pöllänen 2003*). In the release examined in this EIA report, a cesium-137 fallout of approximatly 50 kBq/m^2 is possible at a maximum distance of 10 kilometers from the accident location. The activity in fish, predatory fish in particular, may still exceed the level recommended for natural products up to 300 kilometers from the plant in the spreading direction of the release.

In a sea environment, fallout generally has a less severe impact than in lakes because the larger water volume in the sea dilutes the radioactive content more effectively. After the Chernobyl disaster, the highest concentrations of cesium137 in fish in the Baltic Sea have been less than one tenth of the maximum concentrations in freshwater fish (*Pöllänen 2003*).

Following the Chernobyl disaster in May 1986, the average cesium-137 concentration was 1,000 Bq/m^2 in lichen in Lapland. The increase of cesium concentration in reindeer meat became evident after the beginning of the winter slaughter, when the average activity content of cesium-137 in reindeer meat was about 0.70 kBq/kg. Fifteen years after the accident, the concentration was under 0.20 kBq/kg (*Pöllänen 2003*). According to a recommendation of the EU Commission, the maximum permitted concentration of wild food products to be placed on the EU market is 0.60 Bq/kg (Recommendation 2003/274/Euratom).

The use of reindeer meat would have to be restricted after the fallout, if the fallout spread in the direction of the reindeer herding area. The reindeer herding area begins at the approximate distance of 100 kilometers from the Pyhä-

Table 7-22. Nuclide fallout at the distances of 1–1,000 km from the power plant (95 % fractile).

	Fallout at various distances (kBq/m^2)								
	1 km	**3 km**	**10 km**	**20 km**	**100 km**	**150 km**	**300 km**	**500 km**	**1000 km**
Cs-134	640	220	79	37	8.5	5.8	3.0	1.9	0.97
Cs-137	330	140	49	23	6.0	4.2	2.3	1.4	0.79
Sr- 90	51	17	6.2	2.9	0.67	0.46	0.24	0.15	0.08
I-131 (as an aerosol)	5,700	1,900	690	320	78	53	28	17	9.0
I-131 (elemental)	1,700	630	140	64	11	7.3	3.3	1.9	0.87

Table 7-23. The fallout resulting from the release and the food products radioactivity caused by the fallout at the distances of 1–1,000 km from the power plant (95 % fractile).

	Activity concentration in various food products at different distances from the plant (kBq/kg)									
	1 km	**3 km**	**10 km**	**20 km**	**100 km**	**150 km**	**300 km**	**500 km**	**1,000 km**	**Limit set by authorities (STUK 2012b)**
Reindeer meat, Cs-137 + Cs-134	No conditions similar to Lapland				5.9	3.9	2.0	1.2	0.58	**0.6**
Milk, I-131	12	4.2	1.1	0.51	0.1	0.06	0.03	0.02	0.01	**0.5**
Milk, Cs-137 + Cs-134	6.5	2.3	0.68	0.32	0.07	0.04	0.02	0.01	0.01	**1.0**
Meat products, Cs-137 + Cs-134	39	14	4.1	1.9	0.39	0.26	0.13	0.08	0.04	**1.25**
Freshwater fish, Cs-137 + Cs-134	97	36	14	6.6	1.7	1.2	0.64	0.41	0.22	**0.6**
Freshwater fish, I-131	24	8.3	3.0	1.4	0.32	0.22	0.11	0.07	0.04	**2.0**
Mushroom, Cs-137 + Cs-134	16	5.7	1.7	0.8	0.16	0.11	0.05	0.03	0.02	**0.6**

joki plant location. The cesium release could result in a concentration of 7,7 kBq/kg in the meat of the reindeer that live closest to the plant. The concentration is of the same magnitude with the values measured in reindeer after the nuclear weapons testing in the 1960s (*Pöllänen 2003*). Based on the Nuclear Liability Act, the licensee of a nuclear power plant has the obligation to compensate for the damage caused by an accident. The contamination of reindeer meat can also be considered to be included in such damage.

7.13.1.4 Measures after a severe accident

The required protective measures after a nuclear emergency are defined in the STUK Guide VAL 2, *Protective measures during intermediate phase of a nuclear or radiological emergency*. Guide VAL 2 defines the criteria for launching, continuing, reducing and ending measures to protect people, the living environment, production operations and traffic. In addition to using the guide, careful consideration of the case and the conditions is necessary when selecting the measures. Figure 7-51 is a presentation of the protection measures after a nuclear power plant accident. Waste that contains radioactive substances is generated by many of these measures. Guide VAL 2 also includes instructions on the treatment of such waste.

7.13.1.5 Social impacts of a severe accident

Provisions for the consequences of a severe nuclear accident have been considered in the CEEPRA (Collaboration Network on EuroArctic Environmental Radiation Protection and Research) project, funded by the EU and included in the Kolarctic ENPI CBC program. The social impacts of a potential nuclear accident are one of the themes being studied. The principal objective is to understand the impact and mechanisms of a radioactive fallout from a social point of view. A hypothetical example in which an accident is conceived to have happened at the Hanhikivi nuclear power plant in Pyhäjoki, currently being planned, is used in the project. The project also considers the proposals and recommendations that aim to mitigate the social impact of potential accidents. Some of the results of the project are introduced in the following paragraphs. (*CEEPRA 2013*)

According to the study, social impacts are realized through physical changes in the environment. The impacts depend on the radiation level of the radioactive fallout, the number of exposed communities or people within the fallout area, and the sensitivity of the area and its functions, or the significance of these for everyday life. The living conditions and comfort in the areas with the most intense contamination will be significantly deteriorated. It can, however, be expected that the impact on the living conditions and comfort remains slightly smaller in urban environments than in rural environments. This is mostly result of the more frequent outdoor activities, utilization of natural products and the greater significance placed on nature in rural environments, in which gathering of natural products for domestic purposes as well as primary production (farming, beef and dairy cattle) are important sources of livelihood and ways of life. (*CEEPRA 2013*)

In the areas with the most intense contamination, changes in the social character of the area and the perceived environment may also be significant: the area's attractiveness as a living environment deteriorates, the feeling of health and safety weakens, and the utilization of the natural resources that characterize the area may suffer. Even when there are no direct physical health effects, the worry brought on by changes in perceived health and feeling of security can be considered significant. The perceived impact varies between individuals, and large differences are possible between different people and population groups. (*CEEPRA 2013*)

From a socio-economical point of view, the impacts and changes in the most contaminated areas affect the sources of livelihood that are based on nature, such as the production of foodstuffs. The occupations that are based on the utilization of natural products can be estimated to suffer the most. These include fishing, hunting and reindeer farming as well as the export of natural products. (*CEEPRA 2013*)

7.13.2 Abnormal and accident situations during construction

The machines and equipment at the nuclear power plant construction site need fuel oil and lubrication oils. Chemicals are also used for cleaning parts and equipment. These chemicals may be stored in the construction site.

Leaks during refueling and oil leaks from work machines are generally small, a few liters at most. Oil leaks smear the surface of soil and asphalt, but it does not proceed to groundwater or water systems. An oil leak of a larger scale may occur when a fuel oil or chemical container breaks or a vehicle used for the transportation of chemicals has an accident on main road 8 or the road leading to the Hanhikivi headland.

In the case of a traffic accident, the maximum amount of chemicals that can be released to the environment equals the volume of the container. Transportation of chemicals is carried out in accordance with the regulations concerning the transportation of hazardous chemicals (VAK regulations). The VAK regulations set requirements for the qualification of the driver and the transportation equipment, among other things. Safety arrangements on main road 8 and the road leading to the Hanhikivi headland are described in Section 7.8.

The fuel oil containers used in construction site conditions are usually farm containers of 1–2 m^2. Other chemicals containers are typically plastic containers of 20 liters or lubrication oil barrels of 100 liters. Leaks from small containers are limited to the construction site area in which the container is located. Leaks from fuel oil containers are absorbed into the soil or may be carried through ditches to water bodies, if the leak is not detected in time. In case of a leak, the contaminated soil is removed and sent to a waste company that has the appropriate authorization to treat contaminated soil.

Oil leaks from machines and equipment can be reduced by regular maintenance. The storage containers of work machine fuels must have double casing. Contamination of soil in refueling areas of the construction site is prevented by covering the refueling area with solid asphalt or other similar structure that prevents leaks from being absorbed into the soil. Temporary storage of chemical containers during construction also requires a facility with a roof and a solid base.

Hundreds of people who are employed by many different companies and come from different countries work at the construction site, speaking many languages. The demanding working environment may increase the risk of accidents at work. Injuries are possible during blasting, when working at great heights and when handling chem-

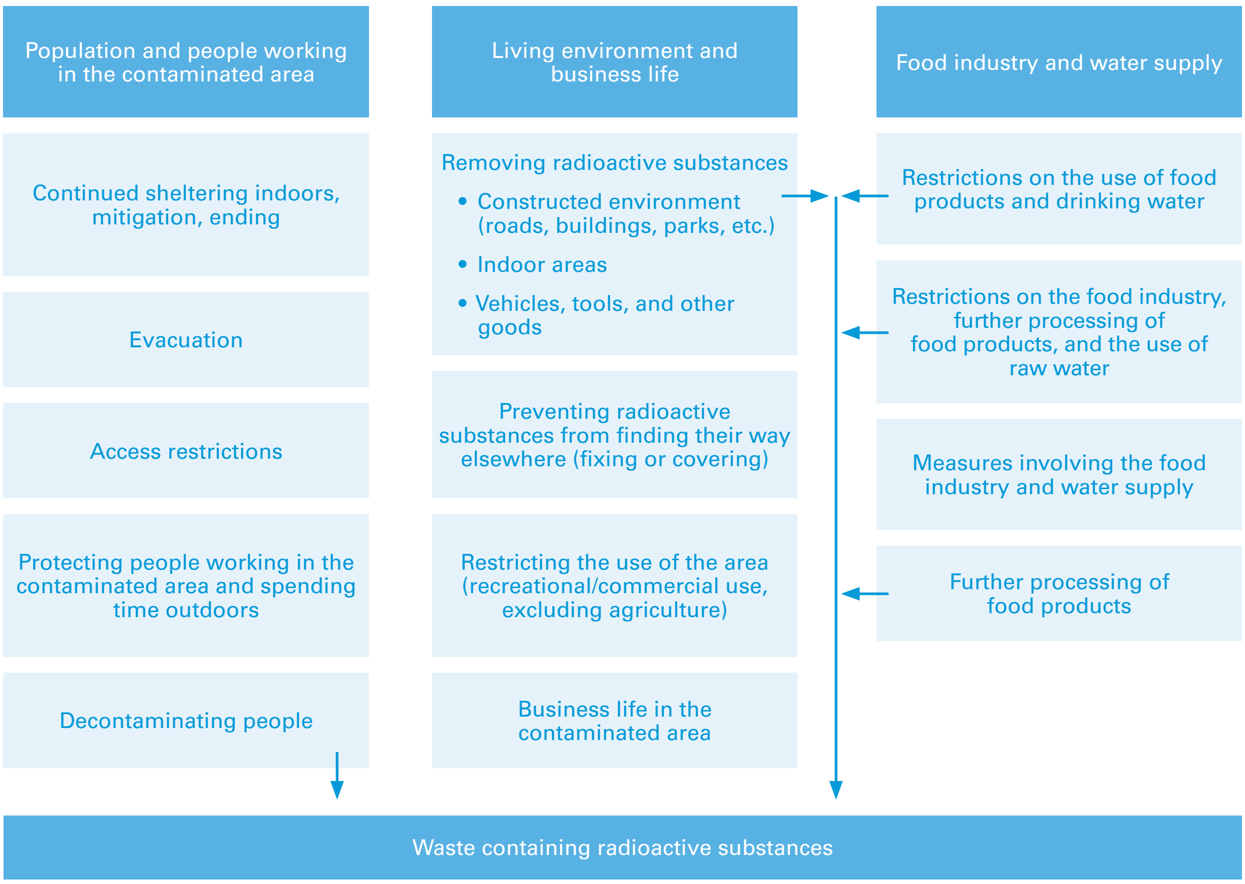


Figure 7-51. Protective measures after a radiological emergency. *(STUK 2012b)*

icals, for example. Contractors and subcontractors must launch immediate mitigation and first aid measures to limit the impacts of any accident. All chemical leaks and accidents at work are reported to the site management in accordance with the environmental and occupational safety management system established for the site.

To avoid accidents, all staff is trained to use safe working methods and familiarized with the site instructions. Instructions are prepared for the training and for the prevention of injuries and environmental accidents, and appropriate qualifications are required of the staff.

7.13.3 Other abnormal and accident situations during operation

7.13.3.1 Accidents with radiation danger

In addition to a severe nuclear accident, other abnormal situations and accidents that may cause radiation danger are also possible in the plant area. Such situations may occur for example when handling, storing and transporting operating waste and spent nuclear fuel. Severe accidents that meet the definition given in Government Decree (717/2013) have been discussed in Section 7.13.1.

Other events with radiation danger are considered in plant design, and any events are thoroughly covered in the safety reports submitted to STUK. Such events with radiation danger include the following:

- Burning liquid or electrical failure causes fire or an explosion in waste management facilities, and radioactive substances are released to the environment as a result.
- Flooding caused by a natural phenomenon or plant operation spreads radioactive substances into the environment.
- An impact or fall affects the tightness of a radioactive waste container, and radioactive material is able to spread into the plant area.
- An employee stays too long in radiation controlled facilities and receives a radiation dose that exceeds the reference values.

Many provisions are made for accidents that may occur in the handling or storage of radioactive waste in the plant area. Prevention and limitation of fires and explosions is mostly taken care of by the appropriate design of the premises and fire compartmentalization. Long-term storage of flammable waste is avoided, and non-combustible and heat-resistant construction materials are preferred. Fire detection and extinguisher systems are installed into the facilities to detect any fires and to prevent the escalation of the situations. The facilities also have a radiation monitoring system that allows the detection of potential transients and accidents. In most accidents, releases are likely to be limited to the nuclear power plant area and will have no significant impacts on the immediate environment.

In the underground repository of the low and intermediate waste only fire could have any impact on the environment if it allowed radioactive substances to spread into the soil, bedrock or atmosphere despite precautions. The possibility of fire is taken into consideration and minimized through the following precautions:

- Prevention of fire is primarily based on the appropriate design and fire compartmentalization of the facilities.
- Underground repositories are equipped with an automatic fire alarm system.
- Underground repositories, where fire could pose a radiation hazard, are equipped with a suitable extinguishing system and first-aid extinguishing equipment.
- When necessary, operating waste transportation vehicles are equipped with a suitable fire extinguishing system.
- Non-combustible and heat-resistant construction materials are preferred in repositories.

In the repository for very low level waste, located on ground surface, emissions are only possible in the case of a fire, and even then, the impacts of radiation would remain insignificant due to the low activity level of the waste. The possibility of fires will be taken into account by ensuring the availability of firefighting equipment in the vicinity of the repository during deposit campaigns. The possibility of a fire will also be taken into account during the sorting and packing of waste.

The repository for very low level waste cannot fill with water because the repository will be located on the ground surface and because flooding will have been taken into account in its design. The base slab of the repository will isolate the waste from the soil, and any seepage water permeating the surface layers covering the repository will be collected and analyzed in order to determine the concentrations of radioactive substances. If necessary, the seepage water can be cleaned in an appropriate manner at the power plant's liquid waste treatment facility before it is released into the water system. This will guarantee that no significant quantities of radioactive substances are released from the repository.

Radioactive waste and spent nuclear fuel are kept in the plant site in designated containers and facilities. Transportation of spent nuclear fuel is carried out using a transport cask designed for the purpose. For transportation, the spent fuel elements are packed into a solid and leak-tight nuclear fuel transport container. An accident could be possible in the transfer and transportation of radioactive waste or spent nuclear fuel if the tightness of a radioactive waste container was compromised as a result of a collision or fall that would allow the radioactive release into the plant area or the environment. Accidents during transfer or transportation of radioactive waste or spent nuclear fuel are prepared for by measures such as equipping the transportation vehicles with appropriate fire extinguishing systems.

The objective is to prevent any accidents caused by human errors of the staff. For example, radioactive facilities and components are indicated and isolated to prevent accidental and unnecessary exposure to radiation. Personal dosimeters give an alarm when the radiation level increases, and help avoid hazardous locations. The plant has its own radiation protection organization that guides people working in the plant area and carries out other radiation protection measures. Training is organized to introduce workers to the correct procedures used in accident situations.

7.13.3.2 Other accident situations

In addition to accidents with radiation danger, other environmental accidents which may take place at a nuclear power plant include accidents related to the transportation, discharge, loading, storage and use of oils and other chemicals. Risk mitigation measures related to the use of chemicals are described in connection with soil, bedrock and groundwater impacts (Section 7.5.4).

The plant's emergency diesel generators use light fuel oil. The oil is stored at the plant. A significant volume of oil is stored in the containers. An uncontrolled oil leak could contaminate the soil and groundwater. If oil is able access a drain ditch, it will contaminate the water and sediment in the ditch. If the oil forms pools in the ditch or is able to access the sea, water fauna, birds and fish will be exposed. In the sea, the oil spill may be carried onto the shores around the power plant. The oil may also be carried to the cooling water intake area, affecting the quality of the power plant's cooling water and the operation of the cooling system. Cooling water intake area is located inside the harbor basin. In case of an oil spill, containment booms can be places to the mouth of the harbor.

Oil containers will be placed so that a potential leak cannot access the sea. The storage containers will have automatic overfill alarms, and they will be placed inside a protective pool. The volume of the pool will be larger than the volume of the oil container, which will efficiently prevent any oil leak from spreading into the environment. Access of oil spills into the sea will be prevented by building a dam into the drain ditch and using containment booms to prevent the spreading of the oil spill. The oil container must also be placed so that it cannot be reached by rising sea water of heavy rain occurring under abnormal weather conditions. This ensures proper functionality in all conditions.

The Port of Raahe is located approximately 15 kilometers from the Hanhikivi headland, and the navigation channel to the port is located 15 kilometers away from the headland. The port has no storage containers of chemicals or oils. The operations of the port are not estimated to pose any risk for cooling water intake. The port is mainly used for exporting products of the chemical industry. Import of chemicals and the import and export of oil, on the other hand, are not frequent at the Port of Raahe. Sea transportation of the chemicals takes place far from the headland, and it is not estimated to pose a risk to cooling water intake in accident situations. An oil spill occurring under unfavorable conditions could spread to the Hanhikivi headland sea area and require mitigation measures.

In addition to the fuel of the emergency diesel generators, substances used and stored at the power plant include acids, bases, gases and detergents. If acids and bases are able to access water, they can change the pH value of the water and temporarily affect the living conditions of fishes. The environmental impacts of any leak would be temporary, as acids and bases tend to neutralize when they come into contact with the soil, groundwater of other water bodies. If leaks of acids or bases come into contact with structures, they will damage concrete and metal, which is taken into account in the design of structures.

Accidents when storing or handling chemicals are unlikely, because the potential abnormal and accident situations will already be taken into account in the design and construction of discharge equipment, storages and transport pipelines of these chemicals. The chemical storage tanks and chemical warehouses will be built in compliance with the Chemicals Act, regulations issued pursuant to it, and SFS standards. Drainage will be designed in a manner which ensures that any leaks will be contained in protective basins, sludge/oil traps, or a neutralization pool.

7.14 Transboundary environmental impacts

7.14.1 Impacts of a severe nuclear power plant accident

In order to evaluate the impacts of a nuclear power plant accident, the EIA procedure has included modeling of the spread of a radioactive release caused by a severe reactor accident, the consequent fallout, and radiation dose received by the general public. The studied release was the cesium-137 release of 100 TBq laid down in the Government Decree (VNa 717/2013), which corresponds to an INES 6 accident. The consequences of an INES 7 accident, which is five times larger, have also been assessed. The modeling methods, a modeled example case, and its impacts are discussed in more detail in Chapter 7.13.1. The assumptions used in the modeling were revised from those used in the EIA of 2008 as illustrated in the attached table (Table 7-24). The analyses included several assumptions concerning the size of the release, its timing, and the calculation of doses to verify that the calculation results and the radiation doses will be conservative. The release amounts and rate are exceptionally high. The dose calculations are based on the assumption that no civil protection measures are implemented. However, the radiation dose from food could easily be limited through various restrictions on the use of foodstuffs, for example.

Table 7-25 illustrates the radiation doses from a severe accident 100–1,000 km from the nuclear power plant.

The severe reactor accident would not cause any immediate health impact on the population in the surrounding areas under any weather conditions. Civil protection measures would not be necessary outside of Finland, because even in the worst case such measures will be necessary at a maximum distance of 15 km from the plant (Table 7-20).

The radiation dose caused by the accident outside Finland would remain statistically insignificant. The Hanhikivi headland is located approximately 150 km from the coast of Sweden. If the wind and the weather conditions were unfavorable, the release would cause a maximum lifetime dose of 8 mSv for a child living on the coast of Sweden, and a lifetime dose of 4 mSv for an adult on the coast of Sweden. At the Norwegian border approximately 450 km from the power plant site, the release would cause a dose of a maximum of 4 mSv for children and 2 mSv for adults. On

Table 7-24. Comparison table on the assumptions used for accidents in the EIA of 2008 and this EIA.

Variable/ assumption	EIA 2008	EIA 2014	Justification
Definition of the source term	SSK 2002	NRC 1995, NRC 1988, NRC 1975	The source term definition reports by the US Nuclear Regulatory Commission (NRC) are globally accepted.
Amount of cesium-137 in the release	100 TBq	100 TBq	The maximum release laid down in the Government Decree (717/2013).
Amount of iodine-131 in the release	960 TBq	1,560 TBq	Based on ref. NRC 1995
Amount of xenon-135 in the release	1,570 TBq	180,000 TBq	Based on ref. NRC 1995
Weather conditions	Average and adverse weather conditions determined by expert judgement based on weather observations made in 2004–2006.	Dilution factors calculated based on the weather observations made between October 2010 and October 2013 (corresponding to the 95% fractile).	Distributions calculated directly based on the weather conditions offer more accurate radiation dose values.
Start of release from the start of the accident	6 hours and 24 hours	6 hours	Only the more unfavorable release, i.e. the one that starts earlier, has been studied in this EIA.
Duration of the release	1 hour and 6 hours	72 hours	The durations of release used in this EIA have been selected in order to assure overestimation of the doses. However, the duration have been selected more realistically than in the EIA of 2008.

Table 7-25. Radiation doses of adults and children following a severe reactor accident at different distances (95 % fractile).

	Radiation dose for a child (mSv)			Radiation dose for an adult (mSv)		
Distance (km)	In 2 days	In 7 days	Over lifetime (70 years)	In 2 days	In 7 days	Over lifetime (50 years)
100	0.2	0.3	10	0.1	0.2	4.8
150	0.2	0.2	8	0.1	0.2	3.8
500	< 0.1	< 0.1	< 3	< 0.1	< 0.1	< 2
1,000	< 0.1	< 0.1	< 2	< 0.1	< 0.1	< 1

the coast of Estonia approximately 550 km from the power plant site, the maximum lifetime dose for children would be 3 mSv and 2 mSv for adults. The dose on the coast of Poland approximately 1,100 km from the power plant site would remain below 2 mSv, also in the case of children. The plant site is approximately 1,850 km from the Austrian border in Central Europe. Even if the weather conditions were unfavorable, the release would cause a lifetime dose of max. 1 mSv for a resident of Austria. In comparison, a person living in Austria may, during their lifetime, receive a dose of more than 200 mSv from natural background radiation (*WNA 2013b*).

The enclosed tables illustrate the fallout caused by the release at different distances from the plant (Table 7-26) and maximum radiation contents in foodstuffs caused by the release (Table 7-27). A severe accident could increase the radioactivity of reindeer meat or freshwater fish to a level that will require temporary restrictions on their use. If these restrictions are followed, the radioactivity in reindeer meat or freshwater fish would not pose any danger to people.

The use of freshwater fish could have to be restricted in the coastal areas of northern Sweden. The restrictions on freshwater fish could be limited to specific rivers and lakes in the worst fallout zone.

The use of reindeer meat might have to be restricted in Sweden, Norway, and the northwestern part of Russia. However, the radioactivity of reindeer meat can be reduced by preventing reindeer from eating lichen, because cesium accumulates in lichen. This could mean that reindeer would have to be removed from the worst fallout zone. The reindeer could also be kept in enclosures feeding on clean food until the radioactivity in the fallout zone has decreased to an acceptable level.

Table 7-26. Fallout of various nuclides 150–1,000 km from the plant (95 % fractile).

	Fallout at different distances (kBq/m2)			
	150 km	300 km	500 km	1,000 km
Cs-134	5.8	3.0	1.9	0.97
Cs-137	4.2	2.3	1.4	0.79
Sr-90	0.46	0.24	0.15	0.08
I-131 (as an aerosol)	53	28	17	9.0
I-131 (elemental)	7.3	3.3	1.9	0.87

Table 7-27. Activity concentrations caused by the nuclide fallout in food products 150–1,000 km from the plant and Finnish statutory limits for the use of food products (95 % fractile).

	Activity concentration in various food products at different distances from the plant (kBq/kg)				
	150 km	300 km	500 km	1,000 km	**Statutory limit (STUK 2012b)**
Reindeer meat, Cs-137 + Cs-134	3.9	2.0	1.2	0.58	**0.6**
Milk, I-131	0.06	0.03	0.02	0.01	**0.5**
Milk, Cs-137 + Cs-134	0.04	0.02	0.01	0.01	**1.0**
Meat products, Cs-137 + Cs-134	0.26	0.13	0.08	0.04	**1.25**
Freshwater fish, Cs-137 + Cs-134	1.2	0.64	0.41	0.22	**0.6**
Freshwater fish, I-131	0.22	0.11	0.07	0.04	**2.0**
Mushroom, Cs-137 + Cs-134	0.11	0.05	0.03	0.02	**0.6**

If the release were the release that is five times higher than the 100 TBq release discussed above (more than 50,000 TBq of iodine-131 equivalents), the accident would be classified as an INES 7 accident. Such a high release is theoretically impossible in terms of noble gases, because the release would mean that five times more noble gases than the reactor contains would be released.

Such a fivefold release would not cause any immediate health impact. If the wind was blowing to the west and the weather conditions were otherwise unfavorable (95 % fractile), the lifetime dose of a child on the coast of Sweden would be approximately 37 mSv and the lifetime dose of an adult approximately 18 mSv. Under similar unfavorable conditions, the radiation dose at the Norwegian border could be a maximum of 14 mSv for children and 7 mSv for adults. The radiation doses in the other countries bordering the Baltic Sea would remain below 12 mSv for children and 6 mSv for adults even if the weather conditions were unfavorable. The lifetime radiation dose in Austria would not exceed 5 mSv for children and 2 mSv for adults.

Such a fivefold release would give rise to restrictions on the use of foodstuffs also outside of Finland. The use of reindeer meat would have to be restricted in the fells of Sweden, Norway, or northwestern Russia, depending on the direction the emissions have spread. Also depending on the direction the emissions have spread, restrictions on the use of freshwater fish could be necessary in Sweden, Norway, northwestern Russia, and the Baltic states. If grazing of cattle were not limited, restrictions on the use of meat could be necessary in the coastal areas in northern Sweden.

7.14.2 Other impacts

The normal operation of the nuclear power plant does not cause any transboundary environmental impacts.

7.15 Nuclear fuel production chain

The Fennovoima nuclear power plant will use approximately 20–30 tons of enriched uranium as fuel per year. The production of this amount of fuel requires 200–350 tons of natural uranium. When natural uranium is used, the phases of production of nuclear fuel will be as follows: excavation and extraction of uranium ore, conversion into uranium hexafluoride (UF_6), enrichment for the U-235 isotope, the production of fuel pellets and fuel rods, and the manufacture of fuel bundles. The excavation and extraction stages are not included in the supply chain of fuel from secondary sources. The fuel production chain is described in the Section 3.7.2.

7.15.1 Impacts of uranium mining

The environmental impacts of uranium mining operations are connected with the radiation of the uranium ore, the radiation impacts of the radon gas released from the ore, mining waste, dust and wastewater.

In subterranean mines, the radon exposure of employees can be reduced to a harmless level not causing any adverse health impacts by ensuring good ventilation. Opencast quarries naturally have sufficient ventilation of radon gases. In Canadian mines operating in areas of deposits with high uranium content, mining has been automated and the machines are operated by remote control to avoid having employees handle uranium ore.. The dust generated at mines is monitored in order to prevent radioactive minerals from entering people's respiratory tract. Dust can be reduced by watering, and if necessary, access to dusty areas can be limited. The radiation doses of employees and the radiation level at the mine are monitored.

Natural radon gas spreads in the environment according to the strength and direction of wind, for instance. The concentrations rapidly become weaker when spreading further from the mine. Other uranium degradation products are solids that can only escape into the environment with water or dust. In addition to radon, harmful radium is precipitated from the circulating water.

The impacts of mining operations on the population are typically relatively minor because uranium mines are primarily subterranean and are located in remote areas, far from settlements. The disposal of mining waste, tailings, and gangue that are generated in the course of mining operations is taken care of in a way that prevents the dissolution of harmful substances from the waste and the release of radon from the area. The waste disposal areas are covered layer by layer to prevent the waste from decaying and rainwater from dissolving the radium. Water flowing through the waste piles is monitored in order to be able to treat it as necessary. Treatment ensures that the quality of water released into the environment fulfils the appropriate requirements. *(WNA 2013a)*

Radiation impacts, the generation of wastewater, and landscape impacts can be largely avoided by applying the underground leaching method.

The uranium oxide generated at the extraction plant is a toxic substance and breathing it is harmful to the kidneys in a manner similar to lead oxide. Precautionary measures similar to those in lead-smelting plants are applied at the extraction plant.

The license application for constructing and operating a uranium mine includes a restoration plan concerning the termination of mining operations. The plan describes in detail how the applicant is committed to take responsibility for land filling and landscaping, and to comply with standards imposed on air and water quality. The plan also explains how requirements related to health and safety will be met. Furthermore, operators must collect funds to cover the costs of restoration and decommissioning.

Currently, in countries with uranium mining operations, such as Canada and Australia, regulations and guidelines issued by the national governments and the environmental and nuclear safety authorities guide the production processes connected with the mines and the further converting of uranium. The authorities monitor the operation of the mines. The status of the environment in the mining area will be monitored for years after operations have ended and even after the restoration measures have been carried out in the mining area. Factors affecting the environment, health and safety of mining activity are managed to an increasing extent by international standards and audits carried out by external parties.

Production companies, mines, conversion and extraction plants, and fuel production and manufacture plants in the uranium fuel supply chain are also audited by the nuclear power production companies that are their clients to ensure that the different phases of the uranium fuel production chain operate in an acceptable way.

7.15.2 Impacts of the conversion and enrichment plant

Conversion and enrichment are chemical operations where hazardous chemicals are handled and stored. Several laws and regulations concerning the management of hazardous materials and wastes regulate the operations of chemical plants. Training of the employees has an important role in the prevention of environmental damage.

At the conversion plant, gaseous and liquid impurities are generated in the production of fluorine, the fluorination of the uranium compound, and the solution purification processes. The most significant gaseous impurities monitored at conversion plants are hydrogen fluoride (HF), fluorine (F_2), and uranium isotopes (U).

The centrifuge plant will generate some gaseous radioactive emissions. For instance, the wastewater from the gas scrubbers of a centrifuge plant is slightly radioactive. In case of any leaks of toxic uranium hexafluoride in a gaseous form, enrichment plants have detectors to protect the plant's employees and prevent emissions outside the plant.

The liquid and gaseous emissions generated at conversion and enrichment plants, as well as waste, are processed appropriately, and the plants do not cause any major environmental impacts under the normal conditions. In actual accidents, the impacts have mainly been restricted to the plant area. State-of-the-art conversion plants circulate the chemicals, which reduces the volume of chemicals used and the need to store them onsite. Environmentally hazardous chemicals can be replaced by less hazardous compounds, as has been done with regard to CFC compounds which destroy the ozone layer. In some cases, chemical processes can also be replaced by thermal processes. *(Cameco 2008, Urenco 2006, Energiateollisuus ry 2006)*

7.15.3 Impacts from manufacture of fuel bundles

No significant radiation impacts will be caused by the fuel plant, since enriched uranium only contains minor amounts of the most hazardous uranium degradation products in terms of radiation, such as radium, radon, or polonium. The fuel becoming critical and/or an uncontrolled chain reaction occurring during manufacture are impossible because no stage of the manufacturing process involves any moderator (water) that would enable a chain reaction.

Several hazardous chemicals will also be processed at the fuel plant, and they will be handled in compliance with the laws and regulations on the processing and storage of hazardous materials.

Exhaust air and wastewater to be released from the production plant will be treated as necessary before releasing them into the environment. Air exiting the plant will be released through a filter. Uranium dust in the working area will be continuously monitored.

7.15.4 Impacts of transport

The amount of fuel used annually by a nuclear power plant is low when compared to energy production plants using other fuels, and the volumes to be transported are relatively low. However, transport is needed at several stages of the production chain, and the transport distances can be long. The intermediate products and fuel assemblies transported from the mines to the power plant will be slightly radioactive at most. Nuclear materials are transported by specialized transportation companies that have the required qualifications and official authorizations.

National and international regulations on transport and storage of radioactive materials are based on the widely accepted standards and guidelines issued by the International Atomic Energy Agency (IAEA; for example, *IAEA 2008a)*. The purpose of the regulations is to protect people and the environment from radiation during the transport of radioactive materials.

The main principle is that the basis of protection is the transport container, regardless of the means of transport used. In addition, protection is based on the management of the radioactive materials being transported, control of the radiation levels caused, prevention of criticality, and prevention of damage caused by heat. *(WNA 2011b, STUK 2013q)*

7.15.5 Environmental load of nuclear fuel per energy unit produced

The amount of fuel required in the production of electricity with nuclear power is considerably lower than in the production of electricity using fossil fuels, such as coal. Several life cycle studies have compared the CO_2 emissions of various energy production forms. The CO_2 emissions of nuclear power have been in the range of 2–40 g CO_2 equivalents/kWh. The emissions of coal have varied between 800 and 1,300 CO_2 eqv/kWh and those of natural gas between 400 and 700 CO_2 eqv/kWh. Most of the CO_2 emissions of electricity produced with nuclear power are generated in the fuel production chain. In the case of fossil fuels, most of the CO_2 emissions are generated at the electricity production stage. *(World Energy Council 2004, World Energy Council & Energiafoorumi ry 2005, WNA 2006)*

7.16 Energy markets

7.16.1 Assessment methods

Impacts on the energy markets were studied in the same manner as in the EIA report of 2008, taking into account current assessments on the future outlook of the electricity market, the fuel market, emissions trading, and the national security of supply when the nuclear power plant is in operation.

7.16.2 Impacts

The Nordic electricity market has traditionally been based on the region's abundant hydropower resources. Under normal conditions, approximately half of the electricity required by the Nordic countries is produced with hydropower. The other half of the electricity demand is covered mainly with nuclear and thermal power, imported energy, and – to an increasing extent – wind power.

Finland is an importer of electricity. The annual net imports have amounted to approximately an average of 11 TWh during the 21st century. A large share of the imported electricity has traditionally come from the Russian market. In the past few years, the low electricity demand in the Nordic countries combined with the high volume of water in water systems has decreased the market price of electricity at the Nordic electricity exchange Nord Pool. At the same timethe capacity charges influencing the price of electricity imported from Russia have increased. Together, these issues have made import of electricity from Russia less profitable, which has significantly decreased the import volume. The deficit has been covered in Finland by importing electricity from the other Nordic countries.

By the 2020s, when the construction of Finland's fifth nuclear power plant unit (Olkiluoto 3) is completed, combined with the increased volume of wind power production, will increase Finland's degree of self-sufficiency. What this means in practice is that the total annual electricity production volume will be better in line with the total annual electricity consumption. The new nuclear power plant unit and the increased volume of wind power production will also prevent the rising of the electricity price in the Nordic countries, by offering electricity with affordable variable production costs to the market.

An updated national energy and climate strategy published by the Government states that Finland will be self-sufficient in terms of the production and consumption of electricity in the 2020s when the nuclear power plant units for which Decisions-in-Principle have been made have been commissioned or other decentralized forms of electricity production have become more common. *(Työ- ja elinkeinoministeriö 2013a)*

The new nuclear power plant will not actually replace any of the already existing capacity. However, it will reduce the annual production volumes of more expensive production methods, which may cause the condensate capacity to exit the market sooner than anticipated. The new nuclear power plant unit will however increase the net production capacity of electricity in Finland.

The increased supply of electricity with lower variable costs will prevent the price of electricity from rising in the Nordic electricity market. However, important factors influencing the price of electricity on the Nordic electricity market are the development of power transmission connections to continental Europe and the subsequent development of the demand for Nordic electricity outside the Nordic countries. When studied separately, the new nuclear power plant will decrease the electricity market price in Finland and the Nordic countries. The development of power transmission connections to the continental European electricity markets will significantly influence the market price of electricity in the Nordic electricity market, which may increase the demand for electricity produced in the Nordic market in countries outside the Nordic market. This would increase the price in the Nordic countries. It is difficult to give any specific assessment in euro on how the new nuclear power plant will influence the market price of electricity in Finland.

The Fennovoima nuclear power plant will improve the security of supply for power production by reducing Finland's dependence on fossil fuels and imported electricity. According to the National Emergency Supply Agency, uranium can, with regard to the security of supply, be compared with domestic primary energy through the use of fuel storage and fuel procurement contracts. There are a variety of sources of uranium supply, and they are located in politically stable areas. Producers of nuclear power use long-term contracts to secure the supply of nuclear fuel. Nuclear fuel can be stored at the plant site, and power plants usually have a sufficient supply of fuel to cater for several months or even a year of consumption. The fact that the Fennovoima nuclear power plant will be built at a new location will also improve the security of supply concerning potential failures in power transmission.

7.17 Combined impacts with other known projects

Projects close to the power plant site that could have combined impacts with the currently assessed power plant of approximately 1,200 MW have been identified.

Rajakiiri Oy is planning an offshore wind farm which would be located in front of a steelworks in Raahe in the Maanahkiainen water area. The southern part of the planned wind farm area is, at its closest, approximately four kilometers from the Hanhikivi headland. Puhuri Oy is planning a wind farm approximately five kilometers to the east of the Hanhikivi headland on the lands of Parhalahti village. A total of 15 other onshore wind farmsare being planned for the area. *(Pöyry Finland Oy 2013)* In addition to the wind farm projects, Morenia Oy is planning a soil extraction project in the sea area off the coast of Yppäri.

The nuclear power plant and the wind farm projects currently active in the region will together create an energy production area of national significance. The area that is currently in its natural state or used for agricultural production will become a large-scale energy production zone.

Other combined impacts of the nuclear power plant and the wind farms could involve power line routes. Power line routes connected to the nuclear power plant project and the wind farm projects are being planned in cooperation. A separate EIA procedure will be applied to the nuclear power plant's power lines, so their impacts will not be assessed in this EIA procedure.

The project may have a combined impact with the planned Parhalahti wind farm project in terms of recreational activities, as both projects will limit land use opportunities thus reducing hunting opportunities. According to the stakeholders, both of these areas are currently being actively used as hunting grounds.

Dredging to be implemented in connection with the offshorewind farm project and the project on extracting soil material could have a combined impact on the fish stock and thus fishing as the result of increased turbidity of the water, should the dredging operations be simultaneously implemented.

The Fennovoima and TVO nuclear power plant projects do not have any combined impacts in the immediate surroundings of the project sites.

7.18 Zero-option

7.18.1 Assessment methods

Environmental impacts of the zero-option have been assessed based on the EIA of 2008 of the available alternative electricity production methods. The assumptions used in the EIA of 2008 have been updated to correspond to the present situation. The assessment is based on public studies about development of the electricity production structure and the environmental impacts of the various electricity production methods. Impacts of the zero-option have been illustrated by means of emissions calculations which take into account the emissions that would be generated if the same volume of electricity was produced by other means. Impacts of the zero-option have been studied both locally and at the electricity market level.

7.18.2 Local impacts of the zero-option

The zero-option means not implementing the Fennovoima nuclear power plant project. In this case, the local impacts of the project described in this environmental impact assessment report would not be realized.

7.18.3 Demand for electrical energy and opportunities to save energy in Finland

In 2010, the total electricity consumption in Finland was approximately 88 TWh. Finnish energy production covered around 88 % or 77.5 TWh of this demand, and the rest was covered with imported energy.

According to the update of the national energy and climate strategy published in 2013, the electricity demand will be around 94 TWh by 2020, which is 9 TWh less than assumed in the version of the strategy published in 2008.

Similarly, the updated strategy estimates that electricity consumption in 2030 will be around 102 TWh, compared to 107 TWh in the strategy of 2008. The enclosed illustration (Figure 7-52) shows the development of electricity consumption in the 21st century and the forecasted demand laid down in the energy and climate strategy (*Työ- ja elinkeinoministeriö 2013a*).

The development of the Finnish energy production capacity is based on increasing nuclear power and wind power capacity. According to Finland's national energy and climate goals, 6 TWh of energy will be produced by wind power by 2020, which will then be increased to 9 TWh by 2025. In order to reach this goal, the capacity must be increased to approximately 2,000 MW by 2020 and 3,000 MW by 2030. Once completed, the third nuclear power plant unit in Olkiluoto will gradually increase the Finnish electricity production capacity. (*Työ- ja elinkeinoministeriö 2013a*)

Figure 7-53 illustrates future development of the Finnish electricity production capacity in light of the currently known goals, investments, and plants to be removed from the production reserve. In terms of nuclear power, only the impact of the third nuclear power plant unit in Olkiluoto has been included in this graph. If the nuclear power plant units for which Decisions-in-Principle have been made are constructed, the Finnish electricity production capacity will increase significantly more than shown in the graph. In the long term, the operating licenses of two of the units in Loviisa (two units of 495 MW) will expire at the end of the 2020s and in the beginning of the 2030s, and the units OL1 and OL3 in Olkiluoto (combined capacity 1,745 MW) will probably reach the end of their service life in around 2040. The combined capacity of all these units is approximately 2,700 MW. The demand for district heating is not expected to experience any significant changes during the studied period, which means that the Combined Heat and Power (CHP) capacity shown in the graph is assumed to not change much.

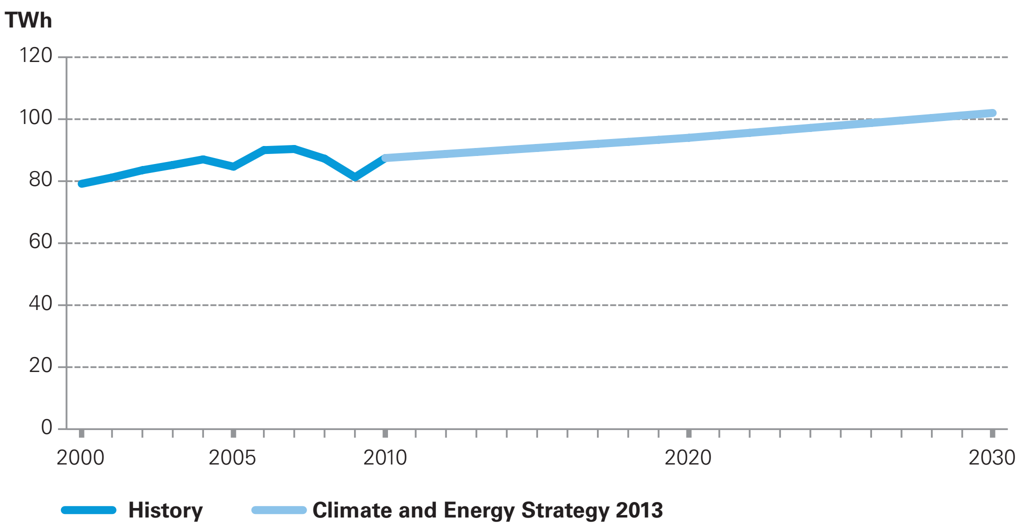
7.18.3.1 Finland's National Energy Efficiency Action Plan

The European Commission issued a proposal for a Directive on energy end-use efficiency and energy services on December 10, 2003. The Directive entered into force on May 17, 2006. According to the Directive, member states must adopt an overall national indicative energy savings target of 9% for 2008–2016. End-use consumption of energy within the scope of application of the Energy Services Directive amounts to 197.7 TWh, and on the basis of this, Finland's national 9% energy-savings target is 17.6 TWh by 2016. Member states are obligated to report in their National Energy Efficiency Action Plan (NEEAP) to the EU Commission every three years during the nine-year validity period of the Directive how well their savings target has been achieved (*Kauppa- ja teollisuusministeriö et al. 2007*).

The second National Energy Efficiency Action Plan (NEEAP-2) was submitted to the Commission in June 2011. It reports the actual savings in 2010 and the savings target for 2016. NEEAP-2 includes energy-efficiency measures, for which energy-saving impact can be calculated and key measures, for which a direct energy-saving impact cannot be calculated. The calculated energy savings in 2010 in the NEEAP-2 are 12.1 TWh, which – according to the Directive's calculation method – corresponds to savings of 6.1%. It has been estimated that these measures will increase the energy savings to 12.5% by 2016 and to almost 18% by 2020. (*Työ- ja elinkeinoministeriö 2011*)

The new Energy Efficiency Directive entered into force on December 5, 2012, replacing the previous Directive on energy end-use efficiency and energy services (the Energy Services Directive) and the Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market (the CHP Directive). The new Directive aims at achieving the energy savings target of 20% set by the EU for 2020. The national laws required

Figure 7-52. Development of electricity consumption in the 21st century and forecasted demand until 2030 laid down in the energy and climate strategy *(Tilastokeskus 2011, Työ- ja elinkeinoministeriö 2013a).*



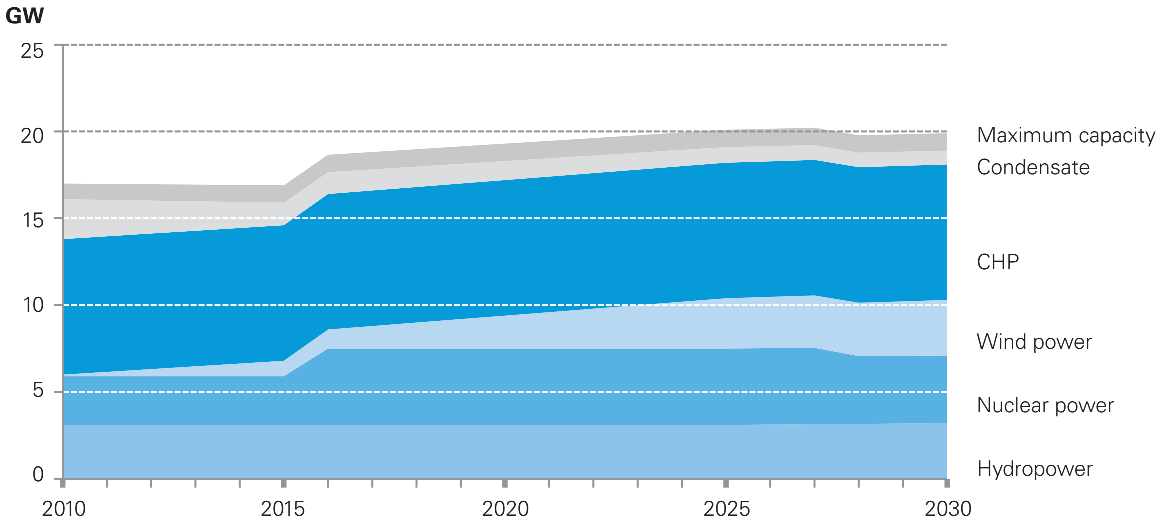


Figure 7-53. Future development of the Finnish electricity production capacity based on currently known goals, investments, and plants to be removed from the production reserve.

by the Directive must enter into force by June 5, 2014. The Ministry of Employment and the Economy has appointed a working group to prepare implementation of the new Directive. The new Directive is expected to make energy savings measures stricter and herald a switch from voluntary action to obligations. The Directive aims at achieving during its seven-year validity period cumulative savings of 79.8 TWh, of which 60 TWh will be covered with new measures (annual savings of 2.1 TWh). It has been estimated that energy saving contracts will cover 28 TWh of this goal. On an annual level, this means new savings of around 1 TWh in addition to the already established targets. *(Työ- ja elinkeinoministeriö 2013b)*

7.18.4 Energy saving measures by Fennovoima shareholders

Energy saving measures of the shareholders of Fennovoima were studied in a survey in 2007. Even though the shareholders have implemented measures to improve energy-efficiency, their potential for improving their energy-efficiency is low when compared to their electricity demand. No energy savings measures could replace the planned nuclear power plant.

7.18.5 Electricity production and cost structure in the Nordic electricity market

In the Nordic electricity market, the plants' operating order and the production forms of electricity are determined according to the variable production costs (Figure 7-54). For example, the variable costs of hydropower and wind power are very low because the sources of energy in these production methods are renewable natural resources that do not cost anything. Furthermore, the share of nuclear fuel costs in the production costs is small. The share of fuel costs in the production costs is relatively high for power plants that use fossil fuels and in biomass plants. The production costs of plants that use fossil fuels are further increased by the costs arising from emissions trading. The cost of an emission permit depends on the price of the emission permit, which is generated on the market, and the emission factor of the fuel used by the plant.

New nuclear power capacity with relatively low production costs would replace more expensive forms of energy production. First, it would reduce the separate production of electricity based on fossil fuels that is located on the right-hand side of the cost curve (Figure 7-54). The marginal production cost in the figure describes the variable production costs from most expensive the production methods required to replace the demand (the price at which the plant could offer electricity to the market), i.e. the electricity market price.

7.18.6 Impact of the zero-option on emissions

If a new nuclear power plant unit is not constructed in Finland, part of the production volume will probably be covered with separate production of electricity in Finland. A large part of the electricity that would have been produced by the nuclear power plant will be replaced with separate production based on fossil fuels in the other Nordic countries and continental Europe.

Figure 7-55 illustrates the sulfur dioxide, nitrogen oxide, small particle, and CO_2 emissions that the zero-option would cause in Finland and abroad. If the Fennovoima nuclear power plant project is not implemented, the same volume of electricity must be produced by other means. The assumption is that, in such a case, 20 % of the Fennovoima nuclear power plant's planned electricity production capacity of 9.5 TWh would be replaced with

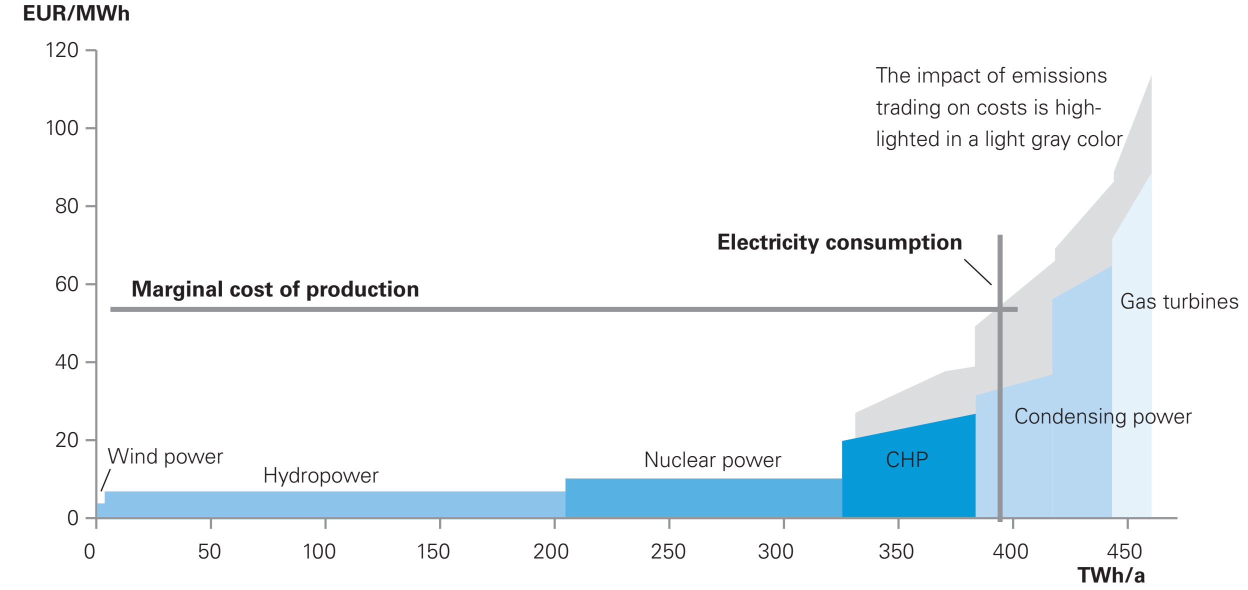


Figure 7-54. Variable costs of electricity production methods and their operating order in the Nordic countries. CHP stands for Combined Heat and Power.

separate electricity production in Finland. The remaining 80 % would be produced abroad. Separate electricity production is assumed to be coal condensate production according to the operating order of plants on the Nordic electricity market (see Section 7.18.5). The emissions from electricity production outside of Finland have been calculated according to the emissions generated by coal condensate production.

The production to replace the Fennovoima nuclear power plant in Finland and abroad would cause a little less than seven million tonnes of CO_2 emissions, a little less than six thousand tonnes of both sulfur dioxide and nitrogen oxide emissions, and a little less than a thousand tonnes of small particle emissions per year. The impacts of the sulfur dioxide, nitrogen oxide, and small particle emissions would be mainly local, while the impact of the CO_2 emissions would be global.

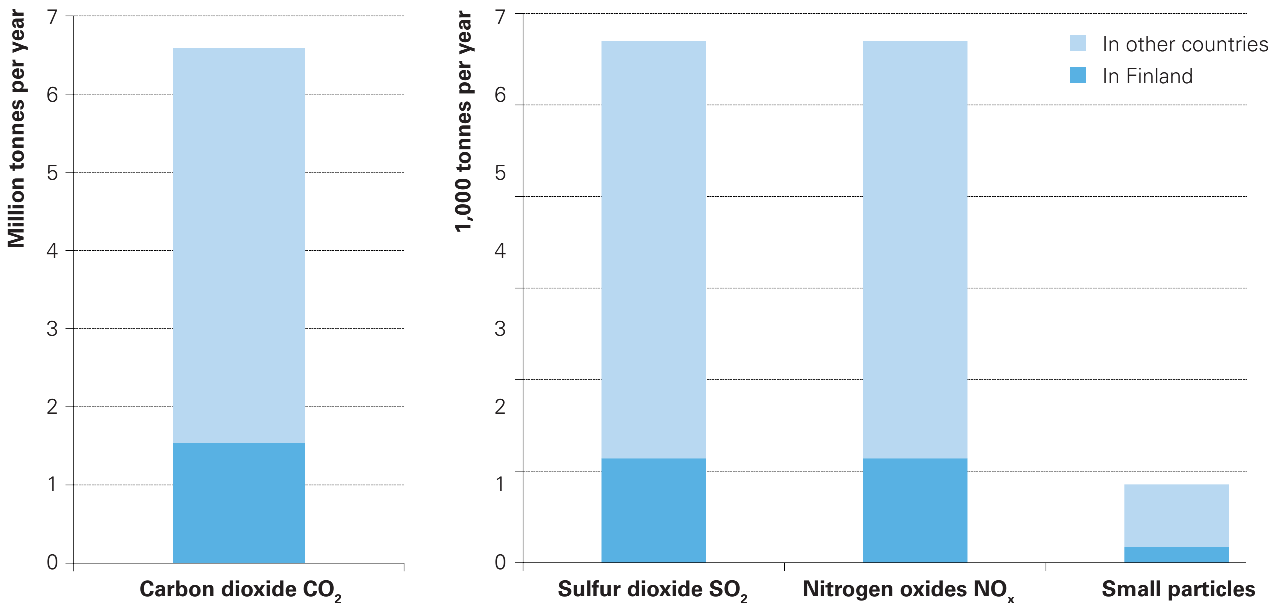


Figure 7-55. CO_2, sulfur dioxide, nitrogen oxide, and small particle emissions from the production (9,5 TWh) to replace the Fennovoima plant in Finland and abroad.

8

Comparison between alternatives and assessment of the significance of the impacts

For the environmental impact assessment, a study of the current status of the environment and the factors affecting it has been conducted based on the available information as well as existing surveys carried out for the EIA procedure. The characteristics of the project being assessed and issues deemed essential in terms of the environmental impacts have been identified on the basis of the available design data. In addition, studies, model calculations and interviews have been conducted regarding the environmental impacts and expert assessments based on experience from similar projects and research data have been obtained. The EIA report of 2008, the supplementary studies provided in connection with the application for the Decision-in-Principle in 2009, research results and reports pertaining to the Hanhikivi headland's sea area and nature as well as reports drafted in connection with the water permit applications have also been used to support the assessment, where applicable.

The environmental impacts of the project have been examined by comparing the changes caused by implementation of the zero-option and the implementation alternative with the current status. Furthermore, the implementation alternative has been compared to a power plant of approximately 1,800 MW that was studied in the EIA of 2008. The significance of the impacts has been assessed on the basis of how much the current status will change and by comparing the impact of future operations with the limit values and

Table 8-1. Comparison of the characteristics of the approximately 1,200 MW plant and the characteristics of the 1,800 MW plant studied in the EIA of 2008.

Description	Nuclear power plant of approximately 1,200 MW	Nuclear power plant of approximately 1,800 MW
Plant type	Pressurized water reactor	Pressurized water reactor
Electric power	Approximately 1,200 MW	Approximately 1,800 MW
Thermal power	Approximately 3,200 MW	Approximately 4,900 MW
Efficiency	Approximately 37 %	Approximately 37 %
Fuel	Uranium dioxide UO_2	Uranium dioxide UO_2
Thermal power released in cooling to the water system	Approximately 2,000 MW	Approximately 3,100 MW
Annual energy production	Approximately 9 TWh	Approximately 14 TWh
Cooling water requirement	Approximately 40–45 m^3/s	Approximately 65 m^3/s
Volume of service water	550–650 m^3/day	550–650 m^3/vrk
Fuel consumption	20–30 t/a	30–50 t/v
Spent nuclear fuel	1,200–1,800 t (during entire plant operating life)	2,500–3,500 t (during entire plant operating life)
Low and intermediate level operating waste	Approximately 5,000 m^3 (during entire plant operating life)	Approximately 6,000 m^3 (during entire plant operating life)
Radioactive emissions into the air	Tritium (T) 3,900 GBq/a Carbon-14 (C-14) 300 GBq/a Iodine (I-131 equivalents) 0.49 GBq/a Noble gases 46,000 GBq/a Aerosols 0.051 GBq/a	Tritium (T) 519 GBq/a Carbon-14 (C-14) 363 GBq/a Iodine (I-131 equivalents) 0.05 GBq/a Noble gases 830 GBq/a Aerosols 0.004 GBq/a
Other air emissions	Diesel generator: small volumes of carbon dioxide, nitrogen dioxide, sulfur dioxide, and particle emissions. Traffic: small volumes of carbon dioxide, nitrogen dioxide, carbon monoxide, and particle emissions.	Diesel generator: small volumes of carbon dioxide, nitrogen dioxide, sulfur dioxide, and particle emissions. Traffic: small volumes of carbon dioxide, nitrogen dioxide, carbon monoxide, and particle emissions.
Radioactive emissions into water system	Tritium (T) 9,100 GBq/a Other beta and gamma 0.065 GBq/a	Tritium (T) 55,000 GBq/a Other beta and gamma 25 GBq/a
Noise	Construction work and construction site traffic will cause noise during the construction period. The most important sources of noise during operation will be the generator transformers, the turbine building, the circulating water pump building, and traffic. The plant layout has been updated. This means that the noise during operation will be directed north, i.e. away from the local holiday residences.	Construction work and construction site traffic will cause noise during the construction period. The most important sources of noise during operation will be the generator transformers, the turbine building, the circulating water pump building, and traffic.
Traffic	Approximately 5,000 vehicles per day during construction. Approximately 600 vehicles per day during operation.	Approximately 5,000 vehicles per day during construction. Approximately 600 vehicles per day during operation.

guideline values set for environmental load, environmental quality standards, and the current environmental load of the area. On the basis of feedback received during the EIA procedure, particular emphasis has been given to studying and describing the impacts that are considered important by the stakeholders as well as the social impacts of the project.

The significance of the impacts have been assessed based on the following factors:

- regional extent of the impact
- impact target and its susceptibility to changes
- significance of the impact target
- reversibility or persistence of the impact
- intensity of the impact and magnitude of the resulting change
- fears and uncertainties associated with the impact
- different views on the significance of the impact.

8.1 Comparison with power plant assessed in EIA of 2008

Table 8-1 compares the characteristics of the approximately 1,200 MW power plant studied in this EIA to those of the approximately 1,800 MW power plant studied in the EIA of 2008. The data for the 1,800 MW plant in this table are based on the EIA of 2008 and more specific information about the plant properties obtained after completion of that EIA. The data for the plant of approximately 1,200 MW currently under study are based on preliminary data for the nuclear power plant type AES-2006. The data will be further specified as designing proceeds.

8.2 Environmental impact comparison

Table 8-2 includes a comparison of the key environmental impacts of the approximately 1,200 MW plant being studied in this EIA and the current status. The table also includes a comparison of the environmental impacts of the implementation alternative and the approximately 1,800 MW plant studied in the EIA of 2008.

The differences between the impacts caused by the plant of approximately 1,200 MW and the impacts caused by the 1,800 MW plant are mainly due to updates made in the project's technical design, new information about the current status of the environment, and revised legislation. According to the assessment results, the size of the plant or the specified plant type does not change the environmental impacts in any significant way.

Table 8-2. Assessment of key impacts of the approximately 1,200 MW plant when compared to the current status and the environmental impacts caused by the approximately 1,800 MW plant studied in the EIA of 2008.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact on infrastructure and land use	The holiday residences on the western shore and some of the holiday residences on the southwestern shore will be removed, and it will no longer be possible to use the southwestern shore for recreational purposes. The new road connection will not cause any significant changes in land use. The significance of Raahe as a strong industrial region will increase, which may improve the preconditions needed for the development of land use.	There are no differences between the impacts on land use and infrastructure since the construction scale and dimensions of the structures are similar.
Emissions into the air and their impact on air quality	No radioactive emissions will occur during construction. The radioactive emissions into the air during operation will have a minimal impact when compared to the impact from the radioactive substances normally found in the environment. The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits and the radiation dose will remain clearly below the limit value laid down in the Government Decree (VNA 717/2013). Furthermore Fennovoima will determine its own emission limit targets for the nuclear power plant. These targets will be stricter than the set emission limits. Other emissions, such as emissions from traffic and the emergency power supply system as well as dust generated during construction, will not have any significant impact on air quality.	According to the preliminary data for the nuclear power plant type AES-2006, radioactive emissions are higher than in the case of the 1,800 MW power plant. However, the impact of radioactive emissions will be of roughly the same magnitude. Other emissions into the air and their impact will remain at roughly the same level.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact on water systems and fishery	**Water systems** No radioactive emissions will occur during construction. The impact on the sea of radioactive process water emissions during operation will be minimal. The Fennovoima nuclear power plant will be designed so that the emissions of radioactive substances remain below all set emission limits and the radiation dose will remain clearly below the limit value laid down in the Government Decree (VNA 717/2013). Furthermore, Fennovoima will determine its own emission limit targets for the nuclear power plant. These targets will be stricter than the set emission limits. Hydraulic construction works will cause some temporary turbidity of the seawater around the Hanhikivi headland. Benthic fauna will temporarily disappear from the dredging areas. Charophyte meadows will disappear from the area around the cooling water discharge structures. Aquatic vegetation and phytoplankton production will increase in the cooling water impact area. The local impact will be minimal due to the open and nutrient-poor sea area. According to the assessments, cooling water discharges will not cause anoxia in the hypolimnion or any significant increase of blue-green algae. The discharging of cooling water may have a detrimental impact on the local Charophyte meadows in the long term as the area becomes more eutrophicated. The project will not have any significant impact on water quality. **Fishery** The noise caused by the hydraulic construction works will drive away fish, and fishing in the immediate vicinity of the areas under construction will not be possible due to noise, turbidity of the water, and traffic. Some spawning areas of the whitefish and Baltic herring will be destroyed by the dredging. The impact of the planned marine spoil area on fishery will be minor. The fact that the temperature of the seawater will increase when the plant is in operation will, in the long term, be favorable to fish species that spawn in the spring. The detrimental impact on spawning areas of whitefish and Baltic herring will be limited to the immediate vicinity of the discharge area. Traps will gather more slime in the summertime and catching whitefish will be more difficult particularly in the fishing area to the north of the Hanhikivi headland. In the winter, the unfrozen water area will hinder ice fishing. On the other hand, the unfrozen water area will extend the open water fishing season and attract whitefish and trout to the area.	The impact of radioactive emissions will be of roughly the same magnitude. The impacts on water systems and fishery will be similar but slightly less significant than in the case of the 1,800 MW power plant. The cooling water will warm the sea in a slightly smaller area.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact on soil, bedrock, and groundwater	Excavation of the bedrock will reduce the geological value of the Hanhikivi headland. As indicated by the land use plans, representative parts of the bedrock will be left exposed. There will be no significant impact on the soil. The risk of polluting the soil will be prevented by proper technical means. Groundwater level and pressure may decrease during construction and also during operation due to the drying of the structures. The project may influence the quality of groundwater mainly during construction due to the use of explosives and injecting of the bedrock. The impact on groundwater will remain fairly local and minor when the proper mitigation and prevention means are used.	The scope and dimensions of construction and structures are similar, thus the impact on the soil, bedrock, and groundwater will be of the same magnitude.
Impact on flora, fauna, and conservation areas	Some of the forests and seashores on the Hanhikivi headland will be changed into constructed areas, which means that some species populations will disappear or change. The construction will cause partial fragmentation of ecological succession forests in the land-uplift coast (a highly endangered habitat). Nature conservation areas and seashore meadows protected by the Nature Conservation Act will remain outside the construction area. The noise from construction and traffic may disturb nesting or resting birds. The discharging of warm cooling water into the sea during operation of the plant may contribute to the overgrowing of the seashore meadows. Paludification may make habitats less favorable to the endangered Siberian primrose. Construction or operation of the nuclear power plant will not cause any significant adverse impact on habitats or species protected by the Natura 2000 conservation criteria or the integrity of Natura 2000 areas. The area influenced by noise during construction and operation will be less than one kilometer from the power plant site, which means that the project will not pose any harm, even temporary, to birdlife in the Natura 2000 areas. The dredging activity will cause some turbidity in the sea water but not – according to the assessment – in the Natura 2000 areas. The turbidity of the seawater off the coast of the Hanhikivi headland also naturally increases during storms or periods of heavy rainfall. The impacts of the cooling water will not reach the Natura 2000 areas.	The impacts are almost identical. The warming impact from the cooling water of the approximately 1,200 MW plant will extend to a somewhat smaller area into the sea. The Parhalahti–Syölätinlahti and Heinikarinlampi Natura 2000 area will not experience any impacts apart from those already assessed.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact on landscape and cultural environment	Main impacts on landscape during construction include cranes that can be seen from far away and increased traffic. The power plant will be located on a highly visible area at the tip of a headland reaching out into the open sea, and it will change the landscape significantly. There is no industry or other heavy structures in the coastal area at present. The status of the nationally valuable Hanhikivi monument of antiquity as part of the landscape and the character of its immediate surroundings will significantly change. The monument of antiquity will still remain accessible. The landscape status of Takaranta, a seashore meadow of regional importance, will change.	The impacts do not differ from each other, since the construction scale and dimensions of the structures are similar.
Impact on traffic and traffic safety	Traffic volumes will significantly increase during the construction period. Traffic volume of the main road 8 to the north of the Hanhikivi headland will increase by approximately 64 %. The increase will be slightly smaller on the south side, approximately 39 %. The total traffic volume on the main road 8 in the immediate vicinity of the intersection leading to the nuclear power plant will increase by approximately 15 %. The volume of heavy traffic will increase by approximately 6 %. The new road to be built from the main road to the nuclear power plant will be designed to be suitable for power plant traffic. The intersection from the main road will include all the required preselection lanes, speed limits, etc. to retain the traffic safe and fluent.	The power plant's traffic volumes and impact on traffic safety are similar. The traffic volume on the main road 8 has slightly increased from 2008 to 2013 and the growth forecasts have been revised to some extent. Thus, the increase in traffic volume due to the power plant of approximately 1,200 MW will be slightly smaller than previously estimated.
Noise impact	According to noise modeling, the noise caused by the project will remain below the guideline values set for residential areas and areas including holiday residences, both during construction and the operation of the plant. The average sound level in the daytime during the noisiest modeled construction phase will be approximately 40 dB(A) at the closest holiday residences. This noise level remains clearly below the guideline value for holiday residences, which is 45 dB(A). According to the modeling results, the noise level at the closest nature conservation areas (the meadow in the northwestern corner of the Hanhikivi headland and the Siikalahti seashore meadow) will be approximately 50–53 dB(A). The areas affected by traffic noise – which will remain at the guideline level of 50 and 55 dB(A) – during the busiest construction phase will remain fairly limited, and there are no residences within the areas affected. The zone where the noise will be approximately 45 dB(A) will extend to a small part of the nature conservation area and the significant area of avifauna near the road connection. According to the calculations, the noise carrying from the nuclear power plant during its normal operation to the residential areas and areas including holiday residences will be fairly minor. The average sound level at the closest holiday residences will remain below 30 dB(A). The noise caused by the power plant traffic will also be minor, remaining clearly below the guideline values for residential areas.	The sources of noise, the magnitude of noise, and the volume of traffic are similar. The plant layout has been updated. This means that the noise during operation will be directed north, i.e. away from the local holiday residences. The noise situation during construction is similar to the previous noise modeling.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact on people and society	The municipality of Pyhäjoki will receive significant property tax revenue during the construction phase. The revenue will vary in relation to the completion stage of the nuclear power plant. The employment effect in the economic area will be approximately 480–900 man-years per year. The project will boost business in the economic area, and demand for private and public services will grow. The property tax revenue to the municipality of Pyhäjoki during the operational phase will be approximately €4.2 million per year. The employment effect in the economic area will be 340–425 man-years per year. The arrival of new residents, boosted business, and increased building activity will increase the tax revenue. The population base and housing stock will increase. Normal operation of the power plant during the operational phase will not cause any radiation impact on the people living nearby. Using the power plant area for recreational purposes will not be allowed, which means that the area can no longer be used for hunting, etc. Warm cooling water will melt or weaken the ice and, as a result, the power plant will restrict recreational activities on ice during the winter, such as fishing or walking. On the other hand, the open water fishing season will be extended. Residents and other parties in the immediate vicinity of the power plant area have very different views on the nuclear power plant project; there are local groups both opposing and supporting the project. Opposition is often based on the perceived risks and fears associated with nuclear power plants, and the belief that nuclear power is ethically questionable. The supporters emphasize its positive economic impacts and environmental friendliness.	There are no significant differences in the impacts on people's living conditions, comfort, health, and recreation. The employment effect of the 1,800 MW plant during construction and its property tax revenue were assessed as slightly lower in 2008 when the investment size was estimated at approximately €4,000 million. The investment of the 1,200 MW power plant is estimated at €4,000–6,000 million.
Impact of waste and waste management	No radioactive waste will be generated during the construction period. The handling and final disposal of the operating waste will not give rise to any significant environmental impacts, provided that the facilities are properly designed and the waste management actions are properly implemented. Final disposal will be monitored and the radioactive substances contained in the waste will become safe for the environment over time. Careful planning and implementation will eliminate any significant environmental impacts caused by the handling and interim storage of spent nuclear fuel. The status of spent fuel will be regularly monitored during the interim storage period of dozens of years. The environmental impacts of final disposal of spent nuclear fuel will be assessed in a separate EIA procedure. The handling of conventional or hazardous waste at the nuclear power plant will not give rise to any environmental impacts.	The volumes of operating waste and spent nuclear fuel will be lower, which means that the impacts will be smaller. There is no significant difference in the volume of conventional and hazardous waste. When handled correctly, the waste will not cause any environmental impacts.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact of decommissioning	The impacts during decommissioning will remain minor, provided that the radiation protection of the people participating in the decommissioning is properly arranged. Waste generated at the decommissioning phase will be similar to the waste generated during the plant's operation, and it can be treated in the same way. Most of the waste generated during the decommissioning of the nuclear power plant will not be radioactive. The environmental impacts of the decommissioning of the nuclear power plant will be assessed later in a separate EIA procedure.	There are no significant differences in the impacts caused because the plant structures, the demolition methods, and the waste volumes will be similar.
Impacts of abnormal and accident situations	The dispersion of a major radioactive release into the environment has been modeled in the assessment of an accident situation. The modelling has been conducted in compliance with the requirements laid down in Government Decree 717/2013. However, such accident and the consequent radioactive release are highly unlikely. The radiation dose to which people would be subjected in case of such a release would not cause any immediate health impact. Civil protection measures would be necessary in an area extending max. 15 km from the plant in case of such release. Short-term restrictions on the use of agricultural and natural products could be necessary. The use of freshwater fish as nourishment may have to be restricted in an area extending around 300 km from the plant in the direction the emissions have spread. The use of reindeer meat may have to be restricted in an area extending up to 1,000 km from the plant in the direction the emissions have spread. Other possible abnormal and accident situations mainly include chemical leaks that may contaminate the soil or groundwater. Furthermore, situations posing a radiation danger may occur due to a fire or human error, for example.	The modeling results are not dependent on the plant type or size. Thus, the consequences of the assessed severe accident are the same. The risks of other abnormal and accident situations are similar.
Transboundary impacts across the borders of Finland	The dispersion of a major radioactive release into the environment has been modeled in the assessment of an accident situation. The modeling has been conducted in compliance with the requirements laid down in Government Decree 717/2013. However, such accident and the consequent radioactive release are highly unlikely. Radioactive release caused by a severe accident could, if the weather conditions were unfavorable, cause a radiation dose of max. 4 mSv to a person living in the coastal area of Sweden during their lifetime, provided that no civil protection measures were implemented and no restrictions on the use of agricultural and natural products were used. (In comparison, the average annual radiation dose of a Finn is 3.7 mSv.) Due to the fallout, restrictions on the use of reindeer meat could be necessary in Sweden, Norway, and the northwestern part of Russia. The use of freshwater fish could have to be restricted in the coastal areas of Northern Sweden.	The modeling results are not dependent on the plant type or size. Thus, the consequences of the assessed severe accident are the same.

	Key environmental impacts of the 1,200 MW plant	Comparison with the environmental impacts of the 1,800 MW plant
Impact of nuclear fuel production chain	The environmental impacts of the nuclear production chain will not fall upon Finland. These impacts will be assessed and regulated in each country according to local legislation. The environmental impacts of uranium mining operations include radiation from uranium ore, radiation effect due to radon gas released from the ore, mining waste, and wastewater. Any environmental impacts caused by the conversion, enrichment, and production of fuel bundles are related to the handling of dangerous chemicals and, to a lesser extent, the handling of radioactive substances. The environmental impacts of the different stages of the production chain, starting from mines, are governed by legislation as well as international standards and audits by independent parties. Intermediate products transported in the nuclear fuel production chain are, at the most, slightly radioactive. The transport of radioactive substances will be carried out in compliance with national and international regulations on the transport and storage of radioactive substances. Chemical safety will also be verified by applying the appropriate measures.	The impacts are mostly the same.
Impact on energy markets	The new nuclear power plant will make Finland more self-sufficient in terms of electricity production. The Fennovoima nuclear power plant will improve the security of electricity supply by reducing Finland's dependence on fossil fuels and imported electricity as well as maintaining the Finnish electricity production capacity. The fact that the Fennovoima nuclear power plant will be built in a new location will also improve the security of supply concerning potential failures in electricity transmission.	The forecasted demand for electricity has decreased from 2008 but the power plant size has also been reduced. There are no significant differences between the impacts.
Cumulative impacts with other projects	The nuclear power plant and wind farm projects currently planned in the region will create an energy production area of national significance. The area that is currently in its natural state or used for agricultural production will become a large-scale energy production zone. The project may have cumulative impacts with the planned Parhalahti wind farm project in terms of recreational activities, as both the nuclear power plant and the wind farm project will limit land use opportunities and hinder hunting opportunities in the area. Dredging to be implemented in connection with the sea wind farm project and a project on extracting soil material could have a cumulative impact on the fish stock and thus fishing as the result of increased turbidity of the water should the dredging operations be simultaneously implemented. The environmental impacts of the construction and use of the power lines will be assessed in a separate EIA procedure.	Cumulative impacts with other projects were assessed in the EIA of 2008, but the projects were different than those assessed in this EIA.

8.3 Project feasibility

The project is feasible in terms of the environmental impacts. No adverse environmental impacts that are unacceptable or that could not be mitigated to an acceptable level were found during the environmental impact assessment of the implementation alternative of the project.

Furthermore, the project will have positive environmental impacts, such as the impact on the local economy and the fact that the project will increase the carbon dioxide -free energy production capacity.

8.4 Comparison with the zero-option

The impacts arising from non-implementation of the project are discussed in the chapter on the impacts of the zero-option.

Neither the adverse nor the positive impacts would be realized if the project were not implemented. The Hanhikivi headland would remain in its current state. The positive environmental impacts (such as improved employment rate and tax revenue) would not occur. Substitutive methods of electricity production would give rise to the environmental impacts described in Section 7.18.6, such as emissions into the air.

8.5 Uncertainties of environmental impact assessment

The available environmental data and the impact assessment always involves assumptions and generalizations. The plant's detailed technical design is not complete yet. However, several of the technical solutions that were still unfinished when the EIA of 2008 was implemented have been specified (such as the cooling water arrangements and the plant layout). The description of assessment methods includes an evaluation of the related uncertainties. The typical uncertainties related to an environmental impact assessment are fairly well known, and they have been taken into account when compiling the EIA. All of the assumptions used as the basis of the assessment have been determined by selecting the worst-case scenario in terms of the environment.

In summary, the significance and magnitude of environmental impacts has been reliably studied, and the conclusions are not subject to any significant uncertainties.

9

Prevention and mitigation of adverse impacts

The methods to be used to prevent and mitigate the project's adverse impacts are listed in each impact assessment section. A summary of the methods to be used to prevent and mitigate the most important impacts is in the table below (Table 9-1).

Table 9-1. Prevention and mitigation of the project's adverse impacts.

Impact	Prevention and mitigation of adverse impacts
Emissions into the air and impact on air quality	The nuclear power plant will be designed so that its emissions of radioactive substances into the air will remain below all set emission limits. The best available technology will be utilized to minimize emissions into the air when handling radioactive gases during operation, and the emissions will be kept as low as practically possible. Radioactive emissions will be continuously monitored by means of measuring and sampling. Emissions from traffic can be minimized by setting a sufficiently low speed limit for the road to be constructed for the nuclear power plant. Emission limit for energy production will be followed in the case of other emissions, such as emissions from the emergency diesel system.
Impact on the water system	When the project's impact on the water system is being minimized during construction, it may be noted that the efforts used to minimize the impact would prolong the hydraulic construction by an additional twelve months. It has been estimated that a longer construction period would be more detrimental to the environment as a whole than a shorter construction period. The turbidity caused by the hydraulic construction work in the Hanhikivi headland sea area will be continuously monitored. The impact of the activities in the marine spoil area during construction on turbidity can be controlled or limited with the help of online measuring buoys, depending on the prevailing flows. The nuclear power plant will be designed so that its emissions of radioactive substances into the sea will remain clearly below all set emission limits. The best available technology will be utilized to minimize emissions into the sea when handling process water during operation, and the emissions will be kept as low as practically possible. The radioactivity of purified process water will be monitored by means of measuring and sampling prior to release into the sea. The location of the open water area and thin ice areas caused by the thermal load of cooling water will largely depend on the seawater flow direction, and thus the location of these areas cannot be influenced. Signs warning of thin ice can be erected, however.
Impact on fish and fishery	The general disadvantages to fish and the fishing industry caused by the warming of the seawater can be compensated by implementing a fishery subsidy. The disadvantages caused to professional fishermen can be compensated on a case-by-case basis. Fish can be prevented from being driven into the cooling water intake system through a variety of technical methods and with the technical design of the cooling water intake systems. The technical methods include installing a fine mesh net in front of the intake channel and using a variety of fish repellents.
Impact on the ground and bedrock	The excavation work will be implemented in a manner that will leave representative parts of the region's geologically valuable bedrock visible. The impact on the groundwater level and pressure level can be limited to the constructed area. This will also prevent the groundwater flow direction from changing so that seawater and groundwater cannot be mixed, which would influence the groundwater quality.

Impact	Prevention and mitigation of adverse impacts
Impact on the nature	When the project's impact is being minimized during construction, it may be noted that the efforts used to minimize the impact would prolong the construction period. It has been estimated that a longer construction period would be more detrimental to the environment as a whole than a shorter construction period. The construction site will be delineated with fences and proper markings during the construction phase. Access to the power plant site's shoreline areas will be prevented except shorelines where hydraulic construction takes place. Access to any part of the construction site that includes protected species or habitats will also be prevented. Employees will be offered proper training and instructions on how to limit their moving in the environment and in nature conservation areas. Any disadvantages caused by noise to avifauna will be prevented in the manner described in the section on noise impact. The warm cooling water discharged into the sea may change the vegetation of seashore meadows included in the cooling water impact zone. Paludification of the seashore meadows can be prevented by grazing or clearing common reeds and bushes. Conservation of the seashore meadows of the Hanhikivi headland aims to ensure that the habitat type will not appear only in the region in the Parhalahti-Syölätinlahti and Heinikarinlampi Natura 2000 area.
Impact of land use and landscaping	The power plant can be better integrated into the landscape by choosing the correct architectural solutions, properly designing the locations of buildings and plantings, and selecting the correct surface materials and colors. All hydraulic structures will also be designed so that they will stand out as little as possible.
Impact of traffic	Disturbances due to traffic during construction can be mitigated by means of traffic guidance and timing. Disturbances during operation can be mitigated by arranging the employees with bus transport to work. Traffic safety can be improved by, for instance, adding preselection lanes, traffic lights and pedestrian/bicycle routes, and by applying speed limits.
Noise impact	A noise prevention plan will be drafted as the power plant design proceeds further. The plan will take into account location of construction stage functions and the fact that the traffic volumes during construction and operation phases will vary. Adverse impacts from noise will be mitigated by installing noise barriers around all parts of the construction site that will cause lot of noise and around traffic routes, applying speed limits, etc.
Impact on people and society	Social impact caused by the construction can be mitigated by decentralizing the accommodation facilities of the employees into the neighboring municipalities and arranging a variety of training for foreign and local employees. Fears and perceived threats caused by nuclear power can be mitigated by arranging proper communication so that the local residents will have enough information about how the nuclear power plant works and how its safety is ensured. Active communication with all stakeholders can be used to enhance the communication between the organization responsible for the project and the local residents. Furthermore, public events and information events can be arranged locally.
Waste and the impact of waste management	The power plant facilities will contain systems for the safe handling and transportation of waste and the monitoring of the amount and type of radioactive substances. The spent nuclear fuel will be kept in a secure location at all stages of the waste management process.

Impact	Prevention and mitigation of adverse impacts
Impact of power plant's decommissioning	The environmental impacts of the decommissioning of the power plant will be assessed at a later date in a separate EIA procedure. A decommissioning plan will be compiled during early stages of the operation of the plant. One of the primary objectives of the plan is to ensure that dismantled radioactive components will not cause any harm to the environment. STUK will approve the plan and its updated version every six years.
Impact of abnormal and accident situations	The plant will be designed in such a manner that the probability of a severe accident is minimal. The risk of radioactive release will be minimized by applying the defense-in-depth safety principle. The risk of abnormal situations will be prevented by applying strict quality and safety requirements, and by applying the continuous improvement principle. The consequences of a release caused by an accident can be clearly minimized by means of civil protection measures, such as seeking shelter indoors, administering iodine tablets, evacuating residents of local areas, and restricting access. Protection measures influencing the food industry and restrictions on the use of foodstuffs can clearly reduce the radiation dose due to food ingestion. Potential accidents involving the use of chemicals and the processing of radioactive waste will be prevented with technical measures and by providing training to the employees.
Transboundary impacts across the borders of Finland	A severe accident may increase the radioactivity of reindeer meat or frehswater fish to a level that requires temporary restrictions on their use. If these restrictions were followed, the radioactivity in reindeer meat or freshwater fish would not pose any danger to people. The use of freshwater fish may have to be restricted in the coastal areas of northern Sweden. The restrictions will be limited to specific rivers and lakes in the worst fallout zone. The use of reindeer meat may have to be restricted in Sweden, Norway, and the northwestern part of Russia. However, the radioactivity of reindeer meat can be reduced by preventing reindeer from eating lichen, because cesium accumulates in lichen. This could mean that reindeer would have to be transferred from the worst fallout zone. The reindeer could also be kept in enclosures feeding on clean food until the radioactivity in the fallout zone has decreased to an acceptable level.

10

Environmental impact monitoring program

The environmental legislation requires that parties responsible for projects and operations affecting the environment must arrange environmental impact monitoring. In the case of a nuclear power plant, the regulations and guidelines issued by virtue of the Nuclear Energy Act also require environmental impact monitoring and reporting by the parties responsible for nuclear power plant projects and activities.

10.1 Monitoring of radioactive emissions and radiation monitoring in the surroundings of the nuclear power plant

10.1.1 Measuring radioactive emissions

During normal operation of the nuclear power plant, an extremely small portion of the generated radioactive substances will be released to the environment in the form of emissions. Exhaust air and purified gases, which have been discharged from processes, will be released from the plant into the atmosphere. The main emission pathway into the air will be the plant's vent stack.

The plant process waters will be treated in the power plant's own liquid waste treatment plant from where they will be drained via a radiation control point to the cooling water discharge channel and from there to the sea.

Radioactive emissions will be monitored by means of process and emission measurements inside the plant and by monitoring radioactive substances and radiation present in the environment. This is to ensure that emissions into the air or water will not exceed the plant-specific emission limits confirmed by the Radiation and Nuclear Safety Authority. The measuring methods to be used will be chosen on the grounds that their reliability and accuracy are as high as possible with the best available technology. The emission pathways can be monitored also when the system has a single failure. The sampling and measuring arrangements and operations will be implemented in such a manner that adequate data on radioactive emissions can be obtained even in the case of a serious accident.

Detailed results of the measuring of radioactive emissions will be reported to the Radiation and Nuclear Safety Authority at regular intervals (quarterly and annual reports). Significant emission pathways of radioactive substances into the air will be monitored with continuous, fixed radiation monitoring systems. In addition, the emission flow of radioactive substances will be sampled, when necessary, to a separate sampling and measuring system. The vent stack will include a sampling system, and its particle filters will be replaced and analyzed in a laboratory at regular intervals.

Isotope-specific samples will also be regularly collected from the gas for a more detailed analysis. In addition to the actual emission pathways, significant gas migration paths within the nuclear power plant, such as exhaust air ducts in active rooms and tanks and gas purification and delay systems, will be monitored by means of continuous radiation measuring.

The activity of wastewater released from the plant into the water system will also be monitored with continuous, fixed radiation monitoring systems. The emission pathways can also be monitored when the system has a single failure. The radiation measuring system monitoring emissions into the sea will automatically and reliably close the discharge line if the measured radioactivity exceeds the upper limit set for the discharge line activity or if the measuring system malfunctions.

Exceptional emission routes (a variety of intermediate circuits and the secondary circuit) will be monitored by means of the radiation measuring systems, proper sampling systems, and laboratory analyses (YVL C.3).

10.1.2 Radiation monitoring in the environment

Radiation monitoring in the environment refers to monitoring the amount of radioactive substances and the radiation level in the immediate vicinity of the plant.

The radiation measuring in the power plant area and its vicinity will ensure that the radiation dose limits defined in regulations issued by the authorities will not be exceeded. The purpose of the radiation monitoring program is to identify the radiation exposure to the environment and people caused by radioactive emissions, and to ensure that it will remain as low as reasonably achievable. The licensee will draft a radiation monitoring program and submit it to the Radiation and Nuclear Safety Authority when applying for an operation license according to the Nuclear Energy Act. The Radiation and Nuclear Safety Authority will approve the program, monitor the results, and perform inspections at the plant.

The radiation monitoring program of the nuclear power plant will be reviewed at least once every five years. When the nuclear power plant is decommissioned, radiation monitoring in the vicinity of the nuclear power plant will be conducted in a manner approved by the Radiation and Nuclear Safety Authority.

A baseline condition survey on the surroundings of the power plant site will be conducted prior to commissioning of the nuclear power plant. The survey will assess the status and environmental conditions prior to operation, and anticipate the impact of operations, such as the level of emissions and their release into the environment during the normal operation of the plant.

The radiation monitoring program will define the persons responsible for the implementation of the program; identify sampling and measuring and their frequency; and describe the methods, equipment, sample and nuclide-specific observation limits, calibration of equipment and methods, and the processing and storing of measurement results.

The radiation monitoring program will include external radiation measuring and analyses of outdoor air, samples representing the different stages of food chains leading to humans, and analyses of radioactivity within the human body. Dosimeters that will be read at regular intervals and continuously operating, protected measurement stations will be placed in the terrestrial environment of the plant to measure external radiation. Their measurement data will be transferred to the plant and to the national radiation monitoring network, and the data can be read in real-time at the Ministry of the Interior and at the Radiation and Nuclear Safety Authority. In addition, gammaspectrometric measurements will be conducted in the immediate vicinity of the plant at regular intervals, and continuous air samplers will be placed in the vicinity of the plant to monitor radioactive particles found in the air.

The radioactivity of the environment will also be measured by sampling at regular intervals. Samples will be collected from indicator organisms to which the radioactive substances contained in the emissions accumulate or which enrich these radioactive substances. In the terrestrial environment, measurements associated with food chains will primarily be targeted at specifying the radioactive substances in the fallout, soil, tap water, grain and garden produce, natural products, wild plants, meat, grass, and milk. These sampling objects constitute a comprehensive representation of the pathways through which radioactive substances may enter the human body. The sampling objects will be located at a distance ranging from 0 to 40 kilometers from the plant. In the aquatic environment, the measurements will be targeted at specifying the radioactive substances in seawater, sedimental material and bottom sediment, hydrophytes, benthic fauna, and fish. Interbody measurements of activity will be conducted on the residents of the surrounding areas to ensure that there are no significant unidentified exposure pathways through which radioactive substances could enter the body of these residents.

In addition to the radiation monitoring program, radiation dose calculations based on emission data and dispersion conditions (measurement data on weather conditions) will be conducted to estimate the radiation exposure of the residents of the surrounding areas. These estimates will be useful in, for example, rescue operations in case of an accident. The calculation programs used in the assessment will be approved by the Radiation and Nuclear Safety Authority (YVL C.4).

10.2 Monitoring conventional emissions

Legally binding obligations pertaining to the monitoring of conventional emissions are determined in the permit conditions of the power plant's environmental permit decision. The environmental impacts of the plant must be monitored in accordance with monitoring programs approved by the authorities. The monitoring programs will be agreed with the authorities to determine the specific details of load and environmental monitoring and reporting to be performed. A monitoring program proposal will be drafted at the permit application stage, and the program should be approved when issuing the permit decision.

The environmental impact monitoring program is a plan regarding the collection of information at regular intervals of environmental load, impact and changes caused by the project in its affected area.

The monitoring objectives are:

- providing information on the environmental load caused by the nuclear power plant and its impact
- studying which changes in the state of the environment are caused by the operation of the nuclear power plant and which are caused by other factors
- studying how the results of the environmental impact prediction and assessment methods correspond with reality
- studying how the measures for mitigating adverse impacts have succeeded
- initiating required measures if significant unforeseen adverse impacts occur.

Regular reports on the monitoring results will be issued, usually annually, and the reports will be submitted to the licensee and the environmental authorities. The monitoring reports will be public documents.

Even though the detailed environmental monitoring programs will not be drafted until at the environmental permit stage, the main contents of environmental monitoring can be presented in this EIA report because the monitoring is highly similar at all nuclear power plants regardless of their location or technical solutions. The following chapters present the main principles of environmental impact monitoring.

10.2.1 Monitoring of water systems

10.2.1.1 Monitoring during construction

Impact of the project's hydraulic engineering works will be monitored in compliance with the monitoring plan connected to the water permit. The monitoring plan will be drafted at the permit application stage, and negotiations regarding the plan will be conducted with the authority so that the plan can be approved when the water permit decision is issued.

Fennovoima has included a monitoring plan proposal in its water permit applications *(Fennovoima Oy 2013a, b & c)*. The turbidity of seawater will be measured using continuously operating meters during the hydraulic engineering works. The measuring will start a couple of days before starting the work and continue for two weeks after the work has been completed. The turbidity of the water in the dredging mass deposition basins in the northwestern part of the Hanhikivi headland will also be continuously measured before discharging the water into the sea.

The spread of turbidity in the area where dredging masses are deposited into the sea will be monitored with two continuously operating underwater meters. Turbidity will only be measured during construction. The measuring will start a couple of days before starting the work and continue for at least two weeks after the work has been completed.

Monitoring of benthic fauna will consist of monitoring the hydraulic engineering works and monitoring the area where dredging masses are deposited into the sea. The impact on the benthic fauna will be monitored one year prior to the construction stage, during the third year of the construction stage, and during the second year after the end of the construction stage. The objective of the monitoring during construction is to find out what kinds of changes the hydraulic engineering works causes in the benthic fauna. The objective of the monitoring after the construction period is to find out how well the benthic fauna recovers after the construction work has been completed. The monitoring activities will also include monitoring of whether the hydraulic engineering works or the structures erected in the sea will cause any permanent changes to the benthic fauna populations.

10.2.1.2 Monitoring during operation

The impact of the discharge of cooling water and wastewater on the quality of water and water fauna as well as the ice conditions in the sea around the Hanhikivi headland will be monitored once the power plant has been commissioned. Regular monitoring will be implemented in compliance with the environmental permit and the monitoring program approved by the North Ostrobothnia Centre for Economic Development, Transport and the Environment. The monitoring results will be compared with the current status of the environment; there is comprehensive data on the current status available due to the surveys and advance monitoring actions of Fennovoima.

The physical and chemical monitoring will consist of taking several water samples each year. Issues to be analyzed from the samples include pH, oxygen content, electrical conductivity, turbidity, oxygen demand, nutrient content, solids content of the water and chlorophyll A concentration (which represents the amount of phytoplankton). Biological monitoring studies will observe changes occurring in the living organisms of the project's impact zone. Such changes may be caused by eutrophication, for example. The biological monitoring will include, for example, monitoring of phytoplankton primary production and species distribution, monitoring of aquatic plant species and their abundance, and monitoring of benthic fauna species and their numbers. Special attention will be paid to any changes in the status of endangered Charophyte meadows in the impact zone.

10.2.2 Monitoring of fishery

10.2.2.1 Monitoring during construction

The impact of hydraulic engineering works on fish and fishery will be monitored as agreed with the environmental authority. The monitoring plan will be drafted at the permit application stage, and negotiations regarding the plan will be conducted with the authority so that the plan can be approved when the water permit decision is issued.

Fennovoima has included a fishery monitoring plan proposal in its water permit applications *(Fennovoima Oy 2013a, b, c)*. The monitoring of fishery will include the monitoring of fish stocks, the number of fry, and professional and leisure fishing. The fish stocks will be monitored by means of Coastal test net fishing and the number of fry will be monitored with Gulf-Olympia lines and dragnets. Fishing will also be monitored by sending a questionnaire to professional fishermen and leisure fishers.

10.2.2.2 Monitoring during operation

The impact of the discharge of cooling water and wastewater on fish stocks and fishing will be regularly monitored during the operation of the power plant. The monitoring will take place in compliance with the environmental permit and the monitoring program approved by the Fishery Unit of the Kainuu Centre for Economic Development, Transport and the Environment. The monitoring results will be compared with the current status of the environment; there is comprehensive data on the current status available due to the surveys and advance monitoring actions of Fennovoima.

The monitoring during operation will consist of the monitoring of fish stocks, fry, and professional and leisure fishing that will be started already at the construction stage. The fish stocks will be monitored by means of Coastal test net fishing and the number of fry will be monitored with Gulf-Olympia lines and dragnets. Fishing will also be monitored by sending a questionnaire to professional fishermen and leisure fishers.

10.2.3 Monitoring emissions into the air

Emissions generated by the emergency diesel generators and the emergency heating plant (sulfur dioxide, nitrogen oxides, particles, carbon dioxide) will be determined and reported in the manner laid down in the environmental permit. A report of the observed carbon dioxide emissions will also be submitted to the Energy Market Authority, the authority managing greenhouse gas emission allowances.

10.2.4 Waste records

The quality, quantity, and treatment of conventional waste generated at the nuclear power plant during operation will be annually recorded in accordance with the Waste Act. The regulatory or permit authority may issue regulations and guidelines on how to comply with the obligation to keep records. The recording and reporting of conventional waste will be carried out in accordance with the environmental permit decision granted for the nuclear power plant and the company responsible for plants waste management.

The recording of radioactive waste will be based on the regulations issued by the Radiation and Nuclear Safety Authority.

A separate waste management plan and separate records will be compiled for the construction period.

10.2.5 Monitoring noise

A noise monitoring plan will be drafted for the construction period. It will determine how noise at the holiday residencies and nature conservation areas closest to the nuclear power plant site will be monitored. The environmental permits that apply to the construction period will probably also include requirements pertaining to the monitoring of noise.

After construction of the nuclear power plant, noise measurements will be performed in the immediate vicinity of the plant to ensure that the noise caused by the plant remains within the guideline values issued by the authorities and the design guideline values. The noise level caused by the operation of the power plant will be studied by taking measurements at the closest sites susceptible to noise. The sound levels of the most important fixed sources of sound that influence the environmental noise level will be measured during normal plant operation. Noise modeling results included in the EIA procedure and possibly the noise modeling made during the environmental permit stage will be further specified based on the measurement results.

10.3 Monitoring flora and avifauna

A separate environmental monitoring program for the construction period is not proposed because noise and impacts on water system will be monitored in compliance with the separate monitoring programs. The monitoring actions listed below will be started during the construction period, however.

The impact of cooling water on the seashore flora of the nearby nature conservation areas that are limited by the sea will be monitored. Monitoring actions should be implemented at least twice before starting any operations to survey the current status of the environment. The monitoring will be regular in compliance with a separate monitoring program to be drafted at a later stage. The monitoring results will be compared with the current status. The plan is to find out whether the seashore flora has experienced any detrimental impact or whether paludification has changed in any way that should be addressed.

Avifauna in the Hanhikivi headland area will be monitored once a year during the construction period and on two consecutive years after commissioning of the plant. The monitoring will aim to study how the construction has influenced local avifauna. There is already a good knowledge of the current status of avifauna in the area, and thus further surveys on the current status are not necessary before construction.

An avifauna monitoring plan regarding the Natura 2000 area will have to be compiled in connection with the EIA procedure for the power lines. The plant itself will not have any impact on the Natura 2000 area or the species there that should be monitored.

10.4 Monitoring of social impacts

The impacts on the living conditions of people as well as their comfort, wellbeing, health, and recreational activities has been assessed during the EIA procedure. Issues brought up in public events, statements and opinions received, and interviews of stakeholders and residents have been used when assessing the impacts in this EIA. Local knowledge has been utilized wherever possible also in connection with the composition of other surveys carried out as part of the assessment. The information obtained will be used to support design work and decision-making, and for mitigating and preventing potential disadvantages. Cooperation with stakeholders is an important part of the business of a socially responsible company. The working methods and contacts created during the EIA procedure can also be utilized in the future both when monitoring the social impacts of the project and when communicating with the stakeholders. Both the respondents to a questionnaire sent to the local residents and the participants of group interviews stressed the importance of continuing open and active communication as the project proceeds.

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Appendix 1

Coordinating authority's statement on the EIA program

Fennovoima Ltd
Salmisaarenaukio 1
00180 HELSINKI, FINLAND

STATEMENT
13 December 2013

TEM/1965/08.04.01/2013

ENVIRONMENTAL IMPACT ASSESSMENT PROGRAMME FOR FENNOVOIMA LTD'S NUCLEAR POWER PROJECT; STATEMENT BY THE CONTACT AUTHORITY

On 17 September 2013, Fennovoima Ltd submitted an environmental impact assessment programme (hereinafter referred to as the EIA programme) on a nuclear power project to the Ministry of Employment and the Economy (MEE or the Ministry) in accordance with the environmental assessment procedure (the EIA procedure or EIA), pursuant to the Environmental Impact Assessment Act (468/1994; the EIA Act). Prepared by the organisation responsible for the project, the EIA programme comprises a plan for conducting the requisite studies and for EIA procedure implementation. The EIA programme also includes a description of the present state of the environment in the area likely to be affected.

Pursuant to the EIA Act, the Ministry of Employment and the Economy will act as the contact authority in the EIA procedure.

On 30 September, a notice of the assessment procedure's initiation was published in the newspapers Helsingin Sanomat and Hufvudstadsbladet and in the following local and regional papers: Kalajokilaakso, Kaleva, Keskipohjanmaa, Pyhäjokiseutu and Raahen Seutu.

The public notice, the assessment programme and the comments and opinions received by the MEE during the consultation can be found on the MEE's website at www.tem.fi.

Members of the public were able to view the EIA programme between 30 September and 13 November at the local government offices or environmental offices of the following municipalities: Pyhäjoki, Raahe, Alavieska, Merijärvi, Siikajoki, Oulainen and Kalajoki.

The Ministry organised a public information event together with Fennovoima Ltd, the company responsible for the project, in Pyhäjoki on 17 October 2013.

For a summary of the comments requested and opinions submitted on the EIA programme, see Chapter 3.

The Espoo Convention (67/1997) will also be applied to the assessment of the project's cross-border environmental impacts. The parties to the Espoo Convention have the right to participate in the EIA procedure. The Ministry of the Environment, which is responsible for the practical arrangements of conducting the international consultation, has notified the following countries of the project: Sweden, Denmark, Norway, Germany, Poland, Lithuania, Latvia, Estonia, Russia and Austria.

1 Project details

1.1 Organisation responsible for the project

The organisation responsible for the project is Fennovoima Ltd. Its consultant in the environmental impact assessment procedure was Pöyry Finland Oy.

1.2 Project and project options

Fennovoima is preparing to build a nuclear power station unit on Hanhikivi site in Pyhäjoki. The nuclear power station option under scrutiny, type name AES2006, is a nuclear power station with an electric power output of some 1,200 megawatts and thermal output of 3,200 megawatts. This pressurized water reactor would be supplied by the Russian Rosatom Group.

For the purposes of this report, the 'project' refers to Fennovoima's entire nuclear power plant project.

The project also includes the on-site interim storage of spent nuclear fuel generated by the new unit and the treatment of low and intermediate level waste.

Should the project go ahead, Fennovoima intends to launch the excavation and water engineering works on the site of the new nuclear power station in 2015. The construction period of the new plant is estimated to be some six years.

As a zero option, the EIA report presents a situation in which the project would not go ahead. Fennovoima would not build a power station of another type in lieu of the nuclear power station project. The zero option would entail increasing the import of electricity and/or implementing power plant projects of other organisations in order to meet the corresponding electricity requirements.

2 Licensing procedures and planning of the nuclear power plant

The licensing procedure of nuclear facilities is described in the Nuclear Energy Act. Decision-making and the licensing system are based on a number of principles, including a continuous review of safety and adding detail to assessments already completed throughout the life cycle of the nuclear facility.

A significant number of other licences are also required for the construction of a nuclear power plant, such as permits in compliance with the Environmental Protection Act and the Water Act, and a building permit granted by the local municipality. All planning phases concerning the nuclear power plant must be completed prior to applying for a building permit and a construction licence granted by the government.

2.1 Environmental impact assessment

Fennovoima will draw up an EIA report based on the assessment programme and the contact authority's statement on the programme, followed by a public hearing on the EIA report. The company expects the EIA report to be completed in February 2014.

The EIA procedure is part of the safety and environmental impact assessment of nuclear power plants associated with the decision-in-principle referred to in the Nuclear Energy Act (NEA 990/1987).

In 2008, Fennovoima implemented an EIA to assess the construction and operating period impacts of a nuclear power plant with an electrical power output of 1500 – 2500 megawatts and comprising one or two reactors on three optional sites, one of which was Pyhäjoki. An international consultation referred to in the Espoo Convention was also implemented in connection with the EIA procedure. The Ministry took this process into consideration when preparing its statement.

As the option that is the object of the current environmental impact assessment was not one of the plant options in the original application for a decision-in-principle, the Ministry of Employment and the Economy requires Fennovoima to bring the project's environmental impact assessment up to date by this EIA procedure. An international consultation referred to in the Espoo Convention will be implemented at the same time.

2.2 Decision-in-principle

The new nuclear power plant complies with the definition of a nuclear facility of considerable general significance referred to in the Nuclear Energy Act requiring the Government's decision-in-principle stating that the construction project is in line with the overall good of society. In accordance with the Nuclear Energy Decree (161/1988, NED), the decision-in-principle shall include, among others, an EIA report complying with the Act on Environmental Impact Assessment Procedure. The scope of the project outlined in the application for a decision-in-principle may not exceed that described in the EIA report.

The processing of an application for a decision-in-principle is not solely based on documents provided by the applicant. The authorities will obtain supplementary reports, both those required pursuant to the Nuclear Energy Decree and other reports deemed necessary, providing a broader analysis of the project. In preparation for processing the application, the Ministry of Employment and the Economy will obtain a statement from the local council of the municipality in which the prospective facility is located, and from its neighbouring municipalities, the Ministry of the Environment and other authorities referred to in the Nuclear Energy Decree. In addition, the Ministry must obtain a preliminary safety assessment of the project from the Radiation and Nuclear Safety Authority (STUK).

A decision-in-principle under Section 11 of the Nuclear Energy Act on Fennovoima's project was made by the Government on 6 May 2010 and upheld by the Parliament on 1 July 2010. However, this decision-in-principle did not address the Rosatom option.

2.3 Construction licence

The actual licensing procedure follows the Government's decision-in-principle. For building a nuclear power plant, a construction licence issued by the Government is required, stating that the construction of the facility is in line with the overall good of society. The prerequisites for granting a building permit also include that the plans concerning the nuclear facility meet adequate safety requirements, that appropriate account has been taken of the safety of workers and the population when planning the operations in question, that the location of the nuclear facility is appropriate with respect to the planned operations, and that environmental protection has been taken into account appropriately when planning operations.

Any decision regarding the construction licence shall describe how the EIA report and the related statement by the contact authority have been taken into account (Section 13 of EIA Act).

In connection with the construction licence application, it will be verified that a site has been reserved for the construction in a local detailed plan and that the applicant is in possession of the site required for the operation of the facility (Section 19(4) of the Nuclear Energy Act). The planning process must therefore have been finalised by this stage (cf. Section 9 of the EIA Act).

A hearing procedure for the relevant municipalities, authorities and citizens will be organised during the application process for the construction licence.

The Government's decision-in-principle adopted on 6 May 2010 laid down as a condition that Fennovoima must apply for a construction licence within five years of the Parliament upholding the decision-in-principle. Fennovoima must thus apply for a construction licence no later than on 30 June 2015.

2.4 Operating licence

A licence to operate a nuclear facility issued by the Government is required to operate a nuclear power plant. In order for such a licence to be granted, the operation of the nuclear facility must be arranged so as to conform with the overall good of society, taking due account of the protection of workers, general safety and environmental protection.

A hearing of municipalities, authorities and citizens will be organised during the operating licence application process.

3 A summary of statements and opinions

A statement on the Environmental Impact Assessment Programme was requested from the following: the Ministry of the Environment, the Ministry for Foreign Affairs, the Ministry of the Interior, the Ministry of Social Affairs and Health, the Ministry of Defence, the Ministry of Finance, the Ministry of Transport and Communications, the Ministry of Agriculture and Forestry, the Finnish Radiation and Nuclear Safety Authority, the Regional State Administrative Agency (AVI) for Northern Finland, the Finnish Environment Institute, the ELY Centre for Northern Ostrobothnia, the Finnish Safety and Chemicals Agency (Tukes), the Regional Council of Northern Ostrobothnia, the Confederation of Finnish Industries EK, Finnish Energy Industries ET, the Central Union of Agricultural Producers and Forest Owners MTK, the Confederation of Unions for Professional and Managerial Staff in Finland Akava, the Central Organisation of Finnish Trade Unions SAK, the Finnish Confederation of Salaried Employees STTK, the Federation of Finnish Enterprises, WWF, Greenpeace, the Finnish Association of Nature Conservation, the National Board of Antiquities, Fingrid Oyj, Posiva Oy, rescue services in the relevant area and the municipalities of Pyhäjoki, Raahe, Alavieska, Merijärvi, Siikajoki, Oulainen and Kalajoki.

The following organisations did not respond to the Ministry of Employment and the Economy's request for a statement: the Ministry for Foreign Affairs, the Central Union of Agricultural Producers and Forest Owners MTK, the Finnish Confederation of Salaried Employees STTK, the Federation of Finnish Enterprises, WWF and the municipalities of Raahe and Alavieska.

In the assessment procedure of cross-border environmental impacts referred to in the Espoo Convention, the Ministry of the Environment notified the authorities of the following countries about the project:

the Swedish Environmental Protection Agency (Sweden), the Ministry of Environment (Denmark), the Ministry of Environment (Norway), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany), the Ministry of Environment (Poland), the Ministry of Environment (Lithuania), the Ministry of Environment (Latvia), the Ministry of Environment

(Estonia), the Ministry of Natural Resources (Russia) and the Federal Ministry of Agriculture, Forestry, Environment and Water Management (Austria).

Sweden, Denmark, Norway, Poland, Germany (the states of Schleswig-Holstein and Niedersachsen), Latvia, Russia, Estonia and Austria are participating in the EIA procedure and have commented on the EIA programme. Lithuania is not taking part in the programme, but it has requested for copies of the EIA report and the prospective construction licence.

3.1 Statements requested by the Ministry of Employment and the Economy from authorities

According to the statement of the *Ministry of Social Affairs and Health*, the EIA programme was expertly drawn up. The Ministry of Social Affairs and Health demands that the new requirements for securing the preparedness arrangements of nuclear power stations included in the proposal for a government decree circulated for comments in spring 2013 be taken into account in the EIA report (the decree entered into force on 25 October 2013). The new requirements increase the total emissions limit of a design-basis accident, while requiring that even in case of a serious accident, no evacuations will be necessary to a distance exceeding five kilometres from the plant. In other respects, the Ministry of Social Affairs and Health had nothing to comment on in the EIA programme.

The Ministry of Defence notes in its statement that the impacts of the smaller plant that is currently being planned will mainly be similar and in the same range or less significant than those of the previous option assessed in 2008.

The Ministry of Finance made no comment on the project.

The Ministry of Transport and Communications noted that as regards transportation of hazardous substances, the Act on the Transport of Dangerous Goods (719/1994) and any decrees issued under it must be complied with when transporting radioactive substances.

The Ministry of Agriculture and Forestry notes that updated information is available on the sea level rise scenarios, and that the situation in 2013 should be verified and the sea level scenario updated if necessary. In addition, the EIA programme should contain a clear statement of the levels at which activities causing hazards will be constructed at the plant in relation to the sea level rise scenarios. Fennovoima intends to assess the operating period impacts on such species as fish, and in particular on migratory fish and fisheries. The Ministry of Agriculture and Forestry finds that for fisheries, it is even more important to also assess the impacts during the construction period.

In the statement submitted by the *Ministry of the Interior,* the Ministry's Rescue Department urges that its statement SM-2008-545/ym-0 on this matter issued in 2008 be taken into consideration.

The Ministry of the Environment notes in its statement that amendments have been made in the marine protection laws since 2008 and proposes modifications in the environmental impact assessment in the EIA programme. The Ministry also reminds the company of the importance of taking the most recent information into account in the assessment and ensuring openness when discussing uncertainties related to long-term effects.

As regards planning, the Ministry of the Environment notes that the information is up to date but asks the company to discuss in the EIA report any additional needs for plan modifications arising from the project and the impacts of such modifications. Regarding nuclear fuel, the Ministry would like a more detailed description of the nuclear waste management measures and the options for organising final disposal, as well as of the risks entailed by the transport of fresh and spent nuclear fuel.

The Ministry also makes five specific and detailed comments on the EIA programme. It further comments on certain ambiguities concerning the cooling periods of spent nuclear fuel and contract law applicable to the plant.

Finally, the Ministry of the Environment stresses that even if the document is an update of the previous EIA report, the new report must be an independent document on the project and its environmental impacts. Existing new information must also be fully exploited, and compliance with any new legislation must be ensured.

While *the Radiation and Nuclear Safety Authority* (STUK) takes into consideration the previous EIA procedure in its statement, it reiterates in some parts its prior statement in order to ensure that an extensive environmental impact assessment will be implemented. Fennovoima's EIA programme covers any issues that are relevant to the Radiation and Nuclear Safety Authority's remit. The EIA programme should be made more specific regarding the power plant description, restricting emissions, and the design basis and design objectives of environmental impacts, and it must contain an evaluation of the possibilities of meeting the existing safety requirements.

The EIA report should examine questions related to site suitability and selection and nuclear waste management options. Nuclear waste management measures implemented in the power plant area must be comprehensively described, including their environmental and radiation impacts.

The Radiation and Nuclear Safety Authority's statement contains miscellaneous comments on making the project description more specific regarding organisation, quality and environmental objectives, and the plant option. The Radiation and Nuclear Safety Authority stresses compliance with new decrees, guidelines and requirements in the EIA report. The report must refer to existing decrees and describe the impacts any amendments have on the project.

The Authority would also like complementary information in the section on the preparedness system. Preparedness and action in emergencies in compliance with legislation and the Radiation and Nuclear Safety Authority's guidelines must be described and specified more clearly.

Regarding the location of the plant, Fennovoima should describe accurately in the EIA report the distribution of population in the vicinity of the plant and specify the nearest vulnerable facilities, including schools, day-care centres and hospitals.

The EIA programme does not contain an estimate of the maximum fuel charge in the reactor and its average burn-up. These values must be given in the EIA report, as they are relevant to the radioactive emissions in case of an accident.

A summary of what the information is based on must be given for the assessment of operating period radioactive emissions and the impacts of accidents and emergencies. The fact that since Fennovoima's previous EIA procedure was completed, a new government decree on the safety of nuclear facilities and a new guideline on restricting emissions from nuclear facilities by the Nuclear and Radiation Safety Authority have entered into force in the course of the procedure, and these should be taken into account when drawing up the assessment and the report, in particular regarding serious accidents.

The EIA report must contain an assessment of whether the current and foreseeable natural conditions will have an impact on the power plant's safety, the spreading of radioactive substances in the environment and site selection. The results of the so-called basic state assessment of Hanhikivenniemi area should be described in the EIA report.

Sea and air transport routes and any impacts caused by the planned site should be described in the EIA report.

The *Finnish Safety and Chemicals Agency* (Tukes) had nothing to comment on in the updated EIA programme. The risks entailed in the processing and storage of hazardous chemicals and preparedness for accidents will be processed at Tukes during the application procedure under the Chemicals Safety Act.

In its statement, *the Regional State Administrative Agency for Northern Finland* considers the EAI programme comprehensive in terms of impacts on humans. However, the Agency stresses that such factors as accident risks, storage of spent nuclear fuel and power plant waste and construction-period impacts should be taken into account in the assessment.

The ELY Centre for Northern Ostrobothnia notes that the EIA report should focus specific attention on whether or not the project under scrutiny results in a need to modify existing or pending plans. As planning procedures are time-consuming, information on any needs to modify the plans should be available as early as possible. In its previous statements, the ELY Centre noted that the long-term impacts of the project are difficult to foresee and that these impacts concern Takaranta flood meadows to the north of Hanhikivi peninsula, forests on the land uplift coast, changes near Heinikarinlampi lake and power lines that expose birds to collision risks. The EIA procedure for the power line project will eventually produce more information on the last point. The other points should be examined during the EIA procedure for the project under scrutiny. According to the ELY Centre, the latest climate scenarios and their impacts on sea levels should be taken into account in the EIA procedure when assessing flood levels.

The National Board of Antiquities brings up the need to provide an adequate protection zone for Hanhikivi boundary stone that is of national significance and that is protected under the Antiquities Act in its statement. This stone lies on the very edge of the construction site EN-1 permitted in previous plans, and unobstructed access to the stone must be secured in all circumstances. The boundary line between Pyhäjoki and Raahe and the view to the direction of the sea should also be kept clear to understand the site. The Board of Antiquities also notes that an assessment focusing on the power line corridor will be needed in connection with the more detailed planning.

The local rescue services note that while safety issues have been taken into consideration in the EIA programme, construction period risks and the management of day-to-day risks have received less attention. The rescue services would like to see a versatile risk analysis included as part of the section on construction period safety in the report, and a study of the impacts of a major accident within a 5-kilometre and a 20-kilometre radius. The rescue services would also like a preliminary plan for the establishment of a safety organisation for the project and its schedule.

The Regional Council of Northern Ostrobothnia finds that the programme clearly shows how the project has evolved since the EIA conducted in 2008. The EIA programme is a clear whole and lays a good foundation for presenting the project's impacts in greater detail. The impacts of the power plant project were extensively assessed in connection with the previous EIA and the planning process concerning the area, and it is thus justified to focus on describing key differences in the impacts when assessing the new option.

Pyhäjoki municipality had nothing to comment on in the EIA programme for Fennovoima's nuclear power station.
The towns of Kalajoki and Oulainen and the municipality of Merijärvi had no comments to make on the EIA programme for Fennovoima's nuclear power station.

In its statement, *the municipality of Siikajoki* finds that the EIA programme put forward by Fennovoima is now comprehensive, and if conducted following the programme, the assessment will make it possible to obtain adequate information on the project's environmental impacts for the purposes of a later consideration of applications for licences and permits. The municipality stresses that a careful assessment of cooling water use will be vital in this relatively shallow and cut-off coastal area of the Gulf of Bothnia. The municipality finally notes that the project is of great importance for Siikajoki and its residents.

3.2 Other statements requested by the MEE

The Confederation of Finnish Industries had nothing to comment on in Fennovoima's EIA programme.

Finnish Energy Industries notes that the EIA programme is comprehensive and expertly prepared, and that the plan for assessing the project's environmental impacts is adequate. According to Finnish Energy Industries, Finland needs additional electricity production capacity to secure the supply of emission-free power in the future, and Fennovoima's project supports both this objective and the emission reduction targets.

Fingrid Oyj notes in its statement that Fingrid has worked together with Fennovoima to study the connection of the power plant project referred to in the decision-in-principle to the national grid on the basis of plant design data submitted by Fennovoima. The need to increase emergency power capacity resulting from Fennovoima's nuclear power plant project will be clarified as the planning progresses, and in its land use plans, Fennovoima has made allowance for locating an emergency power plant on the site.

The Central Organisation of Finnish Trade Unions SAK finds that the EIA programme for Fennovoima's project was expertly drawn up and compliant with the relevant legislation. The project will have a positive impact on climate policy and the energy market, and the plant is no less necessary now than it was in 2008. This fact and its justifications should be brought up in the EIA report. According to the Central Organisation of Finnish Trade Unions SAK, the EIA programme stresses operating period impacts, and it would also be justified to address the construction period impacts on employment and social conditions in adequate detail in the EIA report.

The Confederation of Unions for Professional and Managerial Staff in Finland Akava found nothing to comment on in Fennovoima's project.

In its statement, *Posiva Oy* notes that rather than assume responsibility for the final disposal of all spent nuclear fuel produced in Finland, it is only tasked with managing the final disposal of spent nuclear fuel produced by its owners Fortum Power and Heat Oy (FPH) and Teollisuuden Voima Oyj (TVO).

Greenpeace highlights in its statement the need to take the changes that have taken place since the previous EIA programme was drawn up into consideration in the current EIA procedure. According to Greenpeace's statement, these changes include a more detailed idea of the impacts of a serious nuclear accident, forecasts indicating a more moderate increase in electricity consumption, the change of plant type and supplier, the more specific site location and the negative views of Posiva's current owners of nuclear waste storage.

The EIA programme should also contain an assessment of an INES 7 class accident, including its impacts in all possible weather conditions and the ensuing evacuation needs. The need for emergency power and impacts on the national grid should also be assessed in case of unexpected plant shutdown, and preparedness for natural disasters should be examined, taking into consideration any impacts of climate change during the plant's life cycle. Regarding procurements of nuclear fuel, Greenpeace would like to see an evaluation of alternative suppliers over the entire life cycle of the plant and a report on the properties of nuclear fuel, its suitability for different final disposal solutions of spent nuclear fuel and the possible use of mixed oxide fuel.

T*he Finnish Association of Nature Conservation (SLL)* finds that while Fennovoima's project and its operating environment have undergone a considerable change, the EIA programme is general in its nature, and its justifications have remained unchanged since the 2008 document. SLL stresses the need to take the overall interests of society into consideration in the EIA report.

SLL does not consider a continuous growth of domestic electricity consumption a credible trend and highlights the possibilities of saving energy and improving energy efficiency. In its statement, SLL thus calls for more accurate forecasts of future energy trends and calculations based on recent consumption figures and forecasts. SLL also considers any export of electricity produced with nuclear power a problem in terms of sharing the benefits and negative effects.

Regarding the environmental impacts, SLL would like Fennovoima to produce reference figures on radioactive emissions into water and air from other Rosatom plants. SLL also finds the description of cooling water intake unclear and notes that no information or reports are provided on dredging the harbour basin. In the context of other water management, SLL highlights ambiguities in the procurement of process water and queries how the company intends to organise the procurement of fresh water.

SLL considers the site too low for a nuclear power plant and notes that the impacts of road alignment and raising the road level on the landscape and the natural state of the surrounding area have so far not been assessed, and requests that these aspects be assessed in the new EIA report.

3.3 International consultation statements

Sweden's environmental authority, *Naturvårdsverket*, held a public hearing before drawing up its statement. It received comments from 15 authorities and 13 organisations, and 23 comments or opinions from private individuals.

Naturvårdsverket includes a summary of these comments and views in its statement.

The Swedish radiation safety authority,*Strålsäkerhetsmyndigheten SSM*, has no comments to make on the EIA programme and notes that it has nothing new to add to its statement on the assessment dating back to 2008.

The Swedish meteorological institute, Sveriges meteorologiska och hydrologiska institut *SMHI*, notes in its statement that as a result of serious reactor accidents, radioactive emissions spread over a very large area. Restricting the examination proposed in the EIA programme to a radius of 1,000 kilometres from Pyhäjoki is thus inadequate, and the examination of the geographical distribution of radioactive substances should be extended. SMHI also focuses attention on normal operating period emissions, especially in sea water, and the risks caused by any port activities.

Länsstyrelsen i Norrbotten län draws attention to climate change in its statement and calls for the inclusion of a long-term examination of sea level fluctuations and extreme weather phenomena in the EIA report. The other provincial governments that issued a statement were Västerbotten, Västernorrland, Gävleborg and Uppland.

In a statement representing 13 NGOs, 5 political party organisations and certain private persons, *Nätverket kärnkraftfritt Bottenviken* expresses its deep concern over the project. It focuses attention on the impacts of power plant cooling water on the waters in the Gulf of Bothnia and, for example, the roe of Sea of Bothnia vendace (Kalixlöjrom), the impacts of pack ice and the accident assessments to be conducted.

In *Skellefteå*, a list of some 1,000 signatures has been collected by a number of local and regional environmental organisations, organisations objecting to nuclear power and political parties. The signatories submit a list of 22 items on which they require additional information in the EIA report. These are relevant to the environment in the Gulf of Bothnia, radioactive and thermal emissions, the entire uranium exploitation chain from uranium mining to the final disposal of spent nuclear fuel and the consequences of an INES 7 class accident.

The *Norwegian* environmental authority, or the *Ministry of Environment*, passes on the statement of the Norwegian radiation safety authority *Statens strålevernin*, which welcomes the fact that the new EIA also assesses the impacts of radioactive emissions from any serious reactor accident on a radius of up to 1,000 kilometres. The Norwegian authorities are participating in the assessment process and will comment on the EIA report as necessary.

The *Danish* environmental authority, the *Ministry of Environment Agency*, announces that Denmark will take part in the EIA. It attaches to its statement the comments of four other authorities and two organisations.

In *Germany, the Ministry of Energy, Agriculture, the Environment and Rural Areas Schleswig-Holstein* announces in its statement that it is the competent authority in this matter. The state notes that the new power plant type will influence the environmental impacts, and the state puts to Fennovoima questions concerning the behaviour in accidents of the power plant type under scrutiny and, for example, its ability to resist external forces. The state is also interested in the transport of both fresh and spent nuclear fuel and its possible impacts on the state.

The *state of Niedersachsen* also announced that it would take part in the procedure and that it was interested in any cross-border environmental impacts.

The *Polish environmental authority* announces in its statement that Poland will take part in the EIA.

The Russian Ministry of Natural Resources and Environmental Protection announces that it will potentially take part in the EIA process.

The *Estonian Ministry of Environment,* which is the competent environmental authority in Estonia, announces that it will take part in the international assessment of environmental impacts and stresses that it is particularly interested in discussing accidents that could affect Estonia.

The Latvian Ministry of Environment announces in its statement that the country will take part in the EIA process.

The *Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management* sent the Finnish government a letter in which the country registers its interest in taking part in the EIA procedure. The country also reports that it will strive to organise a public hearing on the EIA report in Austria.

Attached to the letter is Environment Agency Austria's report ”NPP Fennovoima (Hanhikivi 1) Expert Statement to the EIA Program”, Vienna 2013. This report also contains comments on the EIA programme. In practice, Austria calls for an assessment of any possible impacts of Fennovoima's project on Austria. In this assessment, the so-called worst case scenario source terms should be used for the basis of assessing radioactive emissions. According to this report, the accident source term 100 TBq Cs-137 used by Fennovoima is not adequate. The report proposes source terms that would have impacts on the Austrian soil.

The report also calls for additional information about the safety of the AES2006 plant and notes that this plant type is not yet in operation anywhere, even if four plant units of this type are under construction in Russia.

3.4 Other comments and opinions

This section contains a summary of issues and views that were brought up or highlighted in other comments and opinions. In total, 24 other comments and opinions were submitted. Of these, four came from Finnish organisations, and twenty from private persons.

The association *Pro Hanhikivi* proposes in its comment that Fennovoima's nuclear power station project has changed to the extent that it can be said to have returned to square one.

Pro Hanhikivi calls for Fennovoima to take the following themes into account when drawing up the EIA report: 1) more details must be provided about Fennovoima's owners, 2) the responsibilities of the company producing electricity should be described, 3) the company's nuclear power competence must be established, 4) the employment impacts must be studied, 5) the impacts of refusals of any applications for compulsory purchase orders must be examined, 6) a proposal for the connection to the national grid should be presented, 7) the solutions for nuclear waste management must be addressed in greater detail, and 8) information on the need for emergency power and regulating power must be provided.

Pro Hanhikivi also lists requirements concerning the EIA procedure, communication and participation during the project, the options to be assessed and project description, the current state of the environment and the methods to be used. The description of alleviating the negative effects should be more detailed, and for the part of monitoring the project's impacts, the manner in which the follow-up of the 2008 environment impact assessment has been implemented should be described with examples.

Raahe District Development Center states in its comment that throughout the period in which it has been operating, Fennovoima has actively kept in touch with the actors and organisations in the area and openly communicated about the progress of the project and, for example, environmental studies and reports conducted in the project area. The company is highly appreciated in the economic area because of this openness and operating policy. The Development Center feels that Hanhikivi 1 construction project will provide the economic area's business life and, more extensively, the entire region of Northern Finland a unique opportunity of being involved in a major international investment in its home field.

BusinessOulu notes that the regional multiplier effects of Fennovoima's nuclear power plant project on employment, the economy and other socioeconomic aspects, including increasing internationality, should be assessed in the EIA to be prepared to the extent warranted by their importance.

In their statement, the *Naiset Atomivoimaa Vastaan* and *Naiset Rauhan Puolesta* movements object to the building of additional nuclear capacity in both Finland and elsewhere. The construction and operation of nuclear power units entails a number of unsolved problems, including the final disposal of waste and the restricted uranium resources. The operation of a nuclear power station always involves the risk of a serious nuclear accident, in which large quantities of radioactive substances are released in the environment.

In her comment, *Päivi Krekelä* highlights such questions as the final disposal of spent nuclear fuel, the procurement of nuclear fuel and the environmental impacts of these activities. The comment also brings up a need for additional studies concerning impacts on the environment, humans and society. The comment also asks Fennovoima to provide information on the project's impacts on power supply networks and the Finnish energy market, taking into consideration the current forecasts of electricity consumption, which are more moderate than those produced in 2008.

According to a comment by *Soili and Jari Kauppila,* the safety risks inherent in the low elevation on the plant site must be examined. The comment also calls for a clear plan for the safety of interim storage and final disposal of nuclear waste. The comment also urges that such other impacts of the project should be assessed as its impact on the comfort of living, engaging in a trade, safety and the social situation, as well as the impact on constitutional rights of the compulsive purchase applications. The comment also highlights the need to organise a resident survey for the villagers and free-time residents in Parhalahti.

The other comments and opinions submitted by private persons in part discuss the same themes and impacts as those described above. The comments and opinions submitted also requested additional studies on such topics as the obligations of the municipality, the impacts of any accidents, and insurance and compensation in the aftermath of a potential accident. Rather than express views relating to the EIA programme, some comments and opinions oppose the use of nuclear energy in general.

In other countries, two organisations and five private persons submitted their comments or opinions.
The Swedish NGO *MKG - Miljöorganisationernas kärnavfallsgranskning* focuses on the handling and final disposal of spent nuclear fuel in its comment. In the opinion of this organisation, the long-term sustainable and environmentally acceptable final disposal of nuclear waste must be secured when building a new nuclear power station. The organisation also notes that the EIA programme contains little or no information on how Fennovoima plans to manage the handling of spent nuclear fuel and other nuclear waste. The organisation expresses its concern over uncertainties associated with the processing of licenses to use nuclear fuel both in Sweden and in Finland.

The German organisation *Bürgerinitiative Umweltschutz Lüchow-Dannenberg* proposes in its statement that a hearing on the EIA programme be also organised in Germany. The organisation refers to the Espoo and Århus Conventions. The comment also contains a programme of ten items for additional studies, including an assessment of an INES 7 level accident and a more detailed discussion of nuclear waste management. The organisation is opposed to the construction of a nuclear power plant in Pyhäjoki.

In addition, five private persons having submitted their comments or opinions in German focused attention on a hearing in Germany, similarly to what Bürgerinitiative Umweltschutz Lüchow-Dannenberg proposes in its comment. These comments from private persons also contain the aforementioned list of ten requirements.

4 Statement of the contact authority

The Ministry of Employment and the Economy notes that Fennovoima's EIA programme meets the requirements set out in EIA legislation as to its contents and has been processed in the manner required by the legislation. In the comments submitted, the programme is mainly considered appropriate and comprehensive. However, the Ministry reminds the responsible organisation that all points made by the contact authority in this Chapter should be appropriately taken into account when reviewing the EIA programme and drawing up the EIA report.

The organisation responsible for the project should also take into account the additional questions, notes and views presented in the comments and opinions, to the extent this is necessary in order to prepare the EIA report. In the EIA report, the organisation responsible for the project must strive to appropriately and adequately respond to the questions brought up, taking into consideration the requirements laid down in the EIA Act and decree for the contents of an EIA report.

Any clear shortcomings or incorrect information that the comments and opinions have identified in the EIA programme must be corrected. The Ministry proposes that the organisation responsible for the project attach to the EIA report a table in which issues brought up by the contact authority, the organisation's responses to them and any references to the relevant section of the EIA report are set out.

In addition, any questions put forward in the international consultation must also be answered in the English version of the EIA report. The material to be translated into the languages of the relevant countries must be sufficient and include the information referred to in Annex II of the Espoo Convention. The EIA report shall include, as a specific chapter, a description of cross-border impacts. The documentation shall indicate how the comments of the countries participating in the EIA procedure within the framework of the Espoo Convention have been taken into consideration. Particular attention should be focused on the statements of various organisation in Sweden as a neighbouring country.

The EIA must contain as versatile a comparison as possible of the project's various implementation options, and this comparison must be included in the EIA report.

4.1 Project description and options

The EIA programme shortly describes the power output and type of the prospective power station. The operating principle of the pressurized water plant is also explained.

The Ministry requires that the company include an in-depth technical specification of the selected plant type in the EIA report. Similarly, the safety planning criteria for this nuclear power plant type must be presented regarding the limitation of emissions of radioactive substances and environmental impacts, as well as an assessment of the possibilities of meeting the safety requirements in force. The Ministry considers that it would be a benefit to the project if the EIA report contained a short presentation of Fennovoima's ownership structure and project funding.

Several comments and opinions draw attention to the location of built-up areas in the plant’s vicinity. The Ministry finds that the EIA report should contain an illustrative description of where built-up areas will be located in the vicinity of the power plant and a description of the exclusion zone and its impacts on the residents. A general description of possible evacuation measures must also be provided. The on-going compulsory purchasing procedures of certain land areas and any unfinished planning issues should also be described.

The EIA programme shortly describes the so-called zero alternative, in which the increasing demand for electricity in Finland would be covered by growing imports or the power plant projects of other actors.

However, several statements also suggest that in addition to the aforementioned aspects, saving energy and more effective energy use as well as other options for producing electricity should be examined. The Ministry notes that the organisation responsible for the project is a company that only generates power for its shareholders. In other words, the company itself has limited possibilities of taking significant action to conserve energy or to improve the efficiency of energy consumption. The Ministry considers that the assessment report could briefly assess the energy efficiency and conservation efforts undertaken by the project owners.

4.2 Impacts and their assessment

The EIA programme proposes an assessment of the impacts of cooling and waste water and water intake on water quality, biology and fishes, in particularly migratory fish populations and fisheries as well as on other organisms. Compliance with marine protection legislation reformed pursuant to the EU Marine Strategy Framework Directive (2008/56/EY) must be ensured. The impacts of the project on organisms and, for example, protected species in the land area must be described adequately.

The Ministry considers that the impacts of cooling waters form the most significant environmental impact during normal nuclear power plant operation. Consequently, in models aiming to analyse the environmental impacts of sea water warming, any background material available must be utilised extensively. The calculations regarding cooling waters must be presented conservatively. Any uncertainties in calculation results must be clearly illustrated. The dispersion calculations must be presented in concrete terms, and the methods used for dispersion modelling must be described.

Transfer connections must be developed for the new power station, and the plant must be connected to the national grid. Fingrid Oyj has investigated how the nuclear power plant could be connected to the national grid and examined the reinforcement of the grid based on information on the plant received from Fennovoima. A separate EIA will be carried out on connecting the plant to the national grid in 2014.

Assessing the impacts of exceptional circumstances and emergencies must not be limited to the exclusion area or the emergency planning zone for rescue operations. The Ministry considers that the EIA report should contain various accident scenarios involving radioactive emissions and, with the help of illustrative examples, describe the extent of the affected zones and the impact of emissions on people and nature.

The assessment may draw on the International Nuclear and Radiological Event Scale (INES) of the International Atomic Energy Agency (IAEA), and the EIA must contain a clear summary of what the assessments are based on. The EIA report must also contain a description of the measures taken in the aftermath of any serious reactor accident. The assessment must also include a review of the possible environmental impact of radioactive substances on the states around the Baltic Sea and on Norway and Austria.

In Finland, Section 10 of government decree on the safety of nuclear power stations (717/2013) sets 100 TBq of cesium-137 emissions as the threshold for a serious accidents, and this value has been used as the source term that describes an INES 6 class accident in Finnish environmental impact assessments. Several comments and opinions also suggested that the assessment should cover an INES 7 class accident. The Ministry of Employment and the Economy finds it appropriate that the organisation responsible for the project should present a comparison between the assessment used in Finland and an assessment covering an INES 7 class accident.

As exceptional situations, any potential phenomena caused by climate change and preparedness for such phenomena should also be assessed (sea level fluctuations and other exceptional weather phenomena), which were referred to in several comments. The impacts of land uplift and pack ice occurring in the area must also be taken into account.

The socioeconomic assessments related to the EIA procedure should address such aspects as the employment impacts, which the public information event on the EIA programme called for, both during the construction and the operating period, taking the special features of all municipalities and areas into account. The methods used must be described, and their selection justified.

According to the EIA programme, the organisation responsible for the project will examine the environmental impacts of nuclear fuel production and transport, including the mining and enrichment of raw uranium, conversion, isotope separation and nuclear fuel manufacturing. The EIA is based on existing studies. The Ministry finds it reasonable that the organisation responsible for the project should examine the environmental impacts of the entire nuclear fuel supply chain at a general level and, additionally, the company's opportunities of influencing this chain. Any possibilities of using mixed oxide fuel must also be described.

4.3 Nuclear waste management

The Ministry of Employment and the Economy considers that the report should look at nuclear waste management as a whole. In order to produce a general picture, it would also be appropriate to examine the management of power plant waste at an adequate level. The examination must also analyse the handling of nuclear power plant demolition waste. The structure of the final disposal facility must be clarified, for example with suitable illustrations.

The management of spent nuclear fuel must be described at a similar general level as the management of nuclear fuel. The management of spent nuclear fuel at the plant site must be described, and a visualisation must be included in the description of the interim storage of spent nuclear fuel. The description of spent nuclear waste management must also cover the potential transport of spent nuclear waste from Pyhäjoki.

The Ministry notes that according to Fennovoima's EIA programme, the company's environmental impact assessment for the project does not cover the final disposal of spent nuclear waste. This is permitted under the Nuclear Energy Act. A separate EIA must thus be carried out for the final disposal of spent nuclear fuel in Fennovoima's project, as the company's plans for organising nuclear waste management take a more definite shape. However, the EIA report must describe the progress made in Fennovoima's plans for spent nuclear fuel management since 2008.

4.4 Plan for the EIA procedure and participation

The Ministry considers that the arrangements for participation during the EIA procedure can be made as presented in the EIA programme. However, the communications and interaction should be adequately addressed to the entire area that the project affects, across municipal borders and covering all population groups. The Ministry further requests that the responsible organisation consider ways of presenting the impact of participation in the EIA report. The sampling and implementation methods of the resident survey carried out and their use must be justified in the EIA report. Any shortcomings observed and the manner in which these will be redressed must also be discussed.

Once the EIA report has been completed, the Ministry of Employment and the Economy will publish a public notice, make the report available, and invite various authorities to comment on the report. The statement on the EIA report prepared by the Ministry of Employment and the Economy in its capacity as the contact authority will be delivered to the municipalities in the relevant area and to the appropriate authorities.

5 Communication about the statement

The Ministry of Employment and the Economy will deliver its statement on the EIA programme to those authorities which have submitted statements and the organisations which have been invited to submit a comment. The statement will be available in Finnish and Swedish on the Internet at www.tem.fi.

The Ministry will provide copies of the comments and opinions concerning the EIA programme to the organisation responsible for the project. All comments and opinions received by the Ministry can also be accessed on the Internet.

The original documents will be kept on file in the Ministry's archives.

Jan Vapaavuori
Minister of Economic Affairs

Jorma Aurela
Chief Engineer

For information: Authorities having submitted a statement, the organisations from which the Ministry requested a comment and the organisations having submitted comments

Appendix 2

International hearing: Responses to the questions and statements of some foreign countries on the EIA program

7.2.2014

INTERNATIONAL HEARING;

Responses to the statements and questions of some foreign countries concerning Environmental Impact Assessment Program

1 Introduction

The statement of the coordinating authority of the environmental impact assessment procedure, the Ministry of Employment and the Economy (MoEE), requested responses to the questions and comments concerning the environmental impact assessment program (EIA program) returned by the foreign countries. The countries with specific questions or comments are Germany, Austria, Sweden and Denmark.

The main questions and comments of the foreign countries have been presented in the statement of MoEE (Appendix 1 of the EIA report, section 3.3). They have already been answered in the sections 2.7 and 2.8 of this EIA report. The target of this memorandum is to give further answers to the questions and comments of above mentioned countries when considered to be within the scope of the Espoo convention.

The EIA report can be found in English and Swedish for the internet as following:

http://www.tem.fi/en/energy/nuclear_energy/eia_procedures_for_new_nuclear_power_projects/eias_by_fennovoima

http://www.tem.fi/sv/energi/karnenergi/mkb_for_nya_karnkraftsprojekt/fennovoimas_mkb

2 Germany (Schleswig-Holstein)

The Ministry of Energy, Agriculture, the Environment and Rural Areas in Schleswig-Holstein has asked more information on the design concept against incidents and the accident case spectrum, the design of the plant against external events and the design against malevolent acts and other illegal interference by third parties.

2.1 Safety of the plant - design concept

The safety design of the plant has been described in the chapters 3 and 4 of the EIA report. Further the section 3.1 of this memorandum describes the safety systems of the AES-2006 reactor type.

The safety design of the AES 2006 reactor type is based on Russian regulatory requirements and it also takes advantage of EUR (European Utility Requirements), WENRA (West European Nuclear Regulators Association), IAEA safety guides and US NRC regulations. The plant shall also be designed to conform with Finnish regulations and the latest revision of STUK (the Finnish Radiation and Nuclear Safety Authority) YVL Guides, which already implement the WENRA safety objectives and lessons learnt from Fukushima.

The design concept is based on successive levels of defense-in-depth. At each level several redundant and diversified safety systems prevent the accident from progressing further. Successive barriers minimize the impact of ionizing radiation and release of radioactive substances into the environment. The AES-2006 defense-in-depth concept includes five successive levels.

AES-2006 design includes both active and passive systems. The main active systems have 4x100% redundancy, meaning that any one of the four redundancies is enough to fulfill the safety function. The additional passive systems do not require any outside power to function. They can be used to remove residual heat from the reactor through the steam generators, or cool the containment building directly. This means that Fukushima-type, prolonged power loss situations, can be managed safely.

2.2 Safety of the plant against extreme nature conditions

Design of the plant against external threats has been explained in the chapter 4 of the EIA report. Safety related nature conditions of the plant site have been described in the section 3.3. Extreme nature conditions which shall be taken into consideration when designing a nuclear power plant are weather conditions and geological and sea based phenomena.

The Hanhikivi nuclear power plant is designed to take into account all identified extreme weather conditions such as high winds, tornados, downbursts, very low and very high temperatures, high humidity, heavy rain, freezing rain, big snow loads, snow storms and lightning storms. The design is sized to withstand conditions that occur less than once in 100 000 years. For some phenomena an even smaller return level is used. VVER-type nuclear power plants have the benefit that they have decades of operational experience in low temperatures and winter conditions, both in Finland and in Russia.

Sea related conditions taken into account include low and high sea water levels, high water temperature, packed ice, frazil ice, seaweed and other impurities in seawater. The construction elevation of the plant is conservatively chosen in relation to most extreme sea water levels. The seawater intake is designed to minimize the risk of blockage. Nevertheless, the plant is designed to withstand a situation where the availability of cooling water (sea water) is lost. The safety design also takes into account situations where adverse sea- and weather related conditions occur at the same time.

The design basis earthquake for the Pyhäjoki site has been evaluated by Fennovoima together with external experts. The design basis earthquake is determined with adequate safety margin.

In addition to threats posed by nature, the plant safety design takes into account possible man made hazards that could affect the plant. The Hanhikivi nuclear power plant is designed to withstand the impact of a large commercial aircraft and indirect threats, such as oil from an oil spill at sea reaching the cooling channel.

The EU stress tests that were performed following the Fukushima accident have influenced the design of the plant directly as the lessons learnt from the Fukushima are already implemented into the revised YVL Guides issued by STUK.

2.3 Safety of the plant against malevolent and illegal acts

The security arrangements and physical protection measures are planned and implemented according to the requirements defined by STUK in their security related YVL Guides. The physical protection contains for example protection against intrusion, sabotage and a targeted commercial aircraft crash. The detailed information regarding the Design Basis Threats has been classified as confidential by STUK due to security reasons.

3 Austria

Austria has asked several matters to be included to the EIA report. The project and nuclear safety have been described in the chapters 3 and 4 of the EIA report as well as the safety of AES-2006 reactor type. The impact assessment of a severe accident has been described in the sections 7.13 and 7.14. Further some specific answers requested in the Austrian statement have been included to this memorandum.

3.1 Description of the reactor type

The chosen reactor type for the project is the AES-2006/V491. The reactor type and the related safety systems are described in the EIA report in Chapter 3 and in section 2.1 of this memorandum. Fennovoima chose the AES-2006/V491 (versus the AES-2006/V392) as the reference plant because its defense-in-depth approach in relation to redundancy and independency between system trains is closer to the Finnish regulatory requirements.

The safety system concept of the AES-2006 is a combination of active and passive systems. The active systems are arranged in physically separate 4x100% redundancies, where any one of the four redundancies can fulfill the safety function. The passive systems remove heat from steam generators or directly from the containment. The capacity of both systems is 4 x 33%, meaning that the systems are able to perform their function even though one train would fail. Heat sinks for the systems are the condensation pools outside of the containment.

The plant is equipped with a core catcher. The core catcher is designed to retain liquid and solid debris of the degraded core, components of the reactor pressure vessel, and reactor internals in case of a severe accident. Corium is contained and cooled within the core catcher as long as heat is removed from the containment. The core catcher performs several functions: stable cooling of the retained material, ensuring corium sub-criticality, minimization of release of radioactive materials to containment and minimization of hydrogen release. The core catcher requires no human actions during operation.

In the severe accident management strategy the core catcher is held dry before reactor pressure vessel rupture. Additionally the containment structures and the internal geometry of the reactor pit minimize the risks of steam explosion. Further analysis of the core catcher will be performed in the construction license application stage of the project.

3.2 Plant specific safety analyses and severe accident scenario

The Finnish Radiation and Nuclear Safety Authority (STUK) supervises the compliance with the provisions of Finnish nuclear safety legislation and regulations. Fennovoima and the power plant supplier have prepared feasibility studies on the power plant, describing the power plant conceptually and ensuring that it can be built to comply with Finnish requirements. STUK is performing an independent study of the acceptability of the power plant concept on the basis of the feasibility study. A power plant design that could not fulfill the requirements regarding severe accidents shall be eliminated at this stage.

Plant safety design, structural design and basic dimensioning will be described in the Preliminary Safety Analysis Report (PSAR) together with related safety analyses.

STUK will review these documents as a part of the construction license procedure and ensure through an independent study that the design of the selected power plant unit actually fulfills all safety requirements. Preliminary plant specific safety analyses will not be available until the analyses are submitted to STUK for evaluation.

Before the power plant is commissioned, Fennovoima and the power plant supplier will draw up the Final Safety Analysis Report (FSAR) with safety analyses performed based on the detail design of the plant. STUK will review the documents and ensure through an independent study that the design of the selected power plant unit actually fulfills all safety requirements. STUK's approval for the Final Safety Analysis Report is a precondition for the operating license of the plant. In Finland, the initial operating license issued to any nuclear power plant is limited for a period from five to ten years, after which the operating license shall be renewed. STUK will monitor the operation and maintenance of the power plant through a variety of inspections and audits.

In the section 7.13 of the EIA report a severe accident has been modeled and its consequences are presented. In the model the size, timing and duration of the release have been chosen so that they are significantly conservative taken into account the technical design solutions of the AES-2006 power plant (as described in the chapter 3 and section 7.13). When preparing the preliminary and final safety cases of the plant detailed safety analyses of severe accidents and their impacts will be performed. The analyses will utilize plant specific data and are more realistic without excess conservativeness compared to a severe accident described in EIA report. The source term used in the model has been defined according to the Government Decree on Nuclear Safety (717/2013) as a release containing 100 TBq cesium-137. This accident corresponds to an INES-6 accident. According to STUK's safety guides the expectation value for a release bigger than this shall be less than once in 2 000 000 years (5E-7/a). However, for the sake of confirmation, also the consequences of a five times bigger release (500 TBq of cesium-137) release, corresponding to an INES-7 accident, has been assessed. The source term nuclide content is defined based on the NUREG-1465 report, but neglecting beneficial effects from spray etc. The planned maximum average burn-up per fuel-bundle is 60 MWd/kgU so the total average burn-up in the core is less than this. Further information is available in the section 7.13 of the EIA report.

3.3 Site conditions and safety margins

Design of the plant against external threats has been explained in the chapter 4 of the EIA report and in the section 2.2 of this memorandum. Safety related nature conditions of the plant site have been described in the section 3.3.

3.4 Radioactive waste management

Some of the statements take notice of the safety of the water pool storage compared to the dry storage for the spent nuclear fuel. Also notice has been paid to the technique of the final disposal repository of the spent nuclear fuel. According to the statements it does not comply with the requirement of best available technique.

Fennovoima is going to build an interim storage for the spent nuclear fuel in Hanhikivi headland near the power plant. The interim storage of spent nuclear fuel is subject to the same safety regulations as nuclear power plants as a whole. The interim storage of spent nuclear fuel must be designed to withstand the same external hazards as the power plant itself, including the crash of a large commercial passenger aircraft. The interim storage will be either dry cask storage or water pool storage. Fennovoima will select the interim storage concept based on careful safety, economical and technical evaluations.

Water pool storage is the prevailing storage method in Finland and there is a lot of good experience and competence available about this method. Two Finnish power companies have operated two separate water pool storages over 30 years in their nuclear power plants and have proven the safety of the pool storage concept. The Finnish regulatory guides have also been issued for water pool storages to ensure safe design and operation of the storage. Fennovoima has studied the safety functions of the dry cask storage and is considering it due to its passive safety characteristics. Fennovoima is convinced that both interim storage concepts of the spent nuclear fuel can be designed and operated safely in Finnish conditions.

Nuclear Energy Act (990/1987), Section 6a states that nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland. In practice this means that Fennovoima shall dispose of the spent nuclear fuel into the bedrock in Finland. Further the legislation prohibits from unnecessary long interim storage periods. Fennovoima’s current target is to dispose of spent nuclear fuel into deep bedrock in Finland by using KBS-3 concept, which is currently under licensing both in Finland and in Sweden. At the moment the KBS-3 concept is considered to be the best available technology for final disposal in Finland even it has still some technical challenges to be solved. The final disposal of Fennovoima's spent nuclear fuel will start at earliest in 2070's that gives Fennovoima the opportunity to follow the technical development of the final disposal concepts and take part into the development work for 50 years. Fennovoima will update its final disposal plans if the KBS-3 concept is proven unfeasible for some reason.

4 Sweden

4.1 Cooling water impacts

The statements take notice of potential adverse impacts of the warm cooling water on the breeding migration of fishes (salmon and whitefish) and the ecosystem of the Bothnian Bay. Also concerns have been expressed that the cooling water will affect the taste and use of vendace roe of Kalix river. The impacts of the warm cooling water on the ecosystems and the fish fauna and fishery have been described in the section 7.4 of the EIA report.

4.1.1 Impacts on ecosystem of Bothnian Bay

The power plant's impact on the temperature of the sea has been studied with the help of a three-dimensional flow model. The warm cooling water will increase the temperature of the seawater only locally close to the discharge place. The temperature of the seawater will increase by 1°C in an area of approximately 15 km^2. More than 5°C increase is potential in an area of approximately 0.7 km^2 in the immediate vicinity of the cooling water discharge place. The thermal increase will mainly be in the surface water (0–1 meters below the surface). According to the modeling results, no temperature increase will occur at a depth of more than 4 meters. Below the depth of 2 meters the temperature increase is just 1°C.

The sea area in front of the Hanhikivi headland is open and windy and the nutrient content of the water is low. The adverse impacts of the warm cooling water are local and are assessed to limit to the sea area where the average temperature increase will be one degree Celsius. The project is expected to increase the total primary production of aquatic vegetation and to change the composition of species by increasing the growth of filamentous algae in the warming area. The cooling water discharges are not expected to have any adverse impacts on the benthic fauna neither to cause anoxia in deep water nor significantly increased blooming of cyanobacteria. Potential adverse impacts on fish fauna and fishing are assessed to be local. The main impacts on fishing include the build-up of slime in nets and, in the summertime, more difficult whitefish fishing, especially in the fishing grounds north of Hanhikivi. The cooling water and the resulting impacts are not expected to influence the ability to use fish as food.

Fennovoima has implemented a study of the migration routes of the salmon in the Bothnian Bay and the Gulf of Bothnia in 2009. There is a considerable natural breeding population of salmon in Tornionjoki, Simojoki and Kalix rivers flowing into the Bothnian Bay. Salmon smolts usually spend two to four years growing in the river, after which they go on a feeding migration extending to the main basin of the Baltic Sea. The migrating smolts enter the sea between late May and early July, the migration typically peaking when the temperature of the river water reaches 10 °C (Jutila et al. 2005). According to Ikonen (2006), the migrating smolts in the sea, or post-smolts, migrate southwards along both the Finnish and Swedish coasts in the Bothnian Bay, as the sea water warms up more quickly in shallows than in the open sea. South of the Kvarken area, post-smolts mainly migrate along the Swedish coast (Ikonen 2006).

Salmon spawning migration back to their breeding rivers usually takes place near the surface, at depths of 2 m to 3 m, and the migration speed is generally 20 km to 30 km per day (Karlsson et al. 1999, Westerberg et al. 1999). The northward migration usually takes place along the Finnish coast, which being shallower warms up faster than the Swedish coast (Westerberg et al. 1999). Migration may occur along the Swedish coast in cases where the water there is warmer than along the Finnish coast. During prevailing northerly winds and during weak winds, the salmon migration route shifts outward from the Finnish coast (Westerberg et al. 1999).

Returns of tagged salmon indicate that in the northern part of the Bothnian Bay salmon mainly pass to the west of Hailuoto island, probably following sea currents, directly to Karsikkoniemi in Simo (Siira 2007). In Pyhäjoki sea area the salmons mainly pass far from the coast. From Karsikko the majority of the migrating population continues north to the Kemijoki, Tornionjoki and Kalix rivers. Some turn back south towards the mouths of the Iijoki and Oulujoki rivers.

Fish have an accurate temperature sense. It can sense water temperature differences as slight as 0.03 °C (Bull 1936, Ikonen 2006) and it actively seeks a suitable temperature. Thus, fishes can usually avoid cooling water discharge areas when the temperature increases too much. According to studies conducted in several countries, warm cooling water has not been found to have an impact on the migration of fish to rivers (Langford 1990). No significant adverse impact on migration can be observed in cases where warm cooling water does not directly prevent fish from accessing rivers. Access could be prevented in a situation where the entire water area in front of a river from the surface to the bottom is warmed up to a temperature that is actively avoided by fish. The impact area of the warm cooling water from Hanhikivi sea area is considerably away from the mouths of the breeding rivers and it is entirely possible for the salmon and whitefish to avoid the limited area of warmer water near Hanhikivi headland during their migration. There are therefore no grounds to assume that the limited area of the warm cooling water in Hanhikivi sea area would have adverse impacts on the success of the fish migration.

4.1.2 Impacts of radioactive emissions

Concerns about the adverse impacts of the radioactive emissions on the sea ecosystem and fish fauna have been expressed including also the impacts on the vendace roe of Kalix river. The radioactive emissions and their impacts have been described in the chapter 3.16 and 7.3.4 and 7.4.4 of the EIA report.

Radioactive nuclides of the sea environment have been monitored more than 40 years by the Finnish nuclear power plants and the Finnish Radiation and Nuclear Safety Authority. A summary of results yielded in monitoring programs is presented in the doctoral thesis published in 2009 (Ilus 2009). During the long history of the studies, an enormous quantity of results on various hydrographical, biological and radioecological parameters have been collected from the sea areas of Loviisa and Olkiluoto nuclear power plants.

The doctoral thesis concludes that, the radioactive discharges into the sea from the Finnish nuclear power plants have been on average below 10% of the statutory limits. Small amounts of radioactive nuclides have been detected in environmental samples taken from the discharge areas. The samples have been taken regularly from different fish species, seawater, bottom sediments and indicator organisms (e.g., periphyton and the bladder-wrack Fucus vesiculosus) that effectively accumulate radioactive substances from the medium. Discharge nuclides from the nuclear power plants were almost exclusively detected at the lower trophic levels of the ecosystems. Traces of local discharge nuclides were very seldom detected in fish, and even then only in very low quantities. No traces of nuclides had been detected in birds nor in the inner organs and reproductive products of fish and birds (roe, milt, eggs, embryos). The thesis concludes that the environmental risk caused by the ionizing contaminants discharged from the Finnish nuclear power plants was negligible: the doses of radioactive substances to organisms were far below the conservative screening level of 10 μGy h-1 and the doses caused to the population and to biota are very low, practically insignificant.

4.2 Extreme weather conditions

Extreme weather conditions are taken into account in both design basis of the nuclear power plant and also in safety analyses. The probabilistic risk analysis takes into account very rare weather phenomena including those which probability of occurrence is even less than once in 100 000 000 years (1E-8/a). The protection against extreme weather conditions take into account projected climate change during the plants life time.

The extreme weather conditions that are taken into account include for example high winds, tornados, low and high temperatures, humidity, rain, freezing rain, snow load, snow storms and lightning storms. The design basis magnitude for these phenomena is assessed to be such that it would not occur more often than once in 100 000 years, but also rarer phenomena are taken into account. The impacts of combined phenomena are also assessed; for example high winds combined with snow storm might have adverse impacts in regards to ventilation openings.

Design of the plant against external threats (including extreme weather conditions) will conform to YVL Guide B.7. Additional information is also given in section 2.2 of this memorandum and the chapter 4 of the EIA report.

4.3 Transportation of nuclear fuel and spent nuclear fuel

The Swedish statements requested that the risks of transporting nuclear fuel and other radioactive material via Bothnian Bay shall be described in the EIA report including risks of radioactive emissions in air and sea. The transportation of nuclear fuel and spent nuclear fuel has been described in the Sections 3.7 and 3.13 of the EIA report. The impacts of transportations have described in the Sections 7.13 and 7.15 of the report.

4.3.1 Nuclear fuel

Fresh fuel is delivered to Pyhäjoki few times per year. Transportations are done by sea or/and by road. Fresh fuel is uranium dioxide which is not significantly radioactive, contrary to highly radioactive spent fuel removed from the reactor of a plant. Because of low radioactivity, transport containers don't have any special requirements concerning radioactive shielding. The containers to be used are specially designed to shield the fuel assemblies during transportation used. The radiation levels are so low, that nuclear fuel transportations are not causing any risk for the population or environment. Fennovoima plans to use also reprocessed uranium as fuel. The transportation measures of the reprocessed uranium fuel are similar to the natural uranium fuel.

4.3.2 Spent nuclear fuel

After the intermediate storing period spent fuel will be transported to the final disposal facility. The transportation of the spent nuclear fuel will start at the earliest in the decade of 2070. For transportation, the fuel will be transferred into a transport container. The purpose of the container is to protect the fuel from damage during transportation and to protect the surroundings from the fuel. The transport containers are designed to withstand an airplane crash as well as a kerosene fire. The containers must pass several different drop tests in order to be approved for use in transportation of spent fuel. Furthermore, the transport containers must also remain leaktight under pressure. The thick walls of the transport container which are made of dense material effectively attenuate the gamma radiation emitted by the nuclear fuel and completely stop the alpha and beta radiation. In normal transportation situations, the dose rate of the radiation shall not exceed 0.1 mSv/h measured at the distance of 1 meter from the outer surface of the transport container. The container and its contents shall withstand the stresses caused by the transportation without damage. When using reprocessed nuclear fuel in the nuclear power plant the spent nuclear fuel is transported in the same type of containers as described above.

Transport containers manufactured in accordance with the guideline values of the International Atomic Energy Agency (IAEA) shall not break even in the case of a high-velocity collision with a point-like object, e.g. a reinforced steel column. In such a case, the container may bend and lose its leaktightness. However, as the container would not break, only gaseous or otherwise easily released radioactive substances could escape from the nuclear fuel rods into the environment. As the road transportation is carried out at low speeds, the swerving off the road of the transportation vehicle and its collision into a concrete structure or a rock cutting alone cannot generate forces of this magnitude.

Finland follows the international regulations for the transport of dangerous goods. As far as radioactive material is of concern, these regulations are based on IAEA standard IAEA Safety Standard Series No. TS-R-1. A transportation plan including relevant security arrangements is required for nuclear shipments in Finland. This plan shall be approved in advance by STUK. STUK will assess matters such as the transportation plan, the structure of the transport container, the qualifications of the transportation personnel, and the accident and malicious damage preparedness plans.

According to the Finnish legislation spent nuclear fuel shall be disposed in Finland. It can be transported from the nuclear power plant to the disposal repository by road, by rail, or by sea. Sea transportation of spent nuclear fuel requires a vessel specifically designed for the transportation of high level nuclear material (an example of such vessel being the Swedish Sigyn). Sweden has been transporting spent nuclear fuel and other radioactive wastes safely by the sea starting already from 1980's. The dock basin and wharf planned at the western shore of the Hanhikivi headland are designed so that spent nuclear fuel can be transferred into a vessel for sea transport. Another option is to use Raahe harbor. Then the transportation from the Hanhikivi headland begins as road transportation. In road transportation, a special carriage hauled by a truck is utilized. Road transportation will take place under supervision, and each transport will be escorted by supervision and security personnel. In urban areas, police patrols will close off the crossing streets as the transportation convoy passes the area. Taking into account the required stops, the average speed of the transportation convoy will be approximately 35 km/h. In the harbor, the transport container is transferred into a vessel designed for the transportation of nuclear materials. From the harbor, the vessel progresses towards the repository site, where the transport container is transferred by road to the repository site.

4.4 Health impacts of the nuclear power plant

The health impacts of ionized radiation are described in the section 4.6 of the EIA report. Moreover, in the same chapter, the radiation doses that an average Finnish person obtains from other than nuclear power sources are described. The impacts of radiation from the nuclear power plant during the normal operation are described in the sections 7.3 and 7.4 (due to atmospheric and aquatic releases).

Fennovoima's target is to keep all emissions at same level or lower than those from the Finnish nuclear power plants that are currently operating. For example, in 2012 the calculated radiation dose due to the normal operation of Loviisa nuclear power plant for the most exposed individual in the vicinity of the plant was 0,07 μSv per annum. A person living in Finland receives on average that radiation dose from background radiation sources of nature and space in about 30 minutes.

The health impacts of the radiation dose of the studied severe accident are described in the section 7.13 of the EIA report. The radiation dose causes no direct or immediate health impacts since the doses obtained during the first two days for both adults and children are less than 23 mSv, which is well below the limit of detection for deviations in the blood count (500 mSv).

The radiation exposure may cause random impacts, which can only be assessed statistically. According to the data of International Commission on Radiological Protection an exposure of 1000 mSv to a large population increases the cancer risk with 5.5 percent. Without the added risk from the accident, the probability to obtain cancer before the age of 70 is 15-20 percent for men and 15 percent for women (Pukkala et al. 2006). As the population within the 5 km radius is less than 500, the expectation value for cases of cancer because of the accident is less than 1. Within the 100 km radius from the plant, the statistical probability for cancer due the accident is less than 7/10000. This means that if the population within the 100 km radius from the plant site is 1 million, the expectation value for cancer cases due to the severe nuclear accident is about 700. Because of other reasons, about 170 000 Finns out of 1 million will get the cancer before the age of 70.

4.5 Accident analyses

The statements and opinions regarding the severe accident analyses requested that the analyses should also consider dispersion into the sea. Further information regarding the fuel burn-up and fuel uranium type and its impact on the source term was asked for.

The dispersion of a radioactive release and the consequential doses for the public in case of a severe accident are presented in the sections 7.13 and 7.14 of the EIA report. The calculations are performed for a severe accident with the release of 100 TBq Cs-137, which corresponds to the INES 6 –class. The release size is based on the requirement in Section 10 of the Government Decree (717/2013) stating that the design of the plant must be such that exceeding of this limit is extremely unlikely. Failure to meet the release limit would result in that no construction and operating licenses would be granted to the plant, which makes larger releases insensible to analyze. However, for the sake of confirmation, also the consequences of a five times bigger release (500 TBq of cesium-137), corresponding to an INES-7 accident, has been assessed. The source term nuclide content is defined based on the NUREG-1465 report, but neglecting beneficial effects from spray etc. Further information is available in the section 7.13.

The planned maximum average burn-up per fuel-bundle is 60 MWd/kgU so the total average burn-up in the core is less than this. There are currently no plans for utilizing mixed oxide fuel in the Hanhikivi 1 plant, however, reprocessed uranium is planned to be used as a fuel in the first core cycles.

Reprocessed uranium deviates from natural uranium in that it contains some isotopes, which is practically absent in natural uranium. However, upper concentration limits for these isotopes are specified so that the properties of reprocessed uranium are eventually quite similar to natural uranium. In the source term used in calculations of radiological consequences the differences between natural uranium and reprocessed uranium fuel becomes negligible.

The dispersion of radioactive substances in the sea proceeds slower than in air and in a sea release accident there are significantly more time for public protective measures and for setting restrictions on natural products. Furthermore, the concentration of radioactive substances in fish becomes generally bigger in fresh water than in sea because of the smaller diluting water volumes. Therefore, the health impacts on people and impacts on food product restrictions due to a release into the sea are inferior when compared to a release into the atmosphere. Thus and as the assessment shall analyze the most significant impacts, the dispersion and dose assessment in the EIA report is done for a radioactive release into the atmosphere.

4.6 Nuclear liability arrangements

4.6.1 Informing neighboring countries in case of an accident

The international notification procedure in case of an accident is described in section 4.5.3.4 of the EIA report.

In case of an accident, the nuclear facility licensee is obliged to notify the Finnish Radiation and Nuclear Safety Authority and to propose a classification for the event. As per international treaties, STUK will then notify the International Atomic Energy Agency (IAEA). All events classified INES 2 or higher must be notified to the IAEA, which will then convey the information to other governments. The EU has its own notification and information exchange system for events at nuclear power plants and radiation hazards.

Finland has ratified two IAEA Conventions signed in 1986 (SopS 98/1986 and SopS 82-83/1990) that include an obligation to publish radiation monitoring information. These Conventions have been binding upon Finland since 1987 (Decree implementing the Convention on Early Notification of a Nuclear Accident 98/1986) and 1990 (Decree implementing the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency and approving certain provisions therein, and on the entry into force of the Act on the application of the Convention 83/1990 and Act on approving certain provisions of the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency and on application of the Convention 1120/1990), respectively.

Articles 35 and 36 of the Treaty establishing the European Atomic Energy Community (Euratom Treaty) oblige Member States of the EU to monitor radiation levels in the environment continuously and to report on measurements to the European Commission regularly. This applies even under normal circumstances and is not limited to nuclear accidents or other exceptional radiological situations as is the case with the IAEA Conventions.

In May 2005, the European Council adopted the proposals of the European Commission (August 16, 2004) concerning the accession of Euratom to the Convention on Early Notification of a Nuclear Accident (Early Notification Convention) and the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency (Assistance Convention). Finland is also a party to these IAEA Conventions. The Early Notification Convention contains provisions on notification to be made to governments of countries affected by the impacts of an accident. The Assistance Convention contains provisions on procedures to be followed in case of an accident, including the requesting and providing of assistance and compensation for costs incurred through providing assistance.

In June 2001, the Council of the Baltic Sea States agreed in Hamburg on an Agreement on the Exchange of Radiation Monitoring Data (Sop 53/2002). The purpose of this Agreement is to create a legal and administrative basis for more efficient exchange of radiation monitoring data between members of the Council of the Baltic Sea States, both under normal circumstances and in cases of nuclear or radiation accidents or other exceptional events. The Agreement has been binding upon Finland since May 2002 (Act on implementation of legislative provisions in the Agreement on the Exchange of Radiation Monitoring Data 386/2002).

In addition to the aforementioned multilateral obligations, Finland has also entered into more detailed bilateral agreements on exchange of data based on the IAEA Conventions. These include the agreements concluded with Sweden (SopS 28/1987), Norway (SopS 46/1987), Denmark (SopS 27/1987), Germany (SopS 35/1993), Russia (SopS 38/1996) and Ukraine (SopS 66/1997). The agreements contain more detailed provisions on what information is to be included in the notifications and how the exchange of information is to be implemented.

4.6.2 Compensation of costs incurred through evacuation and other measures

The liability of the licensee of a nuclear facility is described in section 4.5.3.4 of the EIA report. 'Nuclear liability' refers to the liability of the licensee of a nuclear facility regarding damage caused to outside parties. According to the Nuclear Liability Act (484/1972), the licensee of nuclear facility is liable to compensate for damage caused by a nuclear event at the nuclear facility, regardless of whether the licensee is actually responsible for the occurrence of that damage. Compensable damage includes personal injuries, damage to property, financial loss, and the costs of environmental restoration measures and damage prevention measures.

The licensees of nuclear facilities located in Finland have unlimited liability for nuclear damage caused by a single nuclear event in Finland. The liability of the licensees of nuclear power plants located in Finland for nuclear damage caused outside Finland is limited to 600 million Special Drawing Rights of the International Monetary Fund, corresponding to approximately EUR 676 million. The licensee of the nuclear power plant shall have insurance covering this liability.

4.7 Alternative energy sources and energy efficiency

4.7.1 Alternative energy sources

Some statements highlight that the EIA procedure shall also include other energy production alternatives than the nuclear power plant. The current owners of Fennovoima and purpose of the nuclear power plant project have been described in the chapter 1 of the EIA report. Fennovoima was founded in 2007 to construct a new nuclear power plant in Finland. The companies involved in Fennovoima’s project are local energy companies and industrial and commercial companies which consume a large share of all the electricity consumed in Finland. Fennovoima’s nuclear power plant project is one of the energy projects of the companies. Other energy projects including also wind power are under development with separate EIA procedures, but they are complementary to the Fennovoima project, they cannot be viewed as alternative.

Furthermore, the very purpose of Fennovoima and the sole reason for its shareholders to have established the company is the planning, construction and operation of a nuclear power plant. The company is not at liberty to engage in other forms of energy generation and therefore it cannot present credible alternatives that can be genuinely considered as a substitute. For Fennovoima, the only alternative to a nuclear power plant is the non-action alternative (zero option) that has been assessed as part of the EIA.

In 2008, Fennovoima implemented an environmental impact assessment procedure to assess the impacts from the construction and operation of a nuclear power plant of approximately 1500–2500 megawatts that consists of one or two reactors at three alternative locations; Pyhäjoki, Ruotsinpyhtää, and Simo. An international hearing procedure pursuant to the Espoo Convention was also performed in connection with the EIA procedure. The comparison between the environmental impacts of the 1200 MW and 1800 MW nuclear power plants are presented in the section 8.2 of the EIA report.

4.7.2 Energy efficiency

Energy efficiency of the nuclear power plant is described in the section 3.4.2 of the EIA report. The nuclear power plant will be designed for the highest possible energy efficiency. The goal is to maximize the production of electricity and minimize the energy consumption of the power plant operations and the amount of waste heat discharged into the sea with the cooling water.

Fennovoima has carried out preliminary technical and financial investigations concerning the combined production of electricity and heat. The investigations have revealed that while the selected turbine technology would make extraction of steam for district heat production technically possible, the small demand for district heat in the Raahe region would make the combined production of electricity and heat financially unfeasible. The decrease in the amount of thermal energy led to the sea would be, at most, approximately 1% in the winter period. As the demand for district heat would be small, any positive environmental impacts created through the combined production of electricity and heat would remain minor. However, part of the steam from the turbine will be used to heat the plant site buildings. In the case that a demand for the production of district heat arises in the vicinity of Pyhäjoki in the future, heat pumps can be used to recover heat from the cooling water.

5 Denmark

5.1 Cooling water impacts

Concerns about the adverse impacts of the warm cooling waters on the ecosystem of the Baltic Sea and the breeding migration of salmon were expressed by the Danish parties. The issues have already been handled in the sections 4.1 and 4.2 of this memorandum.

5.2 Nuclear accident

Statements highlight that the impacts of INES 7 type severe accident shall also include to the EIA. The social impacts of a severe accident (other than health impacts) were highlighted.

The section 7.13 of the EIA report includes a short summary of the preliminary results of CEEPRA (Collaboration Network on EuroArctic Environmental Radiation) project. The one of the project targets is to give information on the social impacts of a severe nuclear accident. The final report of the project will be available in 2015.

The safety of the nuclear power plant has been described in the chapter 4 of the EIA report. The impacts of abnormal and accident situations have been described in the sections 7.13 and 7.14. The section 7.14 also includes the impact assessment of the INES 7 accident.

In order to evaluate the impacts of a nuclear power plant accident, the EIA procedure has included modeling of the spread of a radioactive release caused by a severe reactor accident, the consequent fallout, and radiation dose received by the general public. The studied release was the cesium-137 release of 100 TBq laid down in the Government Decree (717/2013), which corresponds to a severe reactor accident (INES 6). The impacts of a release five times higher than the 100 TBq release (more than 50,000 TBq of iodine-131 equivalents) were also assessed corresponding to an INES 7 accident. However that release is theoretically impossible in terms of noble gases, because the release would mean that five times more noble gases than the reactor contains would be released.

Such a fivefold release would not cause any immediate health impacts. If the wind were to blow to the west and the weather conditions were otherwise unfavorable, the lifetime dose of a child on the coast of Sweden would be approximately 37 mSv and the lifetime dose of an adult approximately 18 mSv. Under similar unfavorable conditions, the radiation dose at the Norwegian border could be a maximum of 14 mSv for children and 7 mSv for adults. The radiation doses in the other countries bordering the Baltic Sea would remain below 12 mSv for children and 6 mSv for adults even if the weather conditions were unfavorable. The lifetime radiation dose in Austria would not exceed 5 mSv for children and 2 mSv for adults. In comparison, a resident of Austria may during their lifetime receive a dose of more than 200 mSv from natural background radiation.

Such a fivefold release would give rise to restrictions on the use of food products outside of Finland. The use of reindeer meat would have to be restricted in the fells of Sweden, Norway, or northwestern Russia, depending on the direction the release has spread. Also depending on the direction the release has spread, restrictions on the use of freshwater fish could be necessary in Sweden, Norway, northwestern Russia, and the Baltic states. If grazing of cattle were not limited, restrictions on the use of meat could be necessary in the coastal areas in northern Sweden.

6 Other statements

6.1 Accident analyses

In their statements Greenpeace Sweden and Greenpeace Denmark have presented results calculated with a tool called flexRISK. The results presented by Greenpeace have bigger consequences than what the analyses presented by Fennovoima have. However, some key assumptions of the analyses presented by Greenpeace are not available neither in the statements of Greenpeace or on the referred web pages. These assumptions would be important to know in order to be able to understand the relevance of the analyses. Thus Fennovoima is requesting further information at least;

- The start time of the release after the initiating event and the duration of the release;
- That accident scenario that the timing of release is based on;
- The assumed release height;
- The probability (per year -frequency) of the release (should be available as there are references to probabilistic risk assessment in the flexRISK background material); and
- The relevance of the above mentioned assumptions for the Hanhikivi 1 AES-2006-plant.

Additionally, in their statements Greenpeace presents the conditional cancer risk assuming the accident to have happened. In order to fully understand the risk for an individual caused by the nuclear power plant it would be important also to take into account the probability of the accident scenario. The conditional cancer risk should be multiplied with the estimated probability of the assumed release and the estimated probability of the release to coincide with the adverse weather conditions. This way one receives the overall risk for an individual. To give the calculated overall risk a context, it could be compared with the risk caused by alternative energy solutions and other risks of life.

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