IMPACTS OF NUCLEAR POWER PLANT COOLING WATER ON THE BALTIC SEA – LOVIISA NPP

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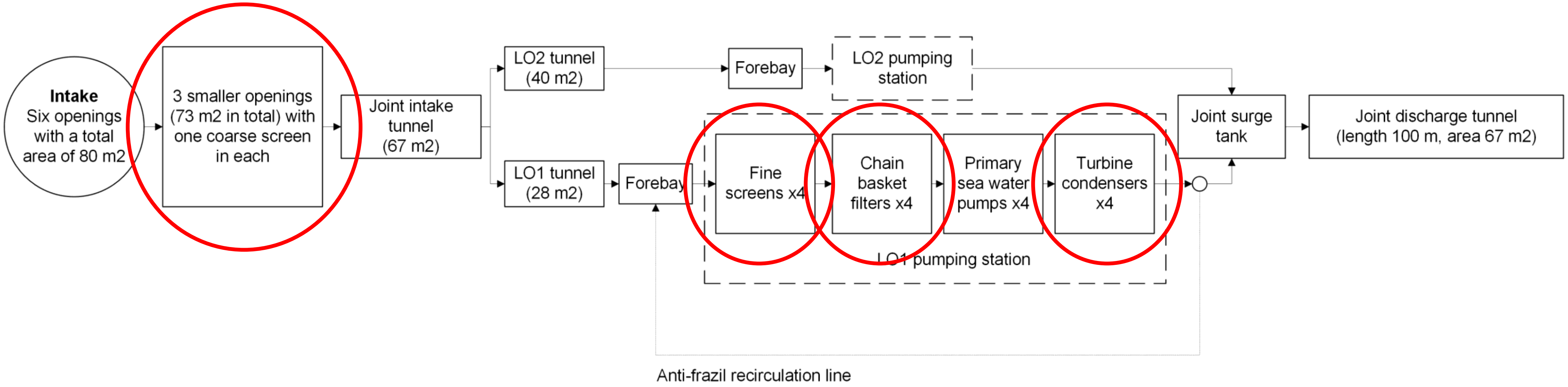
Loviisa NPP

- Two VVER-440 nuclear power plant units (LO1, LO2) with pressurized water reactors (PWR)
- Commercial production began in 1977 (LO1) and 1980 (LO2)
  - Total thermal output 3000 MW
  - Total net electrical output roughly 1014 MW
  - Total net electrical efficiency ~34 %
- 2024: load factor of 88,3 % and 7,9 TWh of electricity
  - 10 % of Finland's electricity production
- Operating license until 2050 (issued in 2023)
  - Original design life 40 years -> 70 years
- Currently valid environmental and water management permit granted in 2009
- The power plant continuously employs around 570 employees and 100 subcontractors

Cooling water arrangements of Loviisa NPP

- **Direct sea water cooling** from the Baltic Sea.
- After the intake, water is led through a shared rock tunnel which branches into two separate tunnels leading to reactor units' sea water pumping stations.



- Coarse screen clearance 80 mm
- Fine screen clearance 16 mm
- Chain basket filter mesh size 1 mm^2
- The cooling water warms up by 8-12 °C in the turbine condensers, average 9,8 °C.

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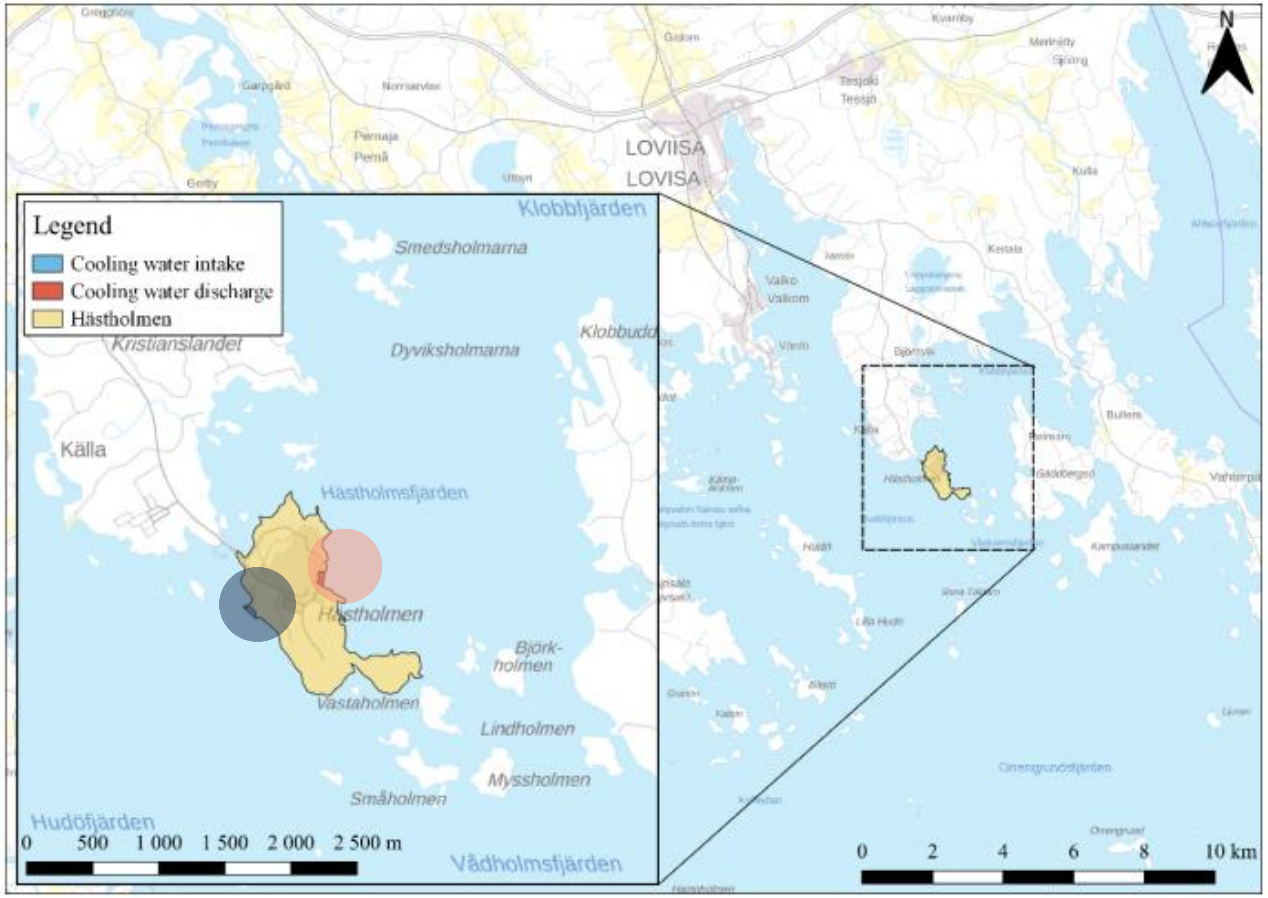
Cooling water intake

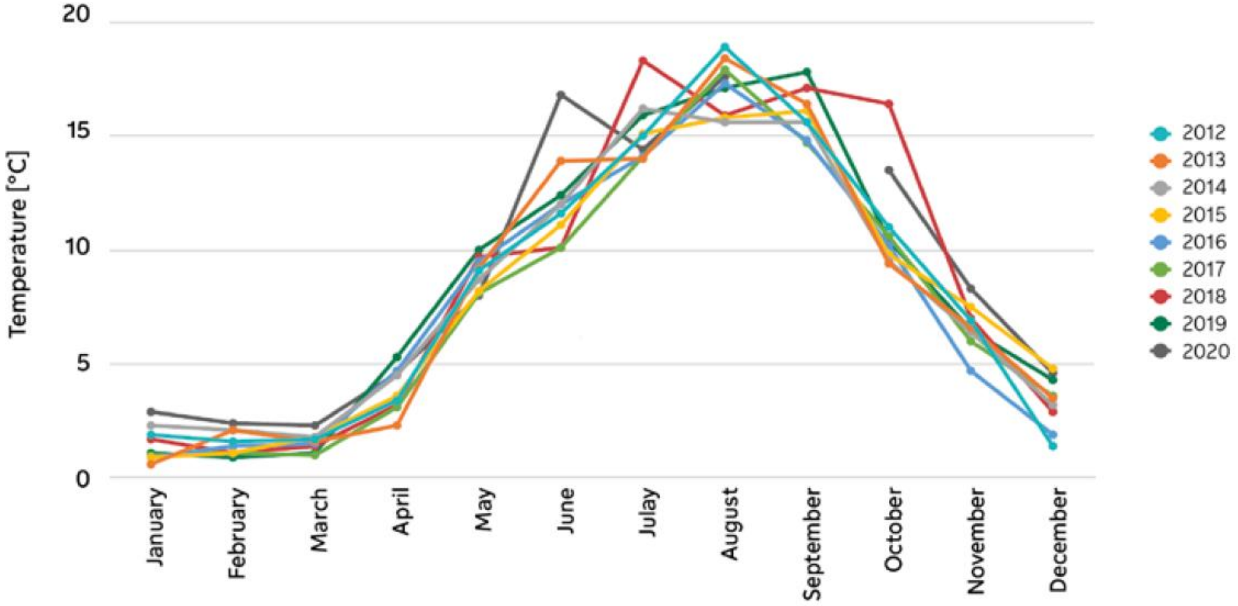
- Cooling water is taken from the west side of the Hästholmen island.
  - Upper edge of the intake structure is at -8,5 m and the lower edge at -11,1 m from sea level.
- Cooling flow rate on average 44 m^3/s, lower in winter, higher in summer:
  - Flow velocity 0,5–0,6 m/s.
  - Environmental permit limit max 55 m^3/s as a daily average.
- Average cooling water consumption 1300 million m^3/a
  - Environmental permit limit: 1800 million m^3/a



Cooling water intake

- Temperature of the cooling water varies between 0–22 °C depending on the season.
  - Largest yearly variations in May-June and October.
  - Highest temperatures in August.
- Surface water temperature at the intake can be as high as 30 °C in some summers (July– August).
- Water taken can be classified as eutrophic (phosphorus) or mesotrophic water (nitrogen).

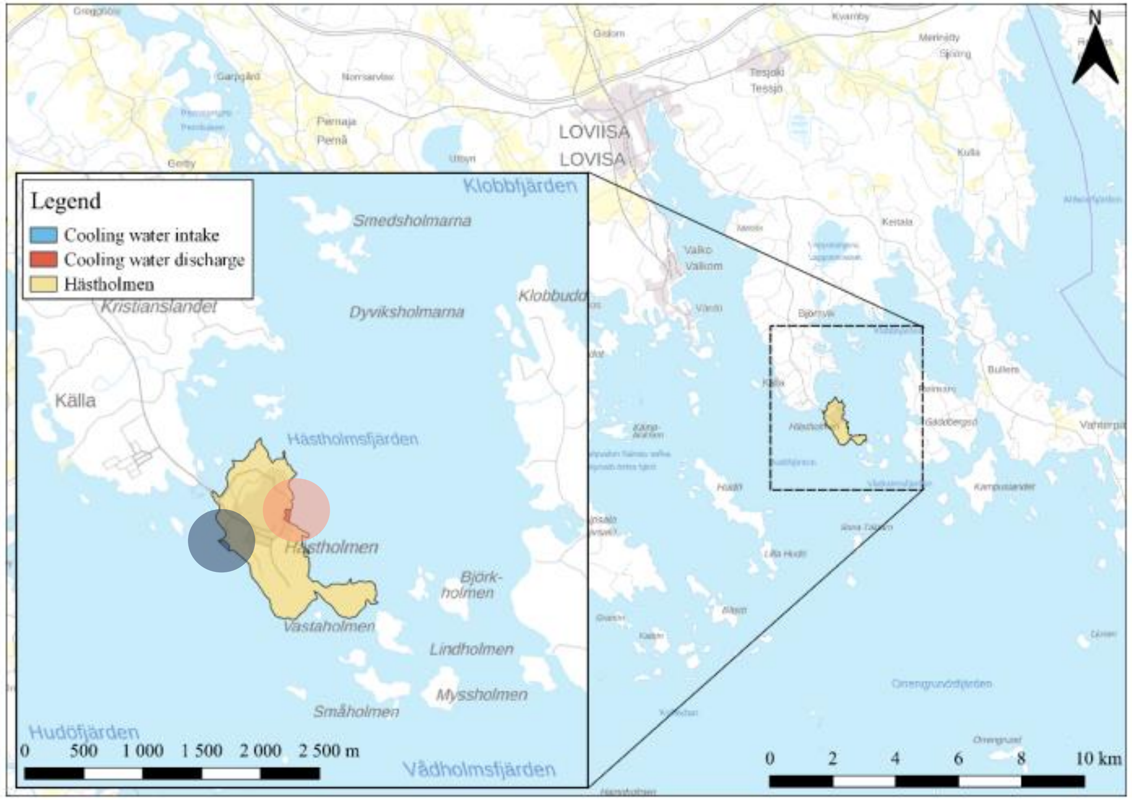
Intake temperature of cooling water LO1, monthly average



Average values in summertime 2020-2022	Intake side: Underwater	Intake side: Surface water
Salinity	4–6 per mil	3.5–5 per mil
Phosphorus	50–90 µg/l	30–35 µg/l
Nitrogen	390–510 µg/l	310–420 µg/l

Cooling water discharge

- Cooling water is discharged from the east side of the Hästholmen island to Hästholmsfjärden (inner part of the Klobbfjärden water body)
  - Surface discharge over an underwater weir.



Cooling water discharge

- Environmental permit limits:
  – Max discharge: 55 m^3/s and 1800 million m^3/a.
  – Heat load into the sea: ~57 000 TJ/a, may not exceed 60 000 TJ/a.
  – Max cooling water Δt 14 °C as a daily average and 13 °C as a monthly average.
  – Max cooling water discharge temperature 34 °C as an hourly average.
  – If the hourly average of the water discharge > 32 °C for at least 24 h

    → permit holder must report on the effects of the excess on the state of the sea area.

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Impacts of cooling water discharge

- The environmental impacts of the Loviisa NPP were extensively assessed in the Environmental Impact Assessment (EIA) procedure 2020–2021*.
  – Option of extending the plant's operation for 20 years and the decommissioning of the plant.
- Among all assessments, the impact of the cooling water discharge to surface waters, fish and fishing and other aquatic species were assessed.
- The impact of cooling water on the seawater temperature was studied by modelling.

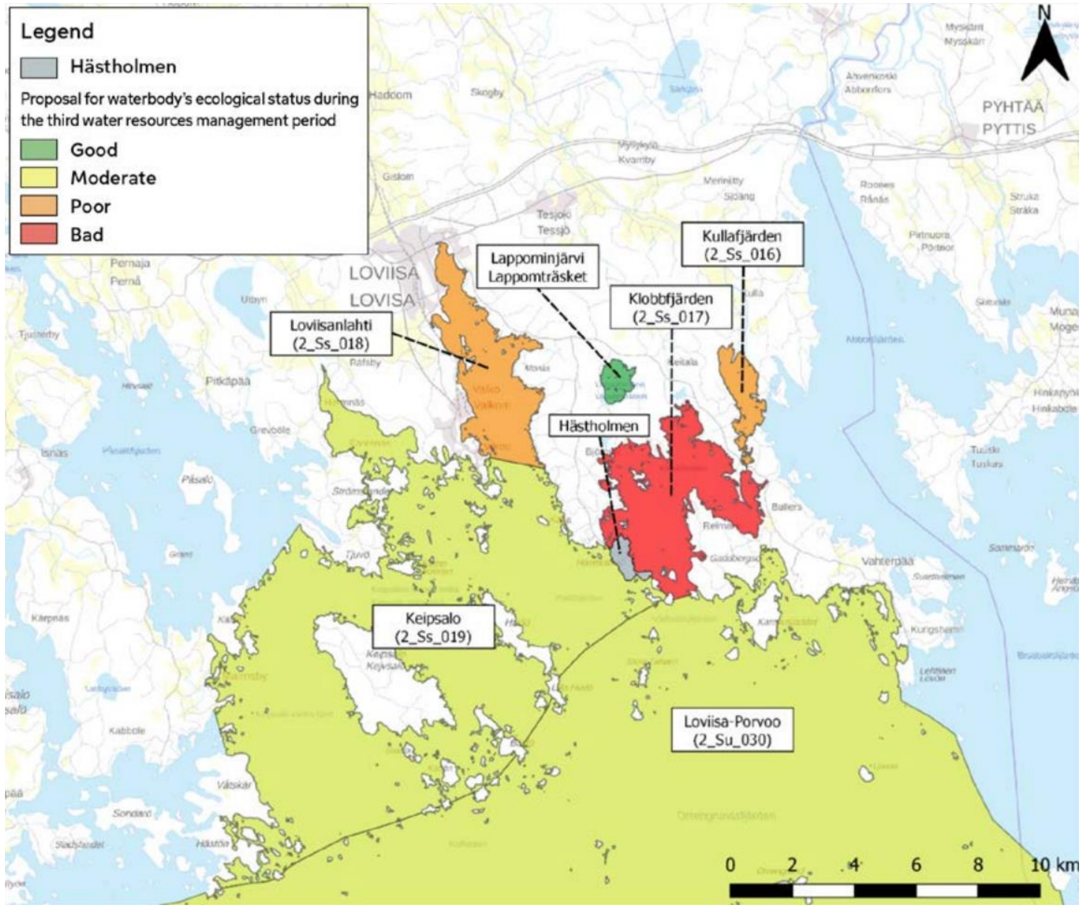
*EIA report in English available at:
https://www.fortum.com/sites/default/files/documents/environmental_impact_assessment_report_2021.pdf

Impacts to surface waters

- Power plant’s thermal load has contributed to:
  - Change in the waterbody’s temperature
  - Stratification conditions
  - Longer growing season
  - Intensification of eutrophication on a local scale
- The marine environment in the discharge area is an entity with complex biological and physico-chemical interactions, where the heat load of the NPP is only one factor.
- Other influencing factors include e.g.:
  - Nutrient loads from rivers
  - Discharge from other facilities (mainly Loviisa municipality's wastewater treatment plant and nearby fish farms)
  - Global warming
  - Major Baltic inflows

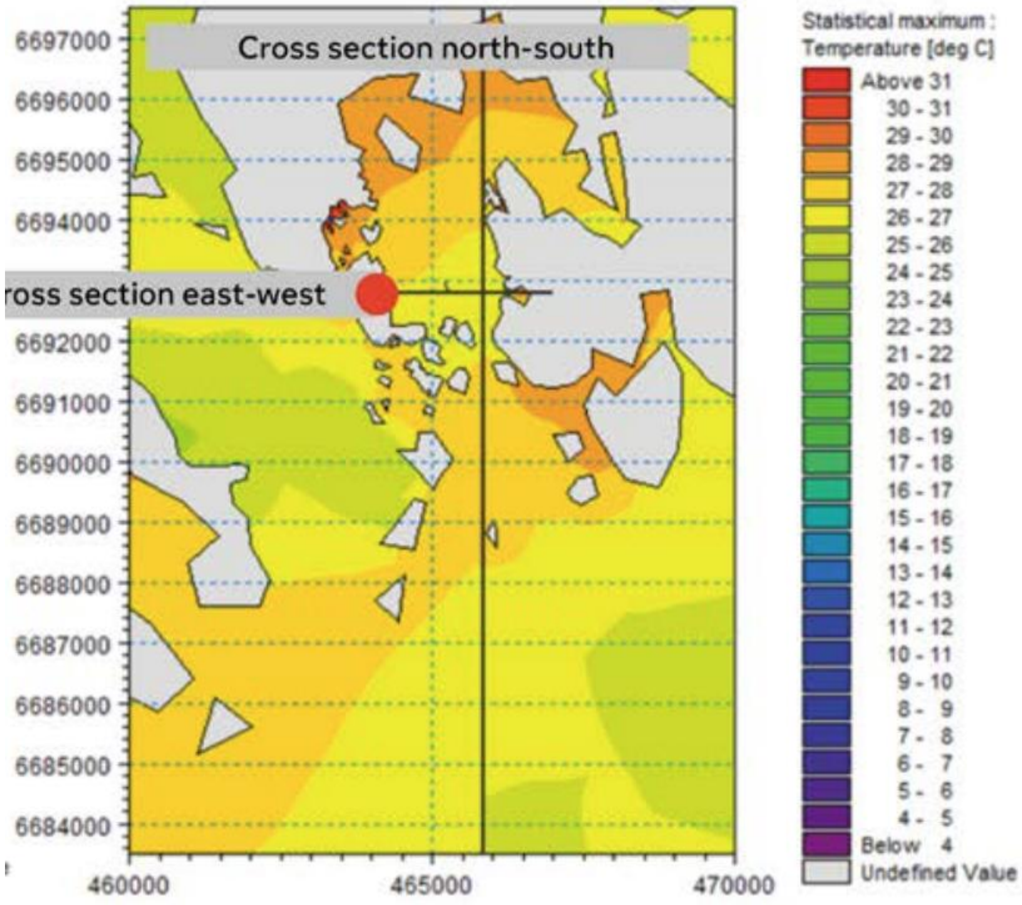
Impacts to surface waters

- Thermal load effects
  - Mainly limited to the Klobbfjärden water body (=Hästholmsfjärden bay + Klobbfjärden bay).
- Status of the water body is also affected by:
  - The general development of the state of the Gulf of Finland.
  - Locally, the development of the water quality of the Tesjoki river.
- The development of the status is the sum of many different factors:
  - In the long term, depends largely on how **climate change scenarios are realized** in the future.
    - Warmer summers combined with the thermal load may increase the thermal effect.
  - Most importantly, what measures will be implemented to reduce **the load from agriculture and other sources.**

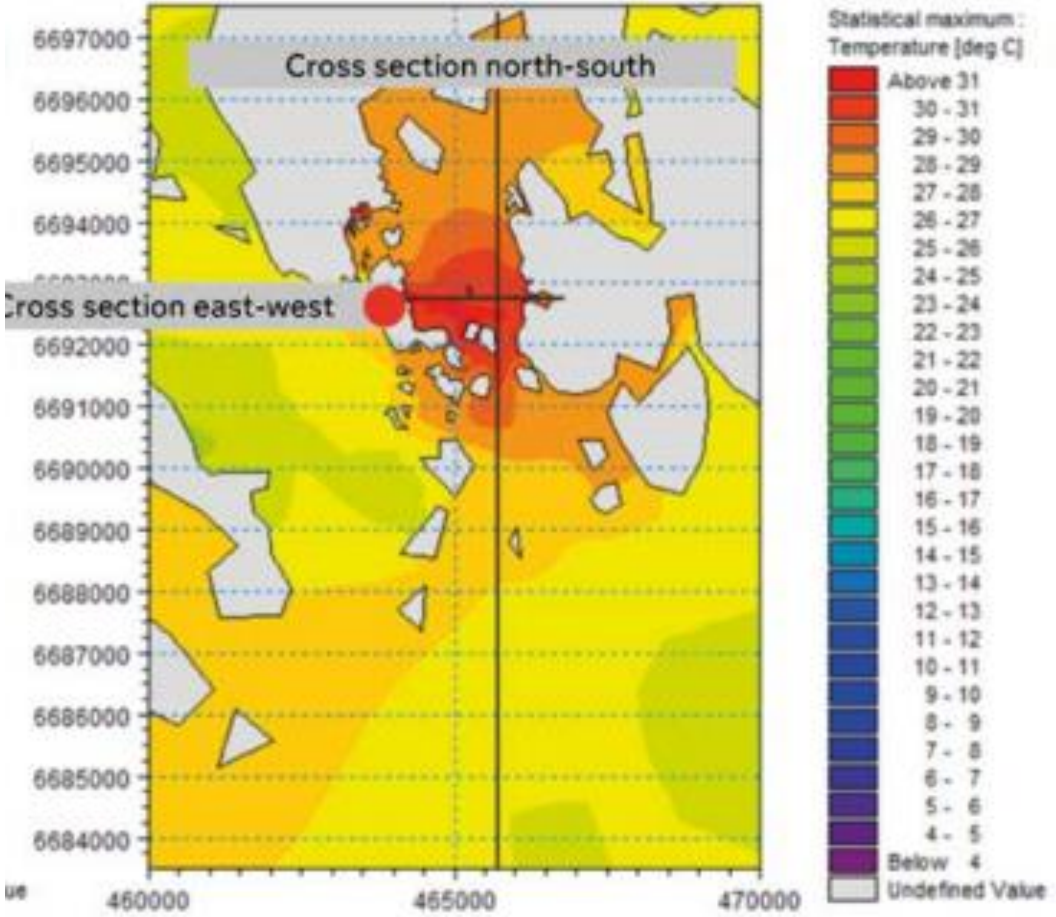


Modelling results: sea water temperature near the NPP in summer

Power plant not in operation, temperature (maximum)



Power plant in operation, temperature (maximum)



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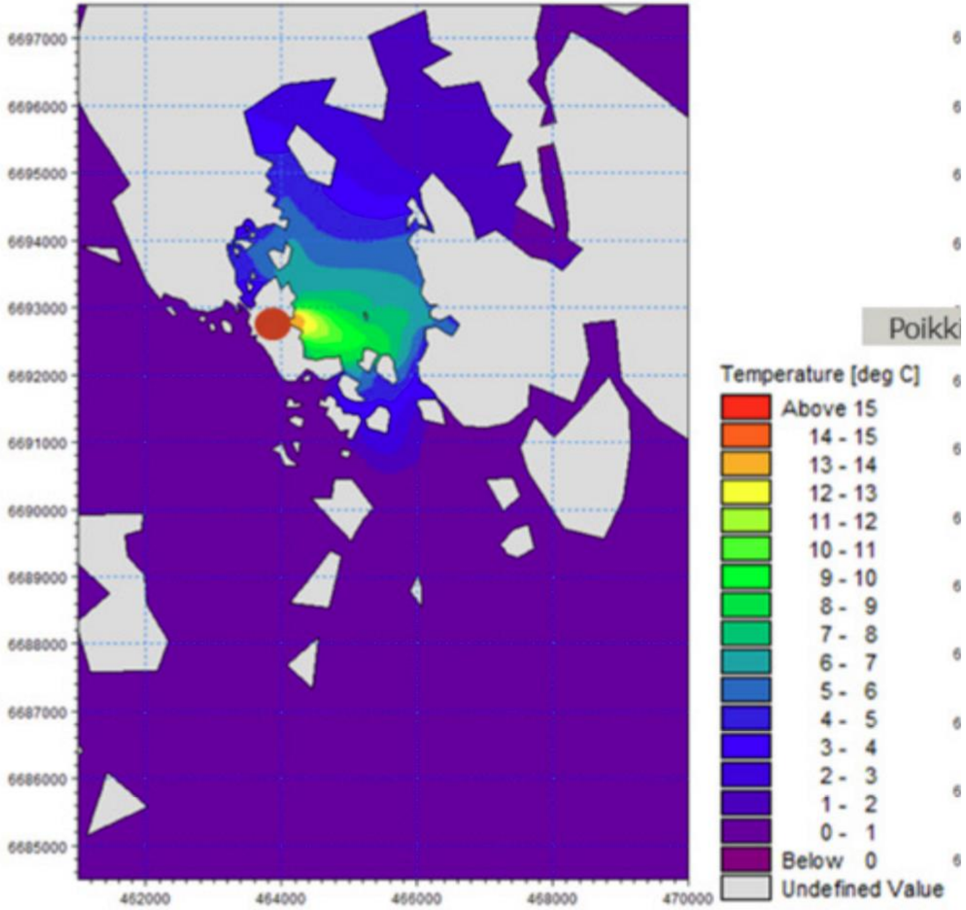
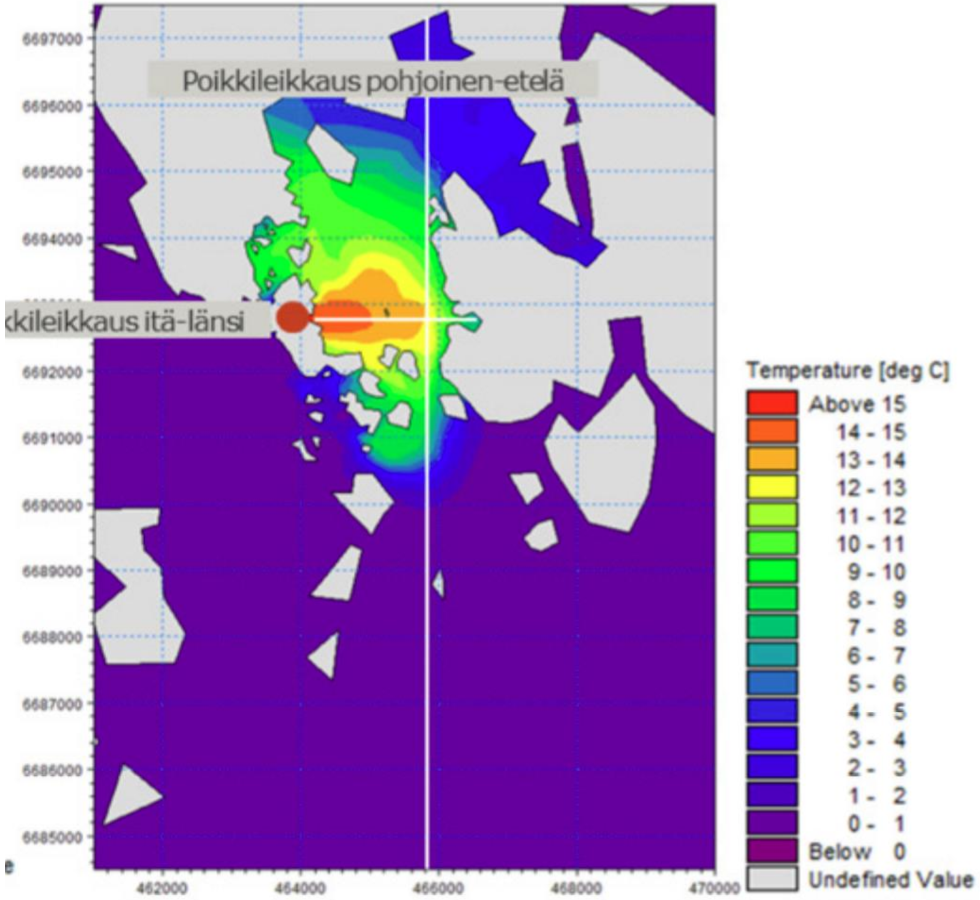
Modelling results: sea water temperature near the NPP in winter

Power plant in operation, temperature (average)

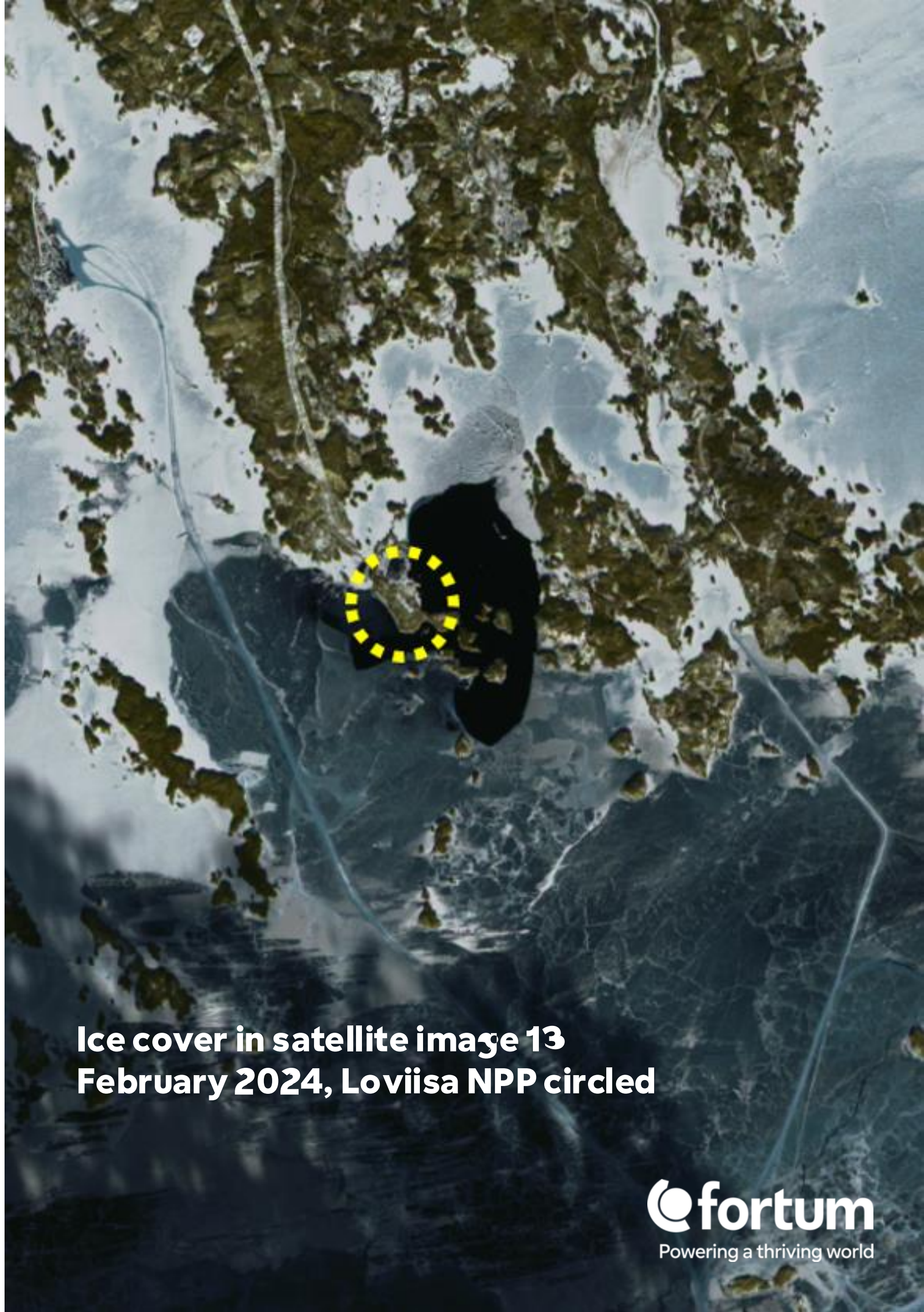


Power plant in operation, temperature (maximum)



Impact to ice cover

- The warm cooling water has a negative impact on the ice cover in front of the power plant and in the straits leading out of Hästholmsfjärden.
  - Permanent ice cover forms later than normally.
  - Ice breaks out earlier than in areas that are not affected by the heat load.
  - Unfrozen water in the area of the discharge site.
- The ice situation and the size of the unfrozen area varies from year to year, depending heavily on the winter weather.
- Warnings of weakened ice are issued on warning boards and in the local newspaper.



Ice cover in satellite image 13 February 2024, Loviisa NPP circled

Impacts on fish and fishery

- Based on fish stock studies, the sea area surrounding the power plant is a fry production area for many fish species.
  - E.g. for herring, goby, perch and pikeperch.
- The warming effect of thecooling water benefits fish species adapted to warm water.
  - E.g. pikeperch and cyprinids.
- The thermal effect may give a competitive advantage to invasive alien species
  - E.g black-spotted goby (*neogobius melanostomus*)
- About 25–30 t of biomass (fish and algae) flows to the cooling water intake per year, of which about 10–20 t is fish.
  - Mainly smelt, herring, pikeperch, ruffe, roach and bream
  - December 2020, a herring loft entered the plant (12 t in 8 h)
- Weakened ice cover impacts ice fishing in winter.

Impacts on birds

- The warm cooling water discharge keeps Hästholmsfjärden unfrozen throughout the winter.
- This has been a significant factor in the formation of a regionally important bird area (MAALI) in the bay area.
- The most significant gathering area for wintering waterfowl in the area.
  - E.g. tufted duck, classified as endangered in Finland since 2015.

Birdlife.fi

Effects of warm water to the NPP

- Reduced plant efficiency due to warm water.
  - Warm surface water in the summer.
  - Recirculation of discharged warm cooling water to the intake.
- High intake water temperatures have led to power restrictions and loss of production during summers due to environmental permit limit.
  - 2025: ~**7 GWH, 218 h** (LO1)
  - 2021: **50 MWh, 5 h** (LO1)
  - 2018: ~**3 GWh , 116 h** (LO1), **~1,3 GWh, 104 h** (LO2)
- Global warming might increase and extend the periods for both reduced plant efficiency and loss of production due to permit limit in the future.

Monitoring and research

- Comprehensive monitoring has been carried out since the 1970s regarding:
  - Wastewater and cooling water discharge
  - Impacts on the sea area
  - Fish and fishery
- Recent studies related to the state of the marine environment:
  - Aliens I (Problems caused by alien species in the Baltic Sea at power plants– Present and future) (2023)*
  - Aliens II (Invasive Alien Species in the Baltic Sea region in power plants using cooling water- DNA Analyses) (2025)*
  - History of Anoxia (Paleolimnological sediment study) (2025)

*Publicly available in Finnish at:

https://energia.fi/julkaisut/vieraslajien-aiheuttamat-ongelmat-voimalaitoksissa-fortum-power-and-heat-oy-2023/

https://energia.fi/julkaisut/vieraslajien-dna-analyysit-itameren-alueella-merivetta-kayttavilla-voimalaitoksilla-fortum-power-heat-oy-2025/

Invasive Alien Species

- Warm cooling water can provide favorable conditions for invasive alien species from “warmer origin” to reproduce and establish themselves in the sea area.
  - Maritime traffic stowaways.
  - Ballast waters, fixed on hulls etc.
- Some are fouling and form harmful growths on power plant structures, potentially clogging heat exchangers and pipelines.
  - Increases cleaning needs and costs.
  - Decreases plant efficiency
  - Impacts plant availability
- Large detached colonies of mussels etc. may cause problems or severe blockages.

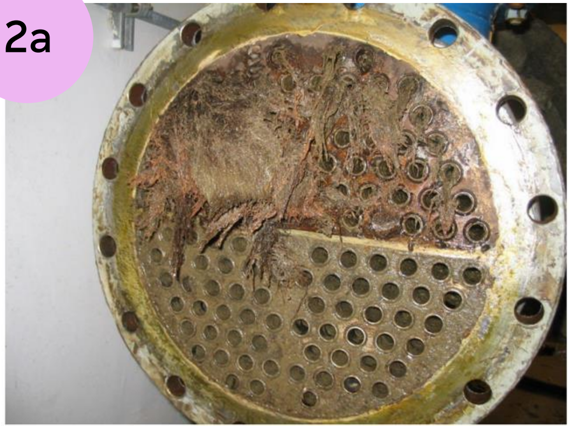
Invasive Alien Species

1. The most significant invasive alien species causing harm at the Loviisa NPP has been the Conrad's false mussel (*Mytilopsis leucophaeata)*
   – Caused fouling problems in 2004.
2. Fouling problems have also been caused by:
   a) Freshwater hydroid (*Cordylophora caspia)*
   b) Bay barnacle (*Amphibalanus improvisus*).
3. The first observations of Atlantic rangia (*Rangia cuneata*) were made in 2022
   – Have not yet caused any actual harm.

1

Conrad's false mussel

2a



Freshwater hydroid growth

2b

Bay barnacle

3

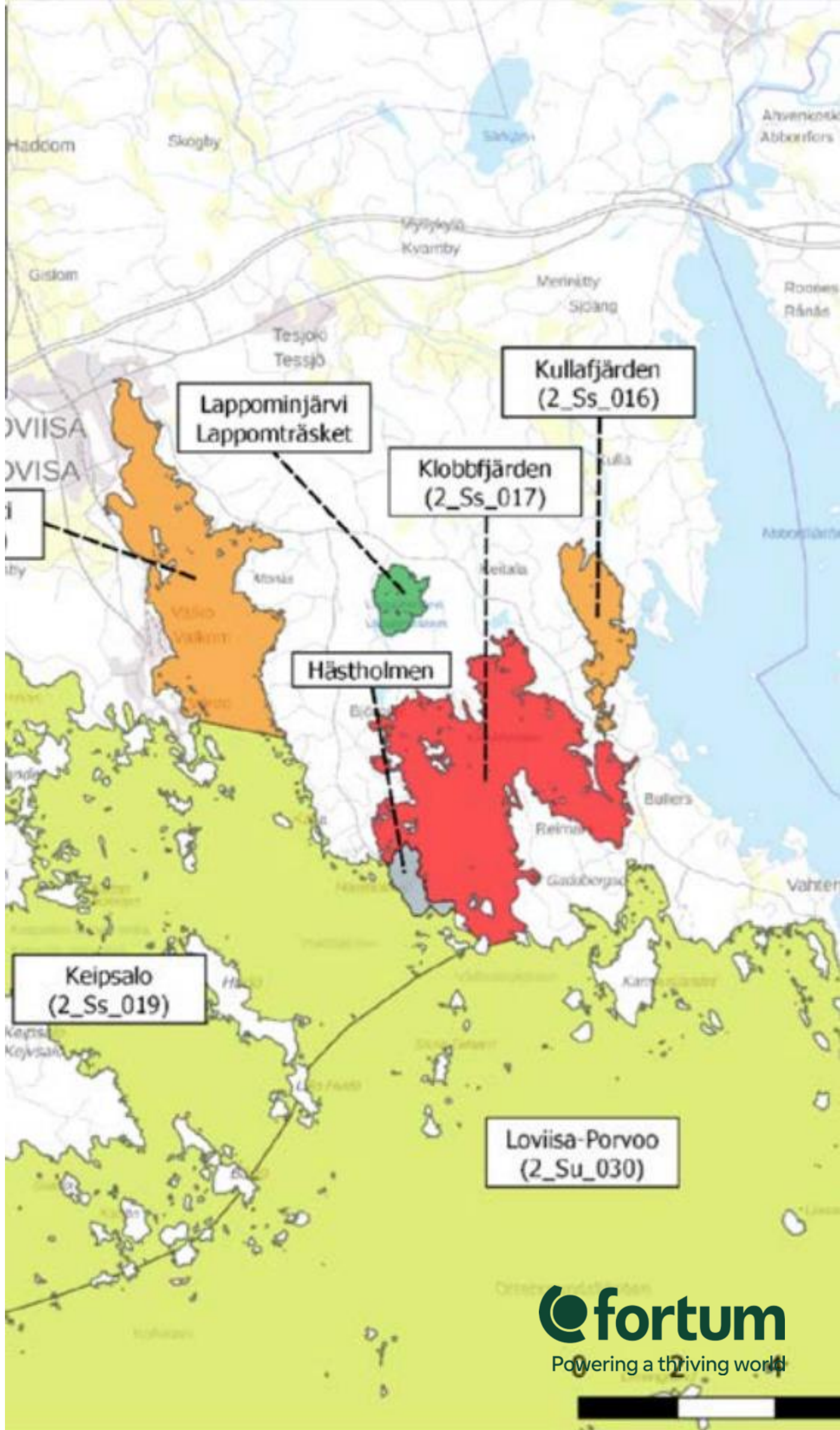
Rangia/wedge mussel

Invasive Alien Species

- Bryozoan *Conopeum chesapeakensis* is the most recent finding.
  - Simple, aquatic invertebrate animal.
  - Brackish water species originating from the North America.
- The first observation in Finnish waters in 2023, in the seawater channels of the Olkiluoto NPP at the west coast of Finland.
- The bryozoan was first observed in the Loviisa NPP's seawater systems in 2024.
  - During the 2025 annual outage, the species was observed to have spread more widely.
- More information on the species and potential control methods are needed.
  - Master's Thesis planned for 2026

Conclusions

- Largest environmental impacts from an NPP with <u>direct sea water cooling</u> are caused by the discharge of the warm cooling water in the receiving waterbody.
- The impacts are manifold.
  - The natural state of the waterbody is changed in many ways.
  - Impacts can be reduced to some extent by design/technical solutions – cost-benefit deliberation.
- Heat load of the NPP is only one factor affecting the status of the nearby waterbody.
  - Complex biological and physico-chemical interactions.
  - Runoff of nutrients from agriculture and other activities.
  - Climate change.
- **Impacts are local -> the whole Baltic sea is not affected**



THANK YOU!

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