Neptunus energy farm

Documentation for notification pursuant to Article 3 of the Espoo Convention

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Administrative tasks

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Project information

Project name: Neptunus Energy Farm

Project website: ox2.com/sv/projects/neptunus

Report: Neptunus Energy Farm – notification under the Espoo Convention

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About the notification

The Espoo Convention on Environmental impact assessment in a transboundary context is an environmental protection convention for Europe, Canada and the United States concerning cooperation to prevent transboundary environmental effects.

Under the Espoo Convention, the party of origin for an activity with a potential transboundary impact is required to inform and invite interested parties (i.e. other countries) likely to be affected by the activity to participate in the environmental impact assessment procedure. As understood in the Espoo Convention, Sweden is the party of origin and the responsible authority is the Swedish Environmental Protection Agency for the current project.

This notification is designed to provide an overall description of the project, the area of activity and a preliminary report on the scope and content of the future Espoo report, which specifically addresses expected transboundary impacts.

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Summary

OX2 AB is one of the leading players in large-scale wind power in Europe and is now planning to establish an energy farm in Sweden’s economic zone in the Baltic Sea. The energy farm is called Neptunus and it is expected to generate about 13- 15 TWh of electricity per year, which corresponds to electricity consumption for up to 3 million households. The project area is approximately 645 square kilometres in size and is located just over 50 kilometres from the mainland of Sweden and 40 kilometres from the nearest Swedish island.

As planned, the energy farm will consist of a total of approximately 120 - 207 wind turbines and associated equipment such as submarine cables, pipelines, transformer/inverter stations and hydrogen production facilities. The maximum overall height of the wind turbines is 420 metres above sea level and the first stage of the energy farm is expected to be operational in 2032.

The distance from the planned Neptunus energy farm to Bornholm, which belongs to Denmark, is about 90 kilometres and the distance to the Danish island of Christiansø is about 70 kilometres Furthermore, it will be about 240 kilometres away from the Danish island of Møn and about 210 kilometres from Zealand. The distance from the energy farm to the Polish mainland is about 100 kilometres. The distance from the energy farm to Lithuania is about 380 kilometres and the distance to Latvia is about 280 km. The distance to Estonia is about 500 kilometres and the distance to the Estonian island of Saaremaa is about 410 kilometres. The distance to the Kaliningrad Oblast in Russia is about 220 km. Finally, the distance from the energy park to the German island of Rügen is about 190 kilometres and the distance to the German mainland about 220 kilometres.

Under the Espoo Convention, the party of origin for an activity with a potential transboundary impact is required to inform and invite interested parties, that is to say other countries) likely to be affected by the activity to participate in the environmental impact assessment procedure. As understood in the Espoo Convention, Sweden is the party of origin and the responsible authority is the Swedish Environmental Protection Agency for the current project.

This notification is designed to provide an overall description of the project, the area of activity and a preliminary report on the scope and content of the future Espoo report, which specifically addresses expected transboundary impacts.

The preliminary conclusions are that the impact, within the Swedish EEZ, of the planned activities is expected to be limited, which means that the potential transboundary impact can also be expected to be limited.

Concepts and definitions

In order to make it easier for the reader, the following list of specific concepts and definitions used in this consultation document has been compiled.

Connection corridors	The area or areas within which the energy farm export cables and export pipelines are located;
Export cables	These are electrical cables that transfer the electricity produced from the energy farm to one or more connection points on land;
Export pipelines	Pipelines that transfer hydrogen gas produced by the energy farm to one or more land connection points;
Power	The speed of energy conversion. Nameplate power is measured, among other things, in kilowatt (kW) and its multiples; 1,000 kW = 1 megawatt (MW), 1,000 MW = 1 gigawatt (GW), 1,000 GW = 1 terawatt (TW).
Energy farm	Offshore wind farm where the renewable electricity produced, in addition to being exported to the electricity grid, can also be used for hydrogen production. The energy farm consists of wind turbines, plant parts for hydrogen production, inter-array cables, internal pipeline network, transformer and inverter stations, met masts, and related parts within the Neptunus project area.
Halocline	A boundary between water masses with two different saline levels. The difference in salinity between surface water and bottom water creates a layering that makes it difficult to mix the different layers.
Inter-array	Internal electrical cable network within the energy farm.
Internal pipeline network	A network of internal pipelines for the transport of hydrogen within the farm.
Environmental impact assessment	A document that is attached to the licence application that must describe the direct and indirect environmental impact on human health and the environment and allow an overall assessment of the consequences arising from the planned activities..
Project area	The area within the Swedish economic zone where the energy farm is planned, bounded by the coordinates that follow from Figure 1.
Consultation paper	A document containing information on the planned project and, on an overall level, an account of the environmental impact that the planned activities are deemed capable of producing.
Mitigatory measures	Mitigatory measures are measures taken to avoid, minimise and reverse adverse environmental impact.
Overall height	The turbine height up to the blade tip when it is at the highest position.

1. Background

1.1. About OX2

Neptunus Energipark AB is a wholly owned subsidiary of OX2 AB (publ). OX2 is a Swedish company that develops, builds and sells onshore and offshore wind and solar power. OX2 also offers wind and solar farm management after completion. OX2’s development portfolio consists of both proprietary and acquired projects in different phases. The company is also active in technology development linked to renewable energy sources, such as hydrogen and energy storage. OX2 operates in eleven markets in Europe: Sweden, Norway, Finland, Estonia, Lithuania, Poland, Romania, France, Spain, Italy and Greece. In 2022, OX2’s sales revenues amounted to approximately SEK 7.6 billion. The company has approximately 400 employees and its head office is in Stockholm. OX2 has been listed on Nasdaq Stockholm since spring 2022.

OX2’s business objective is to accelerate the transition toward a renewable energy system with a net positive impact on natural capital by 2030. The aim is therefore that the wind, solar and energy farms OX2 develops and builds should create as much climate benefit as possible , while protecting or strengthening biodiversity through the projects. In line with its business objective, OX2 has developed a biodiversity strategy with the goal of nature-positive wind and solar farms by 2030.

1.2. About the need for renewable energy

The planned Neptunus energy farm is part of the extensive energy transition in both Sweden and the rest of Europe from fossil-dependent power sources to energy production entirely based on renewable, green and sustainable technologies. In addition to environmental and climate goals driving technology development and investment in renewable energy sources, there is also a very great need for new and fossil-free electricity generation to be established quickly and at a cost that generates competitive electricity By 2045, a demand for electricity in Sweden of at least 300 TWh is forecast, which is twice the current electricity consumption.

There is already very high demand for renewable electricity from companies, industries, transport sector, etc., as all parts of the business sector are undergoing or planning for the transition to more sustainable production and consumption of energy, both for electricity and fuel, such as hydrogen. Companies and industries cannot change, grow or be established because of electricity shortages. An urgent and large-scale expansion of electricity production is required, especially in southern Sweden, if the country is to be able cope with this transition and strengthen Sweden’s competitiveness. The development of hydrogen technology also makes it possible to generate stable energy production using wind power that can deliver renewable energy at all hours of the day.

1.2.1 Offshore wind power

Society is becoming increasingly electrified, for example in the transport and the industrial sector, and forecasts of future scenarios point to a sharp increase in electricity demand. To meet this, renewable energy production needs to increase significantly, and offshore wind power has the potential to be an important part of the future electricity system (Energimyndigheten & Havs och vattenmyndigheten, 2023). Offshore wind power off Sweden’s southern coast has a great potential to contribute with new capacity and at the same time utilise existing electricity grids as efficiently as possible. This location also strengthens the area’s ability to supply itself and create energy stability as the area currently has Sweden’s lowest level of local production of electricity (Lara, et al., 2021).

Compared to onshore wind farms, offshore wind farms can be built using larger turbines with higher power output. The conditions for offshore wind power are also better as the wind speed is higher and the winds blow more evenly, which contributes to more stable and efficient energy production. Offshore wind power can also be used for the production of hydrogen that can be used for industry, vehicles and transport, energy storage for electricity grids and also as energy carriers in further processing into other e-fuels.

1.2.2 Hydrogen

Hydrogen can be produced in a number of ways. The majority of current hydrogen production uses methods that give rise to greenhouse gas emissions (Europeiska kommissionen, 2020; Lara, et al., 2021). Hydrogen produced by electrolysis powered by renewable energy is completely fossil-free. Fossil-free hydrogen will be crucial for the climate transition in industrial uses, shipping and agriculture that cannot be electrified.

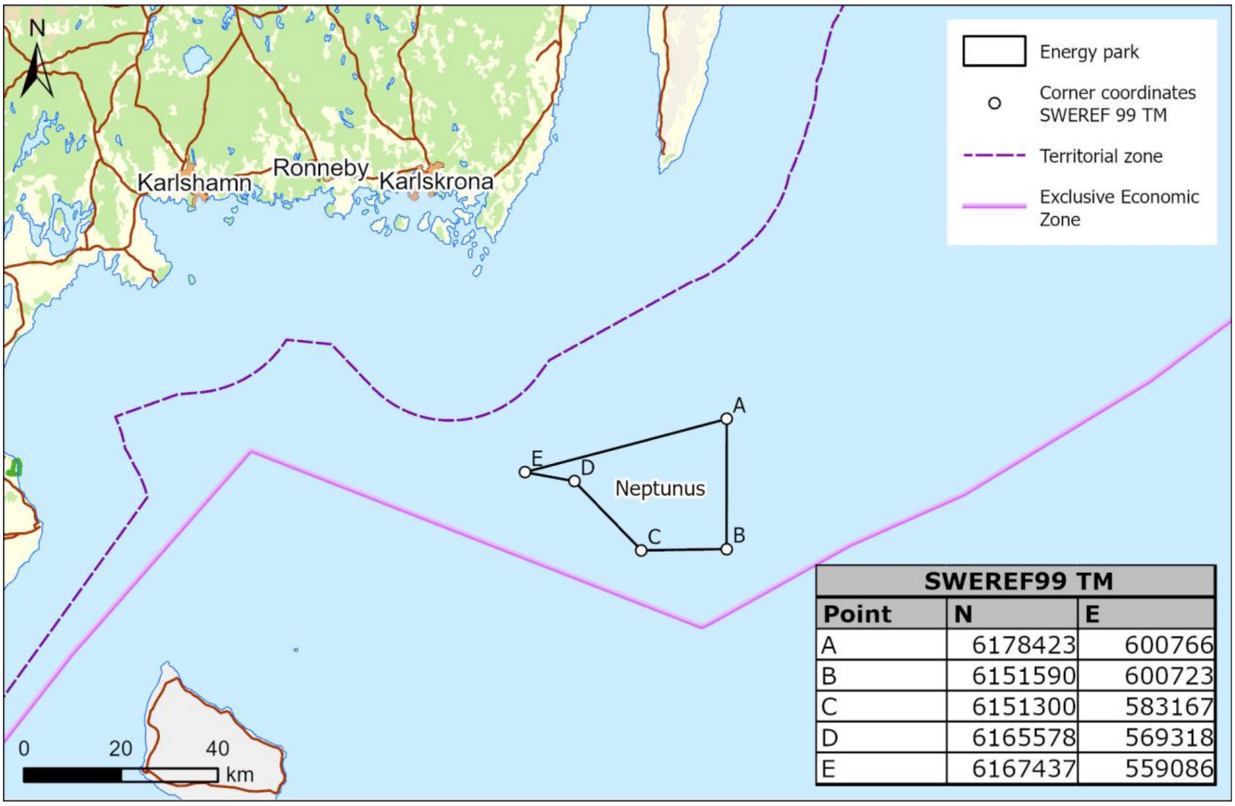
Hydrogen also has the advantage that it can serve to store energy. Wind, solar and wave power are intermittent in nature, which means that production varies over time. Under favourable conditions, the electricity produced may show a surplus, while under less favourable conditions enough to meet demand may not be produced. Intermediate storage, for example by converting to hydrogen, is an alternative to wasting such surplus electricity. Gaseous energy carriers, such as hydrogen, can therefore have an important part to play, through their energy storage capacity, in balancing an electrical system powered by renewable energy sources (Lara, et al., 2021).

The development of technical solutions for energy conversion has gained momentum in Sweden and the rest of the world. The European Commission has set an installation target in the EU of electrolysers for renewable hydrogen production with a capacity of at least 6 gigawatts by 2024 and 40 gigawatts by 2030. This will make hydrogen into an important part of a future energy system.

1.3. Neptunus

OX2 is planning to establish a large-scale offshore energy farm in the Baltic Proper, in the sub-areas Southern Baltic Sea and the South-Eastern Baltic Sea. The energy farm is called Neptunus. The project area for the energy farm is bounded by the corner points using the coordinates of the SWEREF99TM coordinate system, see Figure 1.

When completed, the energy farm will contain 120–207 wind turbines with a total height of a maximum of 420 metres and with a rotor diameters of between 240 and 390 metres. The energy farm is expected to have a nameplate capacity of approximately 3,100 megawatts and produce approximately 13-15 terawatt hours of renewable energy per year This corresponds to the annual energy consumption of up to 3 million Swedish households. The planned energy production would also enable production of approximately 370,000 tonnes of hydrogen per year and 3 million tonnes of oxygen per year



SWEREF99 TM		
Point	**N**	**E**
A	6178423	600766
B	6151590	600723
C	6151300	583167
D	6165578	569318
E	6167437	559086

Figure 1. The energy farm project area with its corner coordinates. © [National Land Survey] 2023

1.4. Espoo consultation

The Espoo Convention on Environmental impact assessment in a transboundary context is an environmental protection convention for Europe, Canada and the United States concerning cooperation to prevent transboundary environmental effects. Sweden ratified the Espoo Convention in 1994, see Sweden’s international agreements SÖ 1992:1.

Under the Espoo Convention, the party of origin for an activity with a potential significant transboundary impact is required to inform and invite interested parties (i.e. other states) likely to be affected by the activity to participate in the environmental impact assessment procedure, see also Chapter 6, Section 33 of the Swedish Environmental Code. The consultation process under Articles 3 to 6 of the Espoo Convention is coordinated by a responsible authority in the respective state concerned. The Swedish Environmental Protection Agency is the competent agency responsible. The Espoo procedure can be summarised briefly in the following horizontal steps:

- Notification (Article 3) - Any planned activity likely to have a significant (harmful) transboundary impact must, through the competent authority, inform potential interested parties. *This step is initiated by this document.*

- Preparation of the environmental impact assessment (Article 4) – To the extent that interested parties continue to participate in consultations under the Espoo Convention, an environmental impact assessment (so-called ESPOO report/EIA) is established.
- Consultation on the basis of the environmental impact assessment (Article 5) – The Espoo report/EIA shall be submitted by the competent authority to the parties concerned who continue their intention to participate in the procedure. The consultation may include, inter alia, alternative locations or alternative implementation and mitigatory measures and precautions for the operation.
- Final decision (Article 6) – After consultation, a final decision on the proposed activities shall ensure that due account is taken of both the results of the Espoo report and the comments received. In the case of trials of offshore wind farms situated within the Swedish Exclusive economic zone, the government's decision to grant an authorisation under SEZ may be considered to be the final decision, which concludes the Espoo consultation.

2. Licensing trials pursuant to Swedish law

2.1. Examination according to Swedish legislation

The energy farm is located within Sweden's economic zone, which is why the Swedish Economic Zone ("SEZ") Act (1992:1140) applies. The energy farm therefore needs a permit from the Swedish government according to Section 5 of SEZ for the construction and operation of wind turbines and associated plants, including plants for the production and storage of hydrogen and oxygen.

A licence from the Swedish government is required pursuant to Section 3 of the Act (1966:314)) on the Continental Shelf (KSL) to lay the inter-array and internal hydrogen pipeline networks within the energy farm.

Activities or actions that could significantly affect the environment in a Natura 2000 site require a so-called Natura 2000 licence pursuant to Chapter 7, Sections 28a-29b of the Environmental Code. As the energy farm borders on the Natura 2000 area Hoburgs bank and Midsjöbankarna meaning that here is a risk they could be affected, a Natura 2000 licence will be applied for in accordance with Chapter 7, Section 28 a of the Environmental Code. For operations within the Swedish economic zone, the application will be reviewed by the county administrative board for the county closest to the operations applied for.

Hydrogen production from the energy farm prompts questions under the Act (1999:381)) on measures to prevent and limit the consequences of serious chemical accidents (Seveso Act). SEZ refers to the provisions of the Environmental Code on consultation under the Seveso legislation. OX2 will thus include Seveso consultations in its upcoming SEZ application and Espoo report.

2.2. Other examination

In addition to the above-mentioned examinations, further consultation processes and licences required for the activities and related activities are described below.

Access corridors, containing export cables and export pipelines, are being considered for the export of electricity and hydrogen to mainland Sweden and to one or more European countries. A licence is required for laying and operation of export cables and export pipelines.

The precise design of potential access corridors will be determined at a later stage and customised for the chosen connection points and the final design of the energy farm. Licences that are required for laying export cables and export will be sought in special order once the appropriate route has been considered. However, this documentation describes the possible alternatives for onshore connection points, in order to give as far as possible an overall picture of the planned operations.

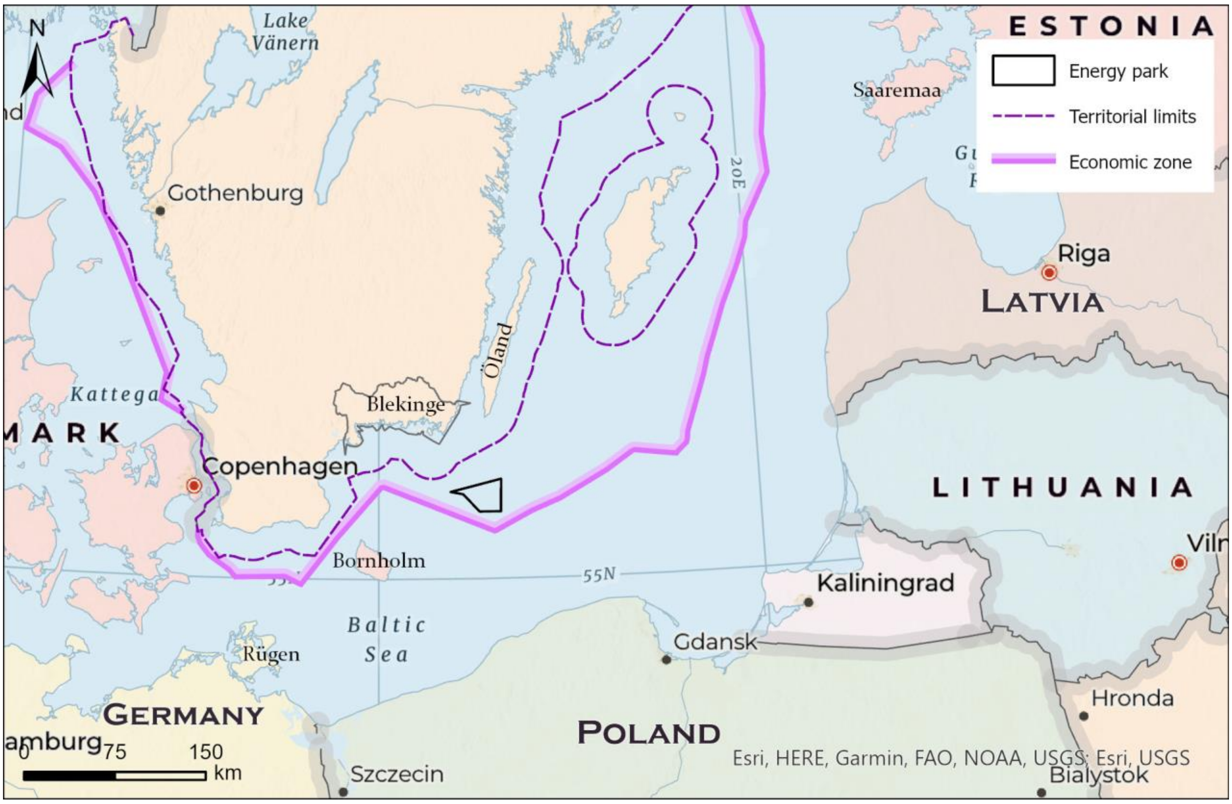
Hydrogen is a flammable gas in accordance with the Act (2010:1011)) on Flammable and Explosive Goods. Consultation and licensing may be required, which will be duly dealt with.

3. Activity description

3.1. Location

The planned Neptunus Energy Farm is located within Sweden’s economic zone in the Baltic Proper, just over 50 kilometres off the Swedish mainland coast. The distance to the Polish and Danish economic zones is about 10 km. See the location of the project area in Figure 1. The area consists of open sea and is about 645 square kilometres in size with a water depth that varies between about 50 and 80 metres.

The distance from the planned Neptunus Energy Farm to Bornholm, which belongs to Denmark, is about 90 kilometres and the distance to the Danish island of Christiansø (belonging to the Ertholmene archipelago) is about 70 kilometres, see Figure 2. Furthermore, the distance to the Danish island of Møn is about 240 kilometres and the distance to Zealand is about 210 kilometres. The distance from the energy farm to the Polish mainland is about 100 kilometres. The distance from the energy farm to Lithuania is about 380 kilometres and the distance to Latvia is about 280 kilometres. The distance to Estonia is about 500 kilometres and the distance to the Estonian island of Saaremaa is about 410 kilometres. The distance to the Kaliningrad Oblast in Russia is about 220 kilometres. Finally, the distance from the energy farm to the German island of Rügen is about 190 kilometres and the distance to the German mainland is about 220 kilometres.



Esri, HERE, Garmin, FAO, NOAA, USGS; Esri, USGS

Figure 2. The Neptunus energy farm project area and its location in the Baltic Sea.

The area is expected to have favourable conditions for the establishment of wind power with an average wind speed of about 9.5 metres a year at 100 m above sea level). The bottom substrate of the project site is dominated by clay and a mixture of sand, coarse sand, smaller rocks and gravel. The deeper layers are dominated by post-glacial and glacial clay.

3.2. Neptunus' design and extent

The Neptunus energy farm will have an nameplate capacity of approximately 4,500 megawatts and consist of two primary parts; wind power production and hydrogen production. Up to 100 percent of the wind turbines' total capacity may be used for hydrogen production. The amount of electricity produced that will be used for hydrogen production will be determined during the detailed engineering.

Depending on their size, the Neptunus energy farm will house from 120 to 207 wind turbines. The wind turbines are anchored to foundations and connected to an inter-array of cables network that connects the wind turbines with a number of transformer and/or inverter stations.

Figure 3 presents two examples of possible farm layouts within the Neptunus project area, showing small and large wind turbines. It should be pointed out that these are only examples of layouts and that the final design may look different.

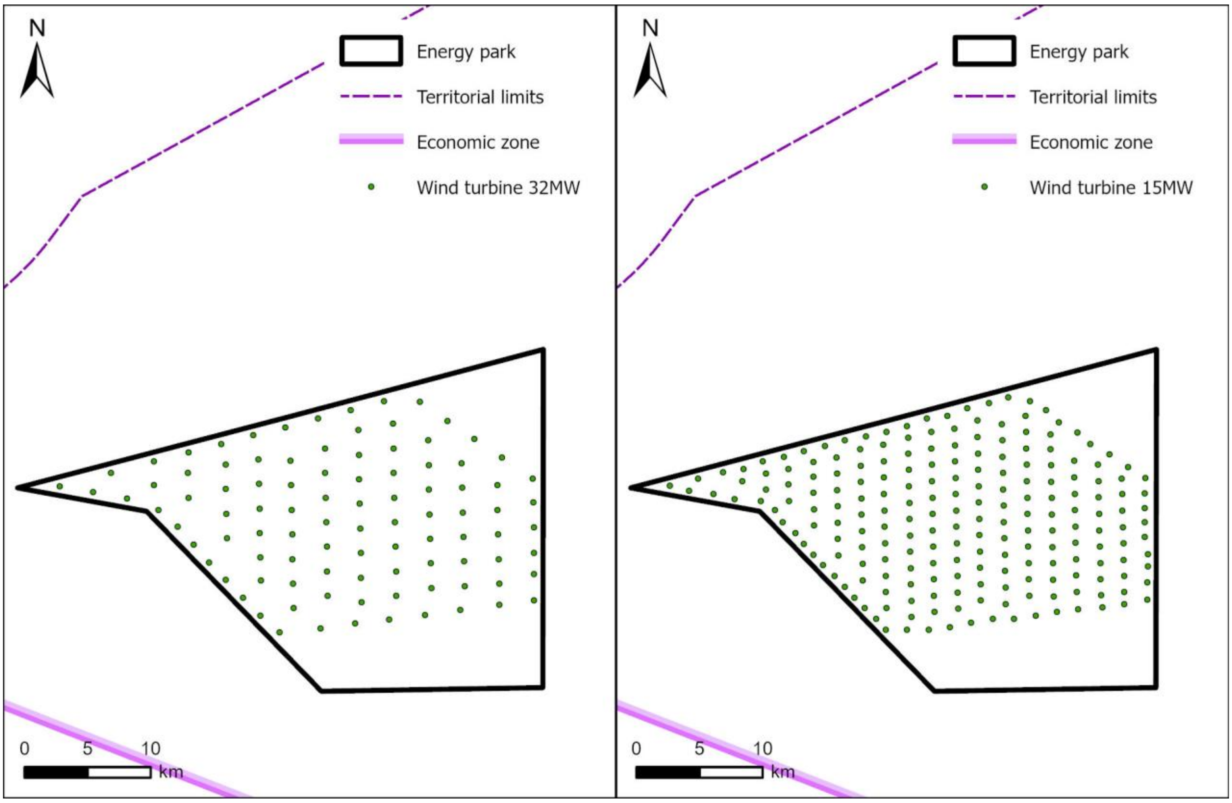


Figure 3. Two examples of farm layouts for the Neptunus energy park, with large and small wind turbines respectively.

Energy storage and/or energy conversion platforms may also be built at the farm. The planned method for hydrogen production is electrolysis. The final number of electrolysers in the project area will depend on the technology solution chosen, the volume of hydrogen production and technological developments. Figure 4 depicts an outline sketch of the various parts that the energy farm will be made up of.

In addition, one or more masts may be installed for meteorological measurements or LiDAR, i.e. Light Detection and ranging, as well as buoys for wave and current measurement.

Figure 4. Outline of the different parts that an energy farm (centralised layout) typically consists of. Illustrator: Nina Fylkegård

3.2.1. *Wind turbines*

A wind turbine consists of a tower, nacelle and rotor blades and is installed on a foundation anchored to the seabed. The tower also contains electrical components. The main components of the nacelle are the gearbox, generator and yaw motors. A transformer will either be fitted in the nacelle or in the tower. The electricity produced by each wind turbine is transferred via an inter array cable network to one or more transformer/inverter stations.

The wind turbines in the energy farm will most likely be a traditional model with three blades on a horizontal shaft, see Figure 5. The rotor diameter is expected to be between 240 and 390 metres and the maximum overall height of the wind turbine is expected to be 420 metres above sea level. The clearance between the tip of the blade and the surface of the water will be about 20– 30 metres.

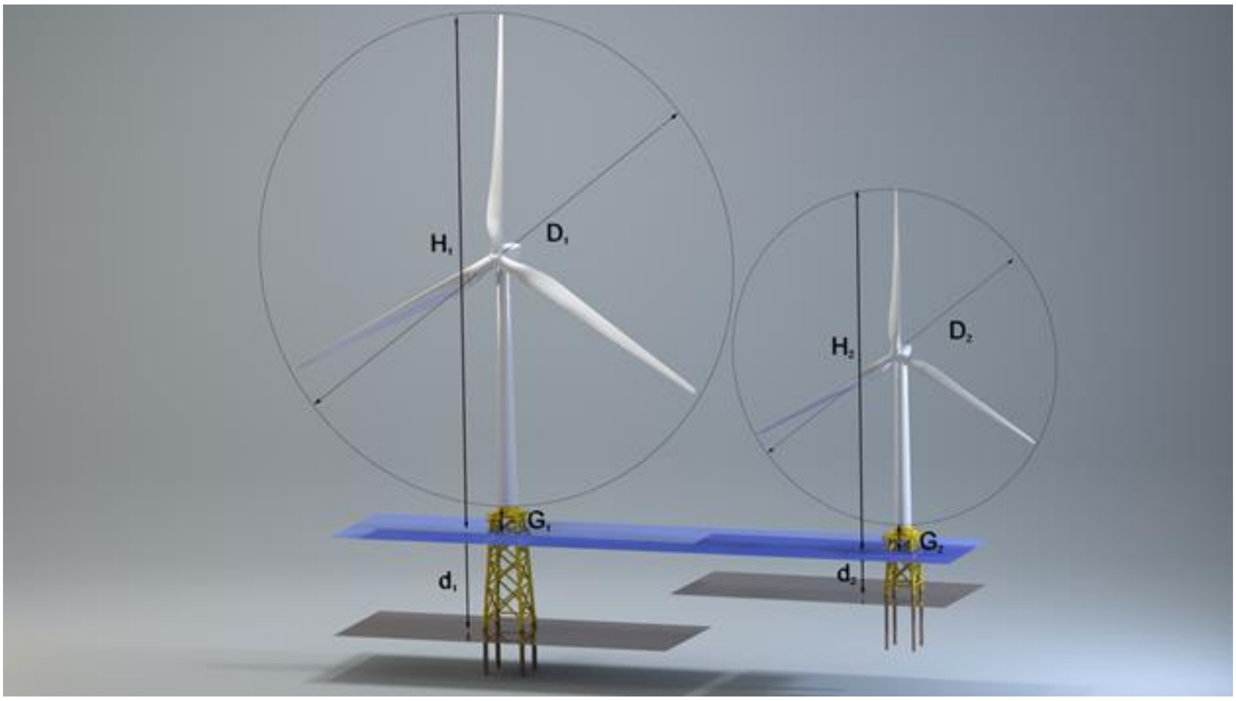


Figure 5. Examples of wind turbines. D = rotor diameter, H = overall height, G = clearance, d = water depth.

Wind turbines are expected to produce electricity at wind speeds from about three m/s and achieve maximum production at wind speeds between 10 and 14 m/s. When the wind speed exceeds around 30 metres per second the wind turbine is shut down automatically and restarts automatically when the wind speed drops.

The turbines and meteorological masts will be marked for air and sea transport in accordance with applicable rules and regulations at the time of farm construction. According to the current regulations, the *Swedish Transport Agency's regulations and general advice on marking of objects that may constitute a hazard to aviation and about notification of obstacles to aviation* (TSFS 2020:88), wind turbines with a height above 150 metres that are located on the outer edge of the farm must be fitted with high-intensity white flashing lights on the nacelle. Energy farms that are wider than four kilometres must also be equipped with high-intensity lights inside the farm and all other wind turbines must be fitted with a low-intensity red light. If a turbine has a total height of more than 315 metres it may require additional lighting.

Additional maritime safety markings may be required, depending on the location of the energy farm in relation to shipping routes and lanes, pursuant to current regulations, the *Swedish Transport Agency's regulations and general advice on the marking at sea with maritime safety* *devices* (TSFS 2017:66). The wind turbines may also be equipped with radar, mist and fog horns and automatic identification systems. In addition, a dialogue will be held with the relevant authorities on the necessary safety-enhancing measures.

3.2.2. *Hydrogen production*

Hydrogen production in a hydrogen plant converts electrical energy from the wind turbines into hydrogen, see outline diagram in Figure 6.

The electricity produced by the wind turbines drives electrolysers that split water (H_2O) into hydrogen (H_2) and oxygen (O). The chemical splitting process uses desalinated seawater, which requires desalination systems. The hydrogen produced can be used for industrial purposes or in the transport sector.

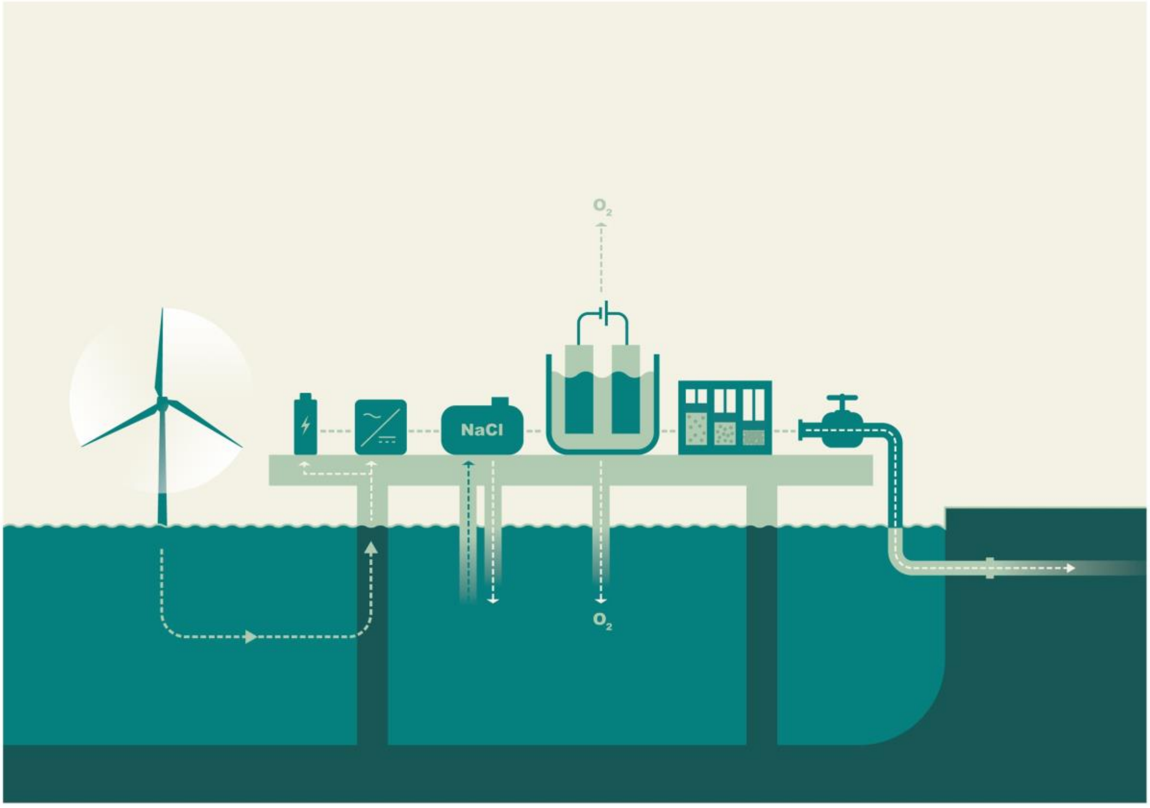


Figure 6. The different parts that are generally required to produce hydrogen. Illustrator: Nina Fylkegård

There are currently several different technologies that use electricity to produce hydrogen that are summarised in Table 1.

Table 1. Techniques for using electricity to produce hydrogen.

Technique	Benefit	Disadvantage
PEM (Polymer Electrolyte Membrane)	The production/load can be changed within seconds. High pressure from the electrolysers. Wide working area. Suits wind turbines' variable production.	Not as proven as alkaline water electrolysis.
Alkaline electrolysis	Proven and established technique.	Caustic soda is used. Low pressure.
SOEC (Solid oxide electrolyser cell)	Unknown	Insufficient knowledge of the technique at present.
AEM (Anion exchange membrane)	Unknown	Insufficient knowledge of the technique at present.

Hydrogen production using PEM electrolysers has at this consultation stage been considered to be the most suitable technology to investigate further, partly because it suits wind power's variable production. Hydrogen is then produced using electrolysis, either directly on the respective wind turbine foundations (decentralised hydrogen production) or on specific platforms within the farm (centralized hydrogen production) depending on the concept. See these two concepts illustrated in Figure 7.

Electrolysis can also take place in a facility onshore. This is not currently being investigated for the Neptunus energy farm, but the option is not excluded in view of potential future technological developments.

When hydrogen is produced by an electrolyser at sea, oxygen, cooling water and brine are produced in addition to hydrogen. The volumes of hydrogen, oxygen, cooling water and brine listed below are based on a maximum scenario where 100 percent of the wind turbines' capacity is used to produce hydrogen. The energy farm is likely to produce a combination of electricity and hydrogen, and the volumes of hydrogen, oxygen, cooling water and brine will then be smaller than the scenario with maximum hydrogen production.

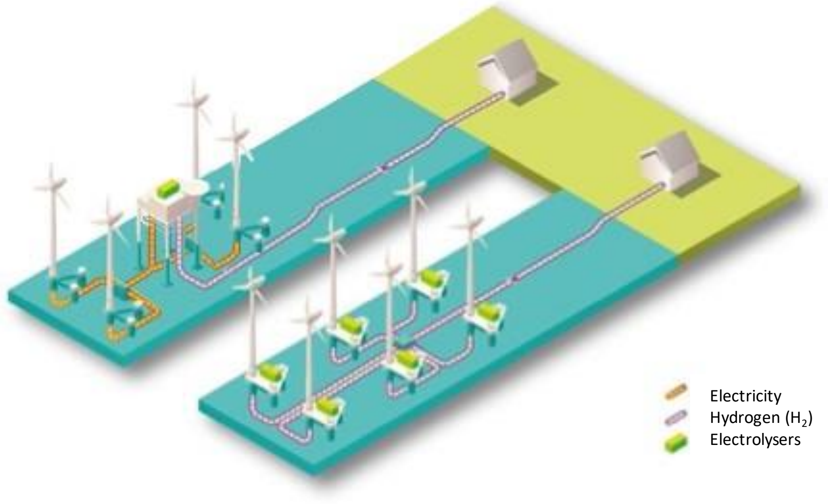


Figure 7. A schematic concept diagram linked to centralised hydrogen production as well as to decentralised production. Illustrator: Nina Fylkegård

Decentralised hydrogen production

Production of hydrogen using electrolysers on each wind turbine is called decentralised hydrogen production. The solution is the most energy-efficient way of producing hydrogen, but it is also a technology under development. Hydrogen from each wind turbine is led via an internal pipeline system, within the project area, to a collector station/compressor station or several connection pipelines that transport the hydrogen to shore where it can be stored, transferred via a gas network, converted to e-fuel, etc. In decentralised hydrogen production with its associated compressors, electrolysers and in internal pipeline networks within the energy farm, a maximum of 100 tonnes of hydrogen will be in the system at the same time. In addition, a buffer tank containing 100 tonnes of hydrogen gas may be needed in connection with the compressor station. The hydrogen is transported from the compressor station via export pipelines onto the shore. The export pipelines themselves contain approximately 100 tonnes of hydrogen. Decentralised hydrogen production means a maximum storage volume within the project area of approximately 300 tonnes of hydrogen.

Centralised hydrogen production

Production of hydrogen on stand-alone platforms within the farm area is called centralised hydrogen production. The electricity from the wind turbines is transferred via the inter-array cables (AC cables) to one or more platforms within the farm area where the hydrogen

production takes place.
The platforms together then comprise a larger system of electrolysers that can receive energy from multiple wind turbines, hence the name of centralised hydrogen production.
The platforms will also contain all auxiliary systems for hydrogen production, such as a compressor station, which can then also contain a buffer tank for approximately 100 tonnes of hydrogen. The hydrogen is transported from the platform via export pipelines onto the shore. The export pipelines themselves contain approximately 100 tonnes of hydrogen. Centralised hydrogen production contains a maximum storage volume within area of approximately 200 tonnes of hydrogen.

3.2.2.1. Other things created by the hydrogen production

Hydrogen production also produces salt water, called brine, oxygen from the electrolysers and cooling water from the process. These are described below in brief. It should also be added that the levels indicated below will vary depending on the size of the share of electricity that is used for hydrogen production. The values given below are based on a maximum design where 100 percent of the electricity produced is converted into hydrogen.

Brine

Desalinated seawater is used to split the molecules. The annual amount of sea water that the system needs to use is up to 7.4 million tonnes, provided that 100% of the electricity is converted into hydrogen. Sea water needs to be desalinated before it can be used to split the molecules. At desalination, part of the intake seawater is desalinated by concentrating all the salt into the other part of the seawater intake. This desalinates the first part of the sea water. The second part of the seawater intake will have a higher concentration of salt than it had at intake and is called brine. Most desalination plants for electrolysis in today’s market produce 45-65 percent desalinated water and 35-55 percent brine. A lower percentage of brine means that the brine will be saltier, a higher percentage means that the brine will be less salt. The sites where the seawater is taken in (depth and location) and where the brine is released can be chosen to create the most optimal conditions for the environment.

Oxygen

Oxygen is formed when water molecules are split. Up to 3 million tonnes of oxygen is produced from the electrolysers per year, assuming that 100% of the electricity is converted into hydrogen. OX2 is currently investigating, together with IVL Svenska Miljöinstitutet, the conditions for combining hydrogen production with an oxygenation stage, where oxygenated water or oxygen gas is diverted to bottom waters. The oxygen can be used to oxygenate the

Baltic Sea’s oxygen-poor bottom water, which can bind phosphorus but also contribute to the re-colonization of demersal animals, which in turn could stimulate fish production, see also section 4.6.2. Alternatively, the oxygen can be released into free air or transported to other potential applications in industry and hospitals. No storage of oxygen, beyond the 800 tonnes that are accommodated in the internal pipeline network, is planned for the operations.

Cooling water

Cooling water is used to keep the system at an optimal operating temperature, mainly the electrolysers. Up to 850 million cubic metres of water per year could be extracted from the sea to cool, for example, the electrolysers (at maximum hydrogen production) via a closed circuit heat exchanger. The cooling process heats the coolant water up and the outgoing coolant water is estimated as having a temperature approximately 15 °C higher than the intake water. Other technologies are also being investigated, such as air cooling via cooling towers, as well as the possibility of reusing the heated coolant water in the desalination process, thereby also increasing the overall efficiency of the system.

3.2.3. *Foundation*

Foundations will be needed at the Neptunus energy farm to attach platforms and wind turbines to the seabed. The choice of foundations depends on a number of factors: Primary water depth, geology, wind and wave conditions, and environmental considerations and costs. As both water depth and geological conditions vary within the energy farm, different types of fixed or floating foundations may be considered in different combinations. The foundation types and installation procedure for hydrogen production and transformer/inverter platforms are similar to those for the wind turbines, but are dimensioned with respect to the loads resulting from the platform’s needs. Based on the geological conditions at the site and the technology available today, both fixed and bottom-solid and semi-submersible floating foundations are relevant for Neptune. The rapid developments in technology mean that other types of foundations may also become appropriate. The following is a brief account of the different types of fixed and floating foundations that are deemed to be relevant.

3.2.3.1. Seabed foundations

Fixed foundations consist of three main parts; A part that secures the foundation in or on the seabed, a part to elevate above the surface of the water and a so-called transition piece that forms the transition between the foundation and the tower to ensure that the tower stands vertically. In connection with the foundations, erosion protection is provided on the seabed to protect the foundation from the formation of erosion holes around the foundation. The need for erosion protection varies depending on waves, currents and the type of bottom sediment at the site. The most common type of erosion protection consists of layers of rock, gravel and sand in varying sizes that are laid around the base of the foundations.

Of the seabed foundations, monopiles and jacket foundations with piles are mainly relevant for the Neptunus energy farm, see illustrations in Figure 8 and Figure 9. The technology is in rapid development so it is possible that other types of foundations may be used. Piling and/or drilling anchors the foundations are anchored to the seabed. Foundations that are fixed to the seabed may also use so-called suction buckets.

Figure 8. Monopile foundation. Illustration COWI

Figure 9. Jacket foundation Illustration COWI

3.2.3.2. Floating foundations

A technology that is under development and is expected to be undergo rapid development in the near future, is that of floating foundations. The technology enables installations at greater depths of water than the traditional seabed foundations.

There are various variants of floating foundations, which can be divided into four categories. Spar, barge and semi-submersible floating are three variants of large foundations that are anchored to the seabed by means of long chains or tie-rods that are moored in some form by anchors. The fourth variant, tension leg platform, has a smaller platform and is anchored to the seabed with vertical running lines. This technology requires very strong tethering lines and a solid anchorage device on the seabed. See floating foundations illustrated in Figure 10.

Of the floating foundation solutions, semi-submersible foundations are currently considered to be most suitable for Neptunus, but neither spar and tension leg can be excluded.

All floating foundations need to be anchored to the seabed using long guy lines/chains. One anchorage line on each turbine is equipped with an “in-line tensioner” in order to adjust the tension on the anchorage line. Tethering solutions that use an anchor that needs to be slightly buried in the seabed for attachment place higher demands on bottom conditions. Gravity anchoring is the technology that is least dependent on the bottom conditions, but the disadvantage of this variant is that it requires extensive use of materials for its manufacture. If necessary, erosion protection is provided around the anchor points. Anchoring with piles often requires pile driving, which generates underwater noise.

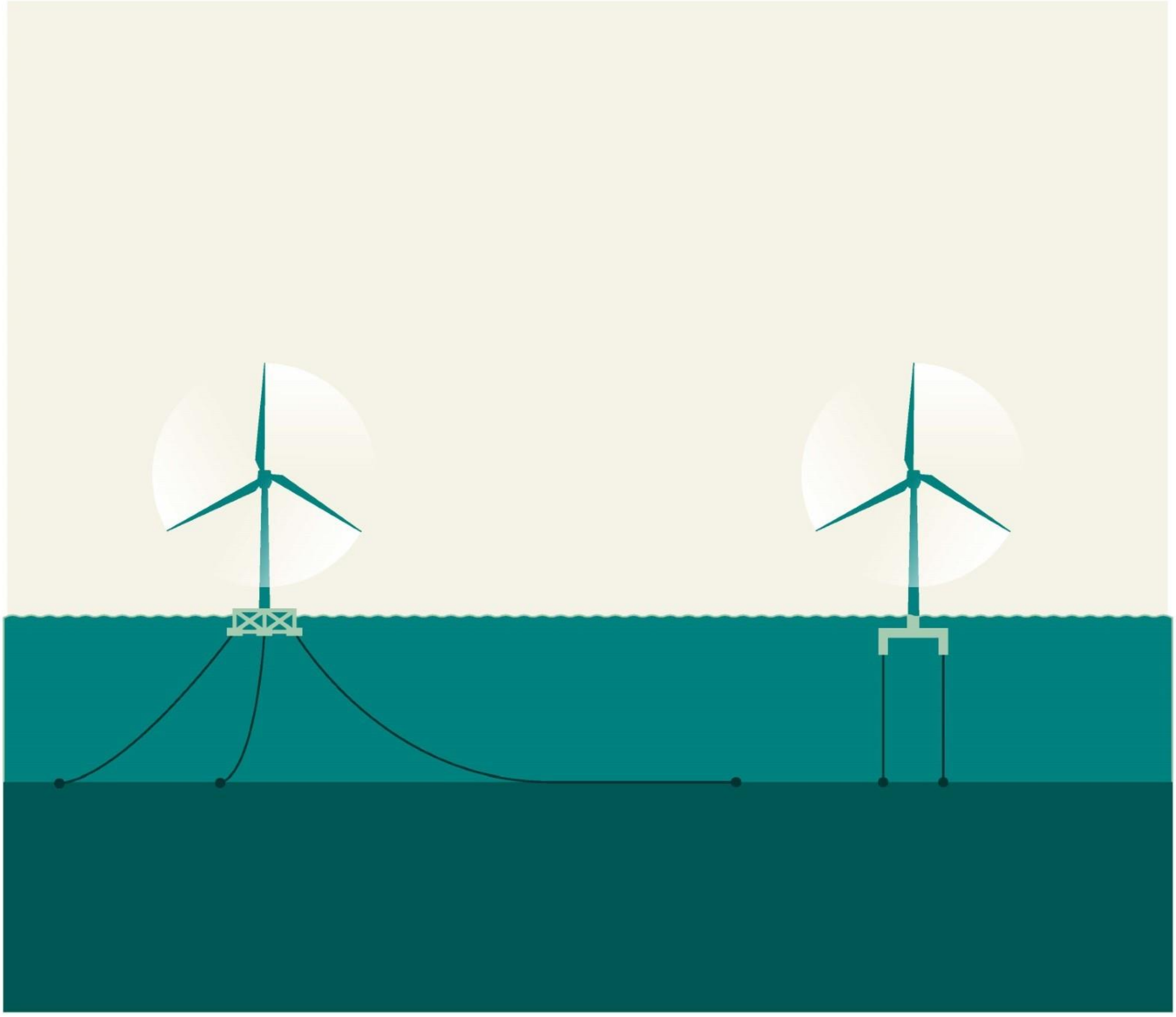


Figure 10. On the left side of the figure is a semi-submersible floating foundation with long anchor lines to the seabed. To the right of the figure is the tension leg platform variant that is anchored to the bottom with vertical tie down lines. Illustrator: Tobias Green.

3.2.4. *Inter-array network and internal pipeline network*

The inter-array cables connect the wind turbines to the transformer/inverter stations by connecting individual wind turbines in groups (so-called radials), which in their turn are then connected to the respective transformer/inverter stations.

For example, based on the cabling technology available today the inter-array cables can consist of 66 kV cables, which can carry a combined power of around 80 – 90 MW per radial. This means that five 15 megawatt wind turbines can be connected along the same radial. However, the voltage level of inter-array cables is expected to rise to approximately 170 kilovolt in the next few years. This would increase the total transmission capacity of each cable, thus reducing the number of radials and thereby the total length of cables. In addition to the cables connecting the wind turbines, additional cables may be established within the energy farm to provide redundancy in the system and power supply to any platforms.

In contrast to seabed fixed foundations, the inter-array cables for floating foundations consist two types of cable, dynamic and static cables. The dynamic cable is a loose hanging part of the cable between the floating foundation and the seabed. Due to the movement of the floating foundations, the connecting cables need to be designed to accommodate such movement. The cable usually has a “lazy wave” design which allows it to be shaped and moved in harmony with the foundation, see Figure 11. The dynamic cable usually connects to a static cable on the seabed that can, for example, be buried in the seabed for protection, see Figure 12. In turn, that connects to a seabed transformer station.

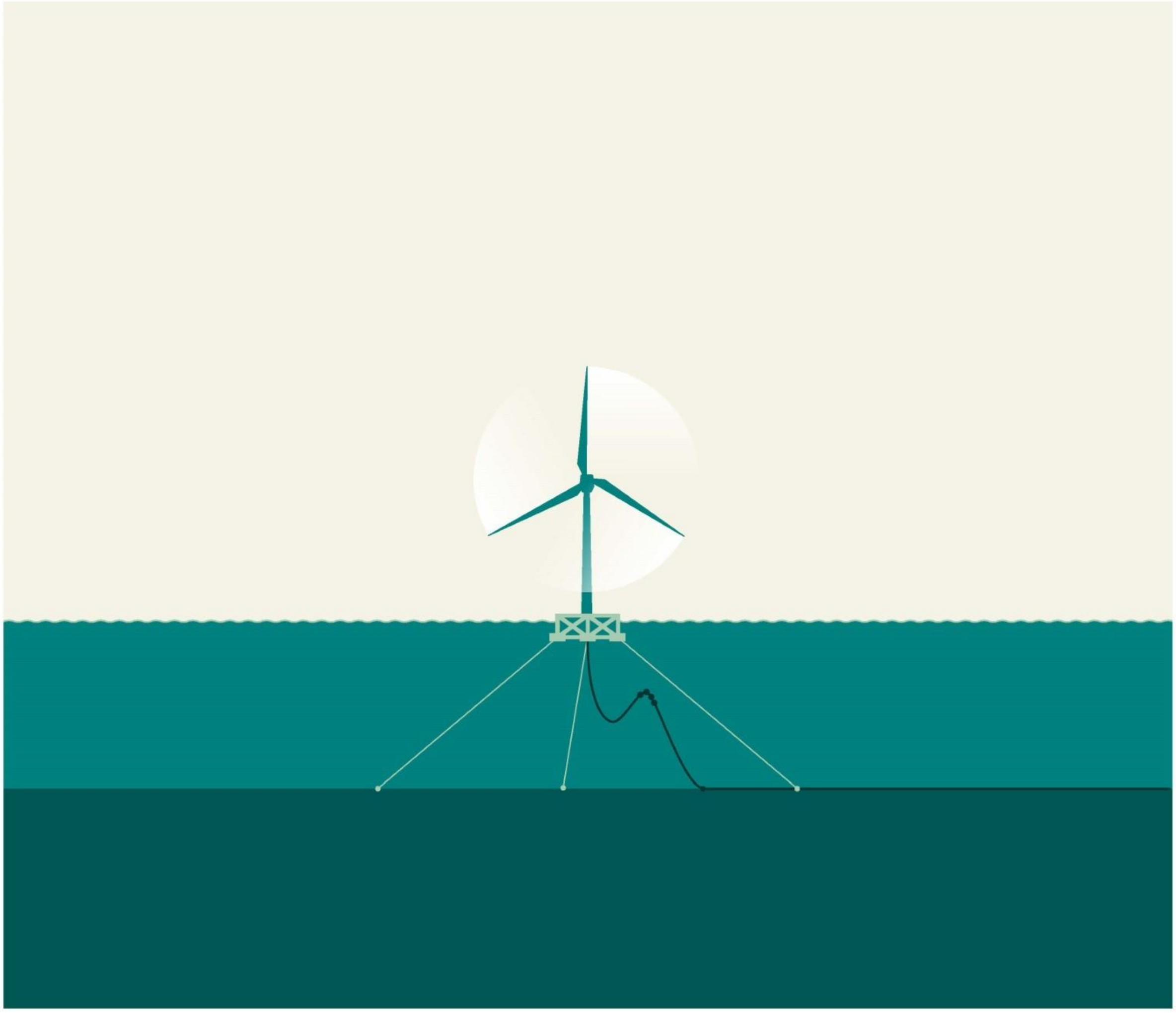


Figure 11. Floating foundation connected with a dynamic cable to accommodate the movement of the foundation. Illustrator: Tobias Green.

Figure 12. Top view showing how the turbines with associated anchorage lines are connected via the inter-array cables. Illustrator: Tobias Green.

If the foundations of the wind turbines include decentralised production of hydrogen, an internal hydrogen pipeline network will be needed. The pipelines connect the wind turbines either in radials or in star formations to a collector station that connects all of the pipelines and compresses the hydrogen, making it at a higher pressure. The collector station can be placed on wind turbine foundation, a separate platform or on the seabed. The internal pipeline may follow the same routing as the inter-array. The exact routing is currently under further consideration.

3.2.5. *Platforms*

Up to 12 platforms are planned to be built at the energy farm site. These will include transformer/inverter stations, so-called offshore substations (OSS), to which the electricity produced by the wind turbines is routed via the inter-array. The transformer/inverter station contains electrical equipment, including transformers that transform the voltage from the internal cable internal cables to higher voltages. If the shore connection is made with direct current, inverters are also included as part of the electrical equipment. These stations are usually referred to as inverter stations.

The transformer/inverter station is a platform with one or more decks, sometimes with a landing pad for helicopters. The platforms are prefabricated and installed in modules on one or more foundations.

If hydrogen production is carried out according to the decentralised concept, a collector/compressor station may be needed to connect the internal pipeline network together and possibly increase the gas pressure. The collector/compressor station may need its own platform. If hydrogen production takes place according to the centralised concept, specific platforms will also be needed for hydrogen production. A large system of electrolysers will be installed on these platforms. See Figure 13 for some examples of how the platforms and foundations can be designed.

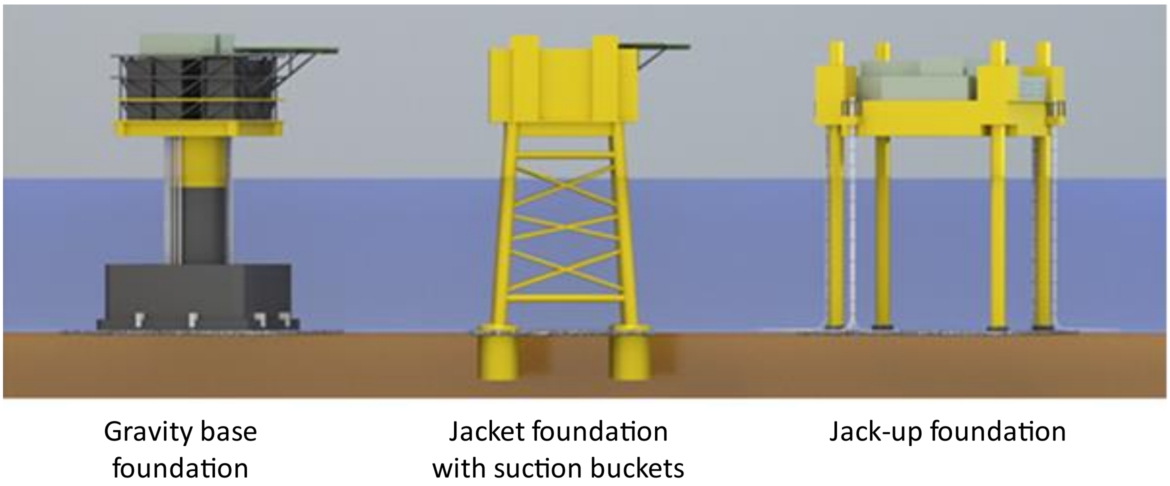


Figure 13. Examples of offshore platforms stations and their foundations. Jacket foundations are specialised foundations.

The exact number, design and location of the platforms will be determined during the energy farm’s detailed engineering process, based on the size and number of turbines, seabed conditions and optimal cable routing. The platforms will be marked in accordance with the applicable regulations for marine and air traffic.

3.2.6. *Measurement of meteorological parameters with a met masts or LiDAR*

One or more met masts may be installed to supplement available wind data from the area and form the basis for detailed design and choice of turbines and their layout. A met mast usually has a height roughly corresponding to the hub height of the wind turbine and is installed in the same way as a wind turbine with a foundation anchored to the seabed.

However, the foundation for a met mast is considerably smaller than for a wind turbine. Data from the met masts can also be used to monitor the conditions for different lifts during installation, where there may be requirements for maximum wind speeds, and later for monitoring of the energy farm’s production. Data from met masts can also be used as the basis for load calculations.

A technology that is rapidly developing and has the potential to replace met masts is called LiDAR. LiDAR technology uses lasers to measure wind speeds above sea level and thus does not require a mast. The equipment can be placed either on a fixed foundation or on a floating platform. At present, this measurement technique has not been certified to provide a basis for load determination, but this is expected to be possible in the future.

3.2.7. *Connection cables and connection pipelines*

After electricity and hydrogen have been produced offshore, it will be transported to land via one or more connection corridors consisting of export cables and pipelines. Figure 14 shows possible onshore connection points for the export cables. Transport of hydrogen to land may also take place via operational gas pipelines to neighbouring countries in the Baltic Sea.

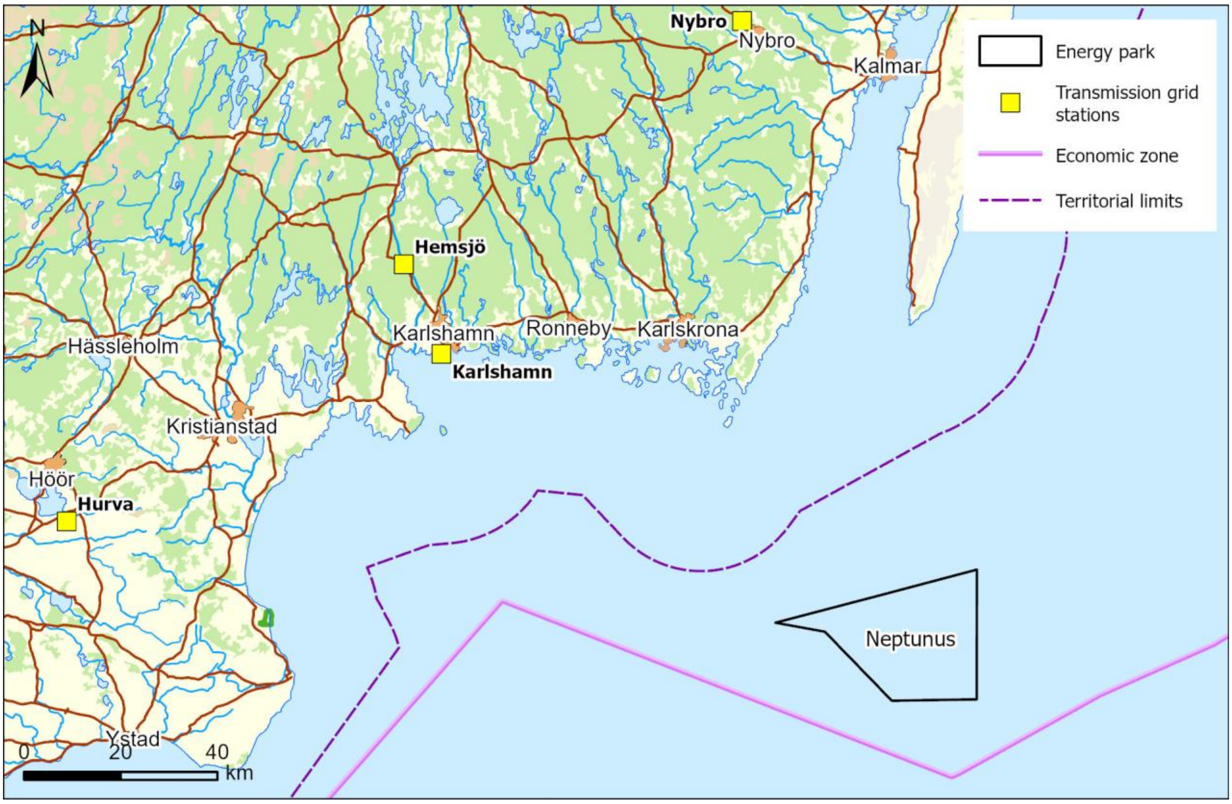


Figure 14. Potential connection points for electricity on land and the Neptunus energy farm. © [National Land Survey] 2023

3.3. Activities in the different phases of the project

This section provides a summary of the activities that take place during the construction, operation and decommissioning phase of the energy farm

The impacts in the Espoo report will be assessed on the basis of the following phases of the project:

- Construction phase
- Operational phase
- Decommissioning phase

3.3.1. *Construction phase:*

3.3.1.1. Construction surveys

Prior to construction of the farm, inter-array and any internal pipelines, site surveys of the seabed conditions will be carried out to study the geology and sediment of the seabed. The purpose of these surveys is to obtain detailed information for final design of foundations and the detailed design of the farm and cable and pipelines, including the exact location of wind turbines. Geophysical studies such as sidescan sonar (SSS) and multibeam echo soundings (MBES) well as various forms of seismic surveys, both 2D and 3D, provide high-resolution bathymetric information about the seabed sediment and its geological composition down to about 80 metres below the seabed. The investigations also provide information about the presence of natural and artificial objects on the seabed and any gas pockets.

Geotechnical surveys include, for example, geotechnical drilling, cone pressure testing and vibrocores, which lead to conclusions on, among other things, load-bearing capacity and therefore design of foundations and provide information for the choice of installation methods. Magnetometry is needed to ensure that construction work can be carried out without risk of, for example, finding mines or other unexploded weapons.

3.3.1.2. Installation

The following is a brief description of how to install a wind farm. It is very common to attempt to conduct installation works continuously during a single season and without interruption for winter.

The planned schedule for installation of the energy farm first installs the foundations, the transformer/inverter stations, hydrogen platforms, including their topside. The export connection to land, the inter-array cables and the internal pipeline network will then be installed. Finally, the wind turbines (including hydrogen components for decentralised hydrogen production) will be assembled with the towers, nacelle and rotor blades. In the case of floating foundations, the wind turbine is installed on the foundation in the assembly port, after which it is towed out to the energy farm and installed on site. Once the turbines have been fully installed, commissioning and operational trials take place before the facility is handed over to the operating organisation after approved tests.

3.3.1.3. Vessel traffic

During installation, the main components of the energy farm (wind turbines, transformer/inverter stations, platforms, meteorological masts, foundations and construction parts for the production, storage and distribution of hydrogen) must be transported to the area, positioned and installed. The main components are shipped out of their respective manufacturing ports and transported either to a final assembly port (a pre-assembly harbour, or directly to the energy farm area.

Daily transportation of personnel and small components takes place from a nearby installation port. In addition to surface vessels, helicopters can also be used for transport.

During the installation of the energy farm, a number of installation vessels and working platforms of various kinds will operate in the area. Usually, several installation stages occur in parallel but in different parts of the project area. A number of support vessels may also be required for equipment and personnel, as well as tugs. All vessel traffic is monitored by a marine coordinator. A safety zone can be established around installation work in progress in order to minimise risks.

For some work, a jack-up vessel or a jack-up platform, may be used, see Figure 15. These vessels lower their legs to rest on the seabed. The vessel's hull or platform itself is raised so that it is well above the highest wave height and therefore no longer affected by wave movements. As an alternative, semi-jack-up vessels can also be used. On semi-jack-up, the hull while the legs are lowered onto the seabed to ensure stability.

Figure 15. Installation of wind turbines by a jack-up vessel. Source: COWI

In addition to the above-mentioned vessels, additional special vessels may operate in the area, for example for various construction surveys or emergency operations. During construction there may also be one or more smaller boats that protect the installation area from other traffic.

3.3.1.4. Installation of foundations

Monopile foundations are floated out to the energy farm or transported on board an installation vessel or a barge. Monopile foundations are placed on the seabed, either from a jack-up platform or floating crane vessel. They are then driven down into the seabed by pile-driving, vibration-driving or drilling. Depending on the nature of the seabed, installation can take place using a combination of these methods.

Jacket foundations require the seabed to be relatively flat, which means that levelling may be required prior to installation. The foundation is transported to the site by a barge or installation vessel and placed on the seabed by a jack-up platform or crane ship. If pin piles are used the steel pipes are driven, vibrated or drilled into the seabed at the respective corners of the foundation. The pin piles are then attached to the foundation by concreting them together or by mechanical tethering. If geology and other conditions make it possible, jacket foundations can be anchored to the seabed using a suction caisson, a steel or concrete cylinder that is sucked into the seabed by means of a vacuum.

Floating foundations are towed out to the site, usually with a fully assembled turbine. The foundation is anchored in place using the same basic principles as for seabed foundations, except that different forms of buried anchors can be used.

3.3.1.5. Inter-array network and internal pipeline network

Before installation, preparatory work is carried out to ensure safe and unimpeded laying and installation of inter-array cables and internal pipelines. The preparatory work includes clearing rocks and boulders on the seabed and removing foreign objects on the seabed such fishing nets, lines, etc. Clearing involves a certain penetration of the seabed. There may also be levelling of the seabed if there are sand dunes or other unavoidable, easily-moved seabed features, or in places where the bed is steep.

Internal pipelines and cables rolled up on large coils, are transported to the project area by special installation vessels. The cables and pipelines are laid on the seabed and then usually buried to a depth of between one to three metres below the seabed to protect the from damage from fishing gear, anchors, etc. When cables or pipelines are placed under the surface of the seabed, they can be protected by covering them with, for example, stone or concrete structures or by laying them in pipes.

If a cable or pipeline needs to cross an existing cable, pipeline or other existing infrastructure, both the existing and the new networks must be protected. The protection can consist of concrete mattresses, steel or concrete bridges, for example. The details of the intersection are set out in a cross-compliance agreement developed by the cable and/or pipeline owners.

3.3.1.6. Wind turbines

The main components of the wind turbines may be transported to the energy farm by the installation vessel or by a separate transport vessel. The components can be transported directly from a port near the wind turbine manufacturer or from an installation port. The various components are then installed using a crane, normally in a single day if weather conditions permit.

Installation of wind turbines with fixed foundations will probably take place in parts out at sea. Installation of wind turbines requires high precision and is therefore restricted by wave and wind conditions. Once the wind turbines have been installed, the components can be connected to the inter-array or to the internal pipeline network (for decentralised hydrogen production), as the wind turbines are tested.

In the case of floating foundations, the wind turbine is installed on the foundation in the assembly port, after which it is towed out to the energy farm. Port installation minimises the impact of such factors as wave and wind conditions.

3.3.1.7. Electrolysers

Electrolysers for hydrogen production will either be installed directly on the foundations of the wind turbines, at junctions or on separate platforms. Installation directly on the foundations of the wind turbines will be carried out after the turbine has been fully assembled.

Hydrogen production platforms are similar on the outside to transformer/inverter station platforms, although possibly larger. Due to the fact that the weight and surface requirements of the electrolysers are greater than those of the corresponding platforms, it is probably more appropriate to use larger platforms for hydrogen production in order to reduce the number of individual platforms in the farm.

Once installed, either on the foundations or platforms, the electrolysers are connected to the internal pipelines.

3.3.1.8. Transformer/inverter stations

A transformer/inverter station is normally installed on its base using a crane vessel. Depending on how the transformer/inverter stations and their foundations are designed, they can also be floating out or installed using other lifting methods, for example with their own legs. Alternatively, the foundation may be built first, after which the superstructure is lifted into place. When the transformer/inverter station has been installed, the inter-array electrical cables are connected to the station.

3.3.2. *Operational phase*

Wind turbines, transformer/inverter stations and plant components for the production, storage and distribution of hydrogen are remotely monitored and unmanned during normal operation. However, continual maintenance takes place at the energy farm, which requires personnel and materials to be transported there by supply vessel, ship or helicopter. Alternatively, transport takes place to a designated platform platform and from there to within the farm. Cables and pipelines are inspected as necessary to ensure, for example, that their protection at the base of the wind turbine is unchanged. If a cable is damaged it can be repaired by the damaged cable section being lifted by a cable-vessel to carry out the repair work, and then replaced onto the seabed using the same method as during the construction phase. In order to protect cables and pipelines from damage, bottom trawling would not be permitted within the project area.

The final operating and maintenance strategy will be determined at a later stage. An onshore operation and service base is likely to be established. It is likely that operations will be carried out by Crew Transfer Vessels or by Service Operation Vessels. Jack-up vessels may be used for more extensive maintenance operations, for example where large components need to be replaced.

3.3.3. *Decommissioning phase*

The energy farm is expected to have reached the end of its service life after 45 years’ service, after which it will be phased out. Decommissioning will be carried out in accordance with the practice and legislation in force at the time of decommissioning. Wind turbines, foundations, transformer/inverter stations and plant components for the production, storage and distribution of hydrogen will be dismantled and foundation sites will be restored to the legally required extent.

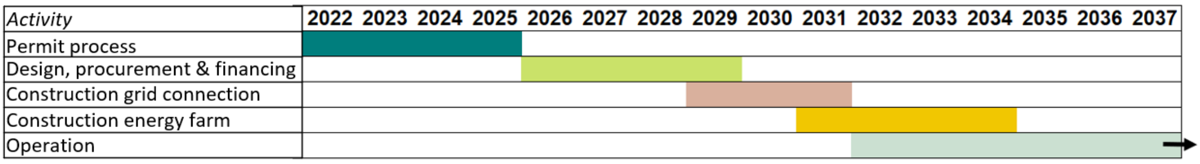
In general, the farm components will be dismantled unless the removal of these individual structures has a greater environmental impact than that of leaving them in place. As the technology and knowledge situation is changing rapidly, detailed energy farm decommissioning will be suitably planned in consultation with the regulatory authority.

It is likely that the structures above the seabed surface will be decommissioned. For example, monopile or jacket foundations can be cut a few metres below the sea floor and the upper part lifted off. Floating foundations and associated wind turbines will be detached from their anchor lines/chains and then towed to port for recycling/scrapping. Some farm parts may be left behind after decommissioning, such as inter-array cabling and internal pipelines.

One reason for leaving some structures behind is that these may have become valuable artificial reefs. If it is necessary to remove cables and/or pipelines they will be released from the seabed and lifted to the surface. Rock used to cover cables and/or pipelines is likely to be left on the seabed, as well as the protection used at intersections. During decommissioning, a temporary safety zone will be established around the location of activities to protect personnel, equipment and safety for third parties.

3.4. Preliminary schedule

The preliminary schedule for the project is presented in Figure 16. The schedule should be considered to be general and preliminary. Several factors may affect the schedule, which may require adjustment during the course of the project. The complete development of the energy farm is expected to take up to six years.



Activity	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Permit process	■	■	■	■												
Design, procurement & financing					■	■	■	■								
Construction grid connection								■	■	■						
Construction energy farm										■	■	■	■			
Operation											■	■	■	■	■	■ →

Figure 16. Preliminary project schedule.

4. Area description

4.1. Geology and depth conditions

The bottom substrate of the Neptunus site is dominated by clay and a mixture of sand, coarse sand, smaller rocks and gravel, see the geology within the energy farm in Figure 17. The deeper layers are dominated by post-glacial and glacial clay. The water depth in the area varies between 50–80 metres with an average depth of 67 metres, see Figure 18.

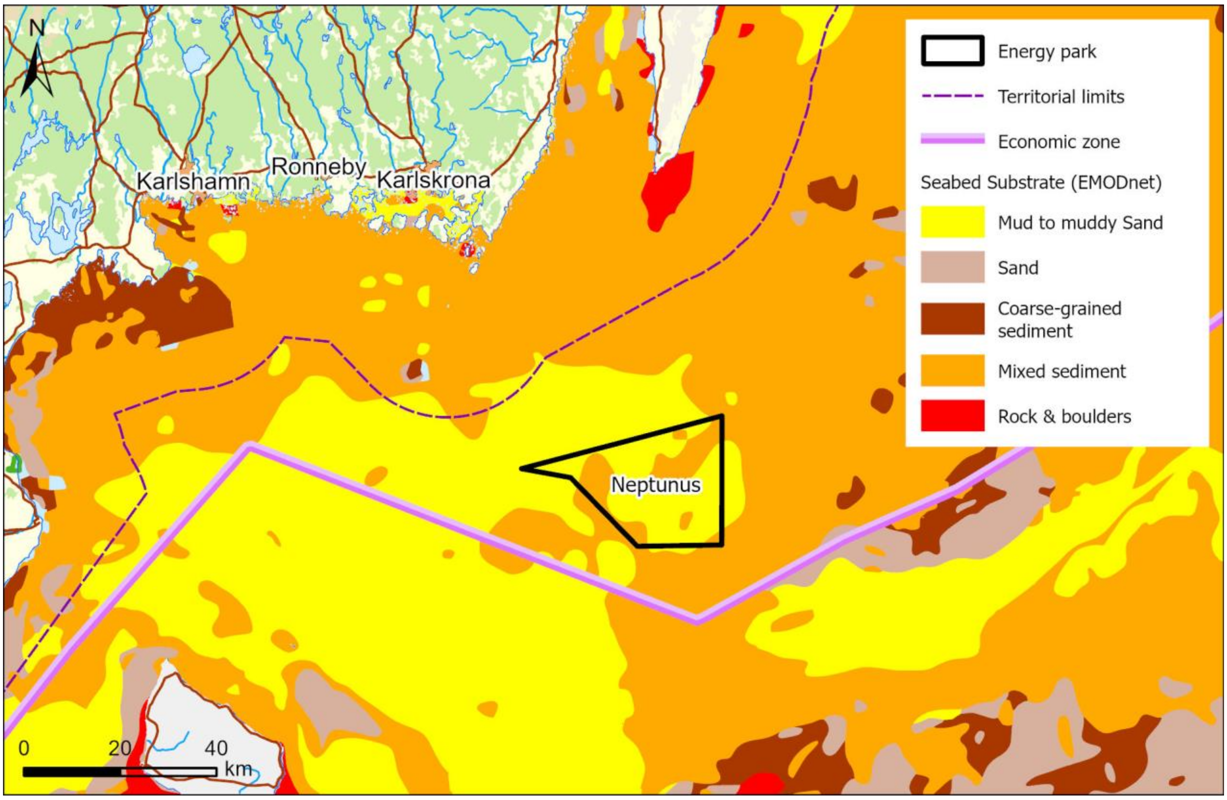


Figure 17. Map of the geology of Neptunus. © [National Land Survey] 2023, [Document: EMODnet] 2022

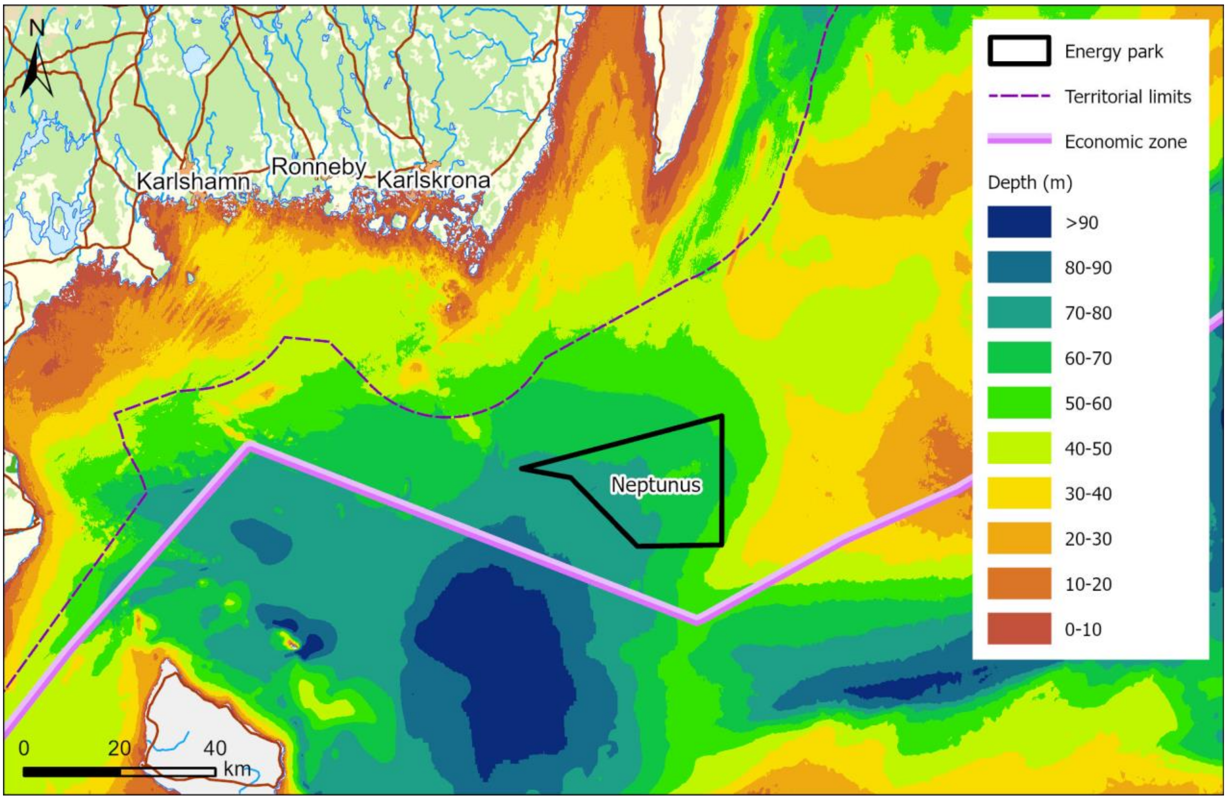


Figure 18. Map of depth conditions within Neptunus.. Water depth is given in metres.. © [National Land Survey] 2023, [Document: EMODnet] 2022

4.2. Meteorology

The average wind speed at the wind farm location is estimated to be about 9.5 metres a second at 100 metres above sea level (NEWA).

4.3. Hydrography

Like the wind, the wave climate is dominated by waves from the west and south-west, which is also the direction giving the largest waves. The average significant wave height is about 1.1 metres (CMEMS, 2020).

In parts of the Baltic Proper, it is expected that the oxygen levels in the bottom water will be low and relatively stable throughout the year. The oxygen content in the Neptunus project area tends to vary over time, and temporary improvements observed are correlated to inflow of water from the Kattegat. Inflows occur irregularly and are of varying volume. According to SMHI’s maps of the spread of anaerobic sea bottoms, defined as $O_2 < 0$ ml/l, and oxygen-poor bottoms, defined as $O_2 < 2$ ml/l, during the years 2019 and 2020 there were oxygen-poor bottoms within Neptunus. In 2021, oxygen-poor bottoms are reported to have increased in the Bornholm Basin compared to the previous year, which also show in oxygen-poor areas in the western part of the Neptunus energy farm (SMHI, 2021). See the oxygen situation in and

around Neptunus in Figure 19.
In 2018 there were both anaerobic and oxygen-poor bottoms, with the anaerobic bottoms being found in the western part of the farm site. It is clear from annual reports from the Swedish Meteorological and Hydrological Institute that the area has been affected by poor oxygen conditions for several years (SMHI, 2019; SLU ArtDatabanken, 2020).

During surveys at the Neptunus site carried out by AquaBiota Consulting in March and August 2021, and in June and August 2022, oxygen-poor water was observed at a depth of approximately 60 metres and anaerobic water at a depth of between 65 and 70 metres. These measurements are in line with SMHI's (2021) surveys of the Bornholm Basin in 2021. However, AquaBiota's studies show a greater spread of anaerobic seabed in the farm area.

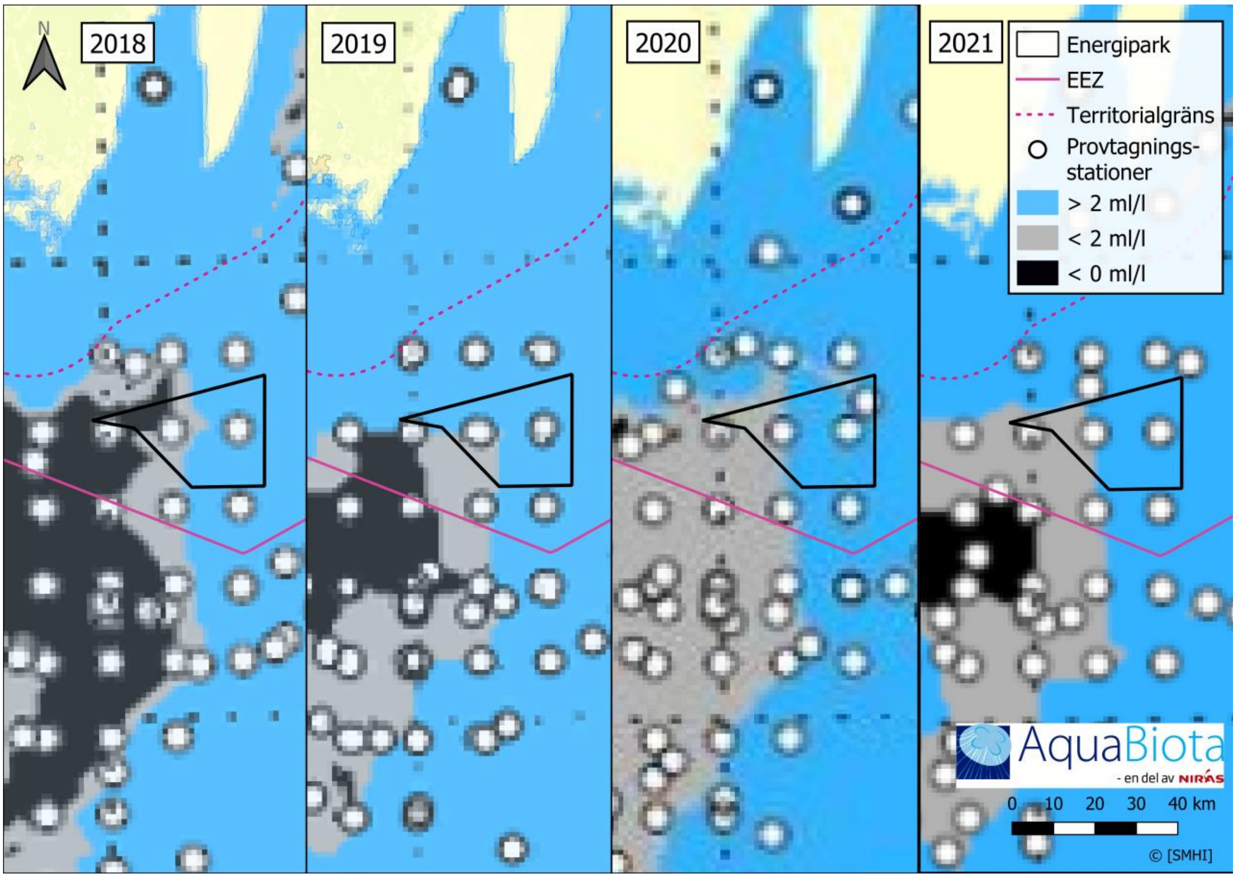


Figure 19. The oxygen situation in and around the Neptunus energy farm during the years 2018-2021. The situation improved in 2020 as a result of new inflows of oxygen-rich salt water in 2019, however, conditions deteriorated slightly again in 2021 (SMHI 2019a, 2020, 2021).

Sea ice can occur in winters when temperatures fall below -5 to -10 °C. The thickness of the ice depends on the salinity of the surface layer, which is around seven parts per thousand in and near the energy farm areas. SMHI's maximum ice spread maps show no years with ice in the Neptunus area over the last 20 years (SMHI, 2022b).

4.4. Natura 2000

The eastern side of Neptunus borders on a Natura 2000 area, the Hoburgs bank and Midsjöbankarna, which have been designated as a protected area under the EU Species and Habitats Directive (SCI) and Birds Directive (SPA), see Figure 20.

4.4.1. *General description*

The Natura 2000 area covers an area of approximately 1,051,000 hectares and is designated for porpoises from the Baltic Sea population (*Phocoena Phocoena),* Long-tailed ducks *(Clangula hyemalis)* and black guillemots *(Cepphus Grylle*) as well as for the nature types reef (1170) and sandbanks (1110). Depths in the area range from 17– 80 metres with shallow waters at the offshore banks. An offshore bank is a shallow marine area surrounded by deeper waters.

The Hoburgs bank and Midsjöbankarna Natura 2000 area occupies a central position in the Baltic Proper and includes two offshore banks, Hoburg Bank and Norra Midsjöbanken (Figure 20). The southern banks, Södra Midsjöbanken and Ölands southern bank border on, but are not part of, the Natura 2000 area. However, Södra Midsjöbanken is important to the species that have been designated for the local nature types. Ölands southern bank, which consists of a small offshore bank, also contributes to the designated values for the Natura 2000 area. The offshore banks consist of a mosaic of shallow sand banks and reefs. The area also includes the deep areas with sedimentary seabed located between the banks. The closest offshore bank, Norra Midsjöbanken, is located over 20 kilometres north-east of the farm area. An extended Natura 2000 area is also being considered for Södra Midsjöbanken.

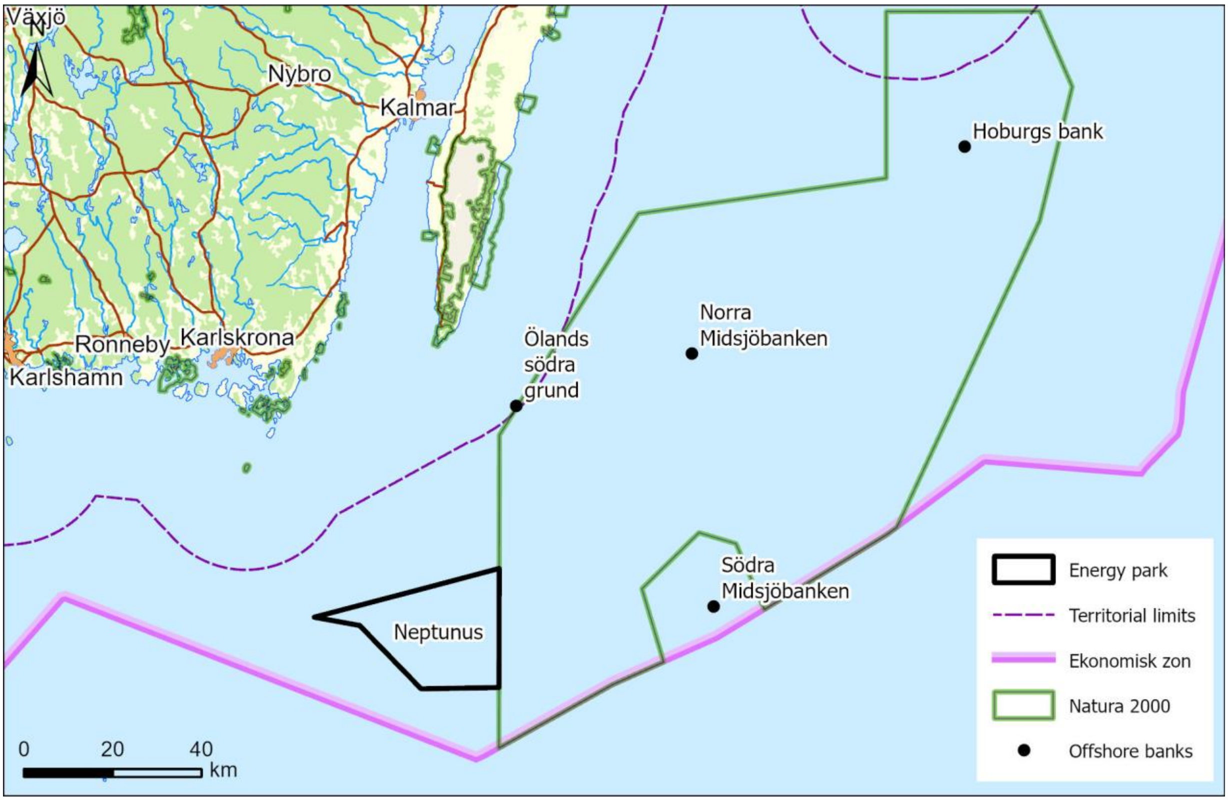


Figure 20. View of the location of the Neptunus energy farm in the Baltic Proper and bordering Natura 2000 areas. © [National Land Survey] 2023, [Document: Environmental Protection Agency, County Administrative Board] 2022

The Natura 2000 area conservation plan points out that the offshore banks provide very good conditions for many animal and plant species (Länsstyrelsen, 2021). There is a high level of water circulation and environmental toxins, eutrophication and human impact that have affected much of the Baltic Sea coast have less effect far from land. The designated offshore banks can therefore contribute to the conservation and improvement of plant and animal life and the environment throughout the region. The offshore banks are important breeding and nursery areas for fish and seabirds and together they constitute the most important wintering area in the Baltic Sea for long-tailed ducks (*Clangula hyemalis)* and the core area for the Baltic Sea population of porpoises *(Phocoena Phocoena)*.

Table 2 shows the designated nature types and species in the area and the factors that, according to the conservation plan, could potentially adversely affect the area and are of relevance to the Neptunus energy farm.

Table 2. Identified nature types and species at Hoburgs bank and Midsjöbankarna, as well as factors that potentially can have a negative affecting on the area.

Natura 2000 area	Designated marine nature types	Designated marine species	Factors that could potentially have a negative impact on the site according to the conservation plan.
Hoburgs bank and Midsjöbankarna (SE0330308)	Sublittoral sandbanks and reefs	Porpoises from the Baltic Sea population (critically endangered), overwintering long-tailed ducks (severely endangered), black guillemots (near threatened)	Impulse sound, continuous sound, sonar, or sonars that overlap the frequencies used by porpoises for echo localisation. Offshore wind farms. Sediment clouding caused by vessel traffic. Displacement of black guillemots and long-tailed ducks from important wintering areas. Cable laying that can damage designated natural types. Climate change.

The Natura 2000 site has a relatively homogeneous demersal environment, with a few dominant species of algae and animals, which is natural for the Baltic Sea. The offshore banks are made up of large areas with blue mussel banks and vegetation-clad bottoms that fulfil important ecological functions. The offshore banks are also potentially important foraging areas for the two seal species, the common seal (*Phoca vitulina)* and the grey seal (*Halichoerus grypus)*. The offshore banks are also feeding and breeding areas for several fish species.

4.4.2. *Natura 2000 sites belonging to other countries*

Natura 2000 sites belonging to the countries around the Baltic Sea (with the exception of the Russian Kaliningrad Oblast) are located both offshore and along the coasts of the various countries, see Figure 21. The Natura 2000 sites of the Baltic Sea countries closest to the planned wind farm are Ławica Słupska (Poland), about 50 kilometres south of the energy farm, and the Erteholmene (Denmark) islands , about 60 kilometres south-west of the energy park. Other Natura 2000 sites belonging to the Baltic Sea countries are located at a greater distance from the wind farm.

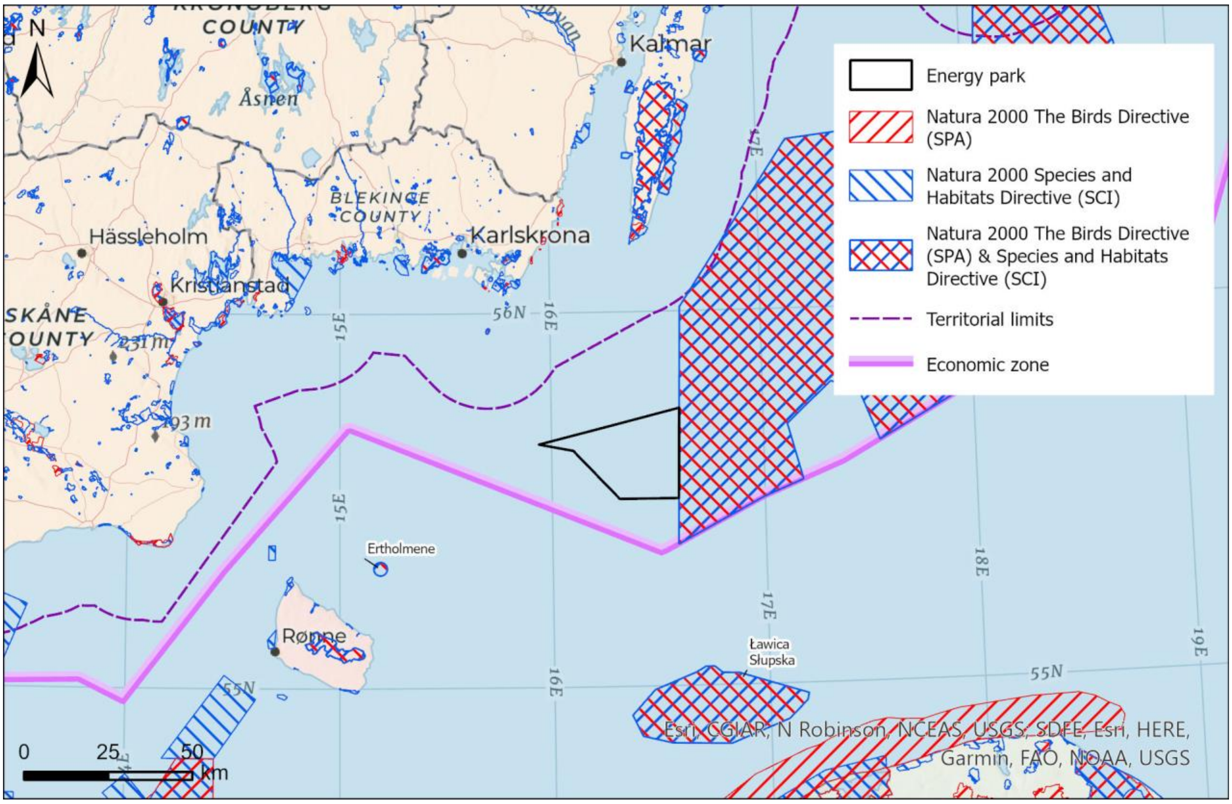


Figure 21. Natura 2000 sites belonging to Baltic Sea countries. [documentation: European Environment Agency (EEA] 2022

4.5. Natural environment

4.5.1. *Bottom flora and bottom fauna*

The bottom substrate of the the Neptunus energy farm site is dominated by clay and a mixture of sand, coarse sand, smaller rocks and gravel. Because the Baltic Sea is a brackish water sea, with relatively low salinity in both surface and bottom water, biodiversity is relatively low. Salinity is a stress factor for both marine and freshwater species, which means that few species are adapted to live in these areas. Biodiversity declines with reduced salinity as a result of the reduced number of marine species that can live in such areas. Furthermore, the demersal fauna is expected to be dominated by animals that live buried in the sediment, so-called infauna, because the bottom substrate is mostly made up of soft and sandy bottoms. See Table 3 for examples of infauna at Neptunus. According to modelling by Gogina et al. (2016), the population density in the area is mainly dominated by the segmented worms (*Bylgides sarsi*) and crayfish (*Pontoporeia femorata*).

Table 3 Typical infauna of the seabed within Neptunus (DHI, 2016; Gogina, et al., 2016).

Typical infauna within Neptunus	
Baltic macoma	(*Limecola balthica*)
The northern astarte	(*Astarte borealis*)
Saduria entoman	(*Saduria entoman*)
Cumacea	(*Diastylis rathkei*)
Amphipods	(*Pontoroperia femorata*)
Segmented worms	(*Bylgides sarsi*)
Penis worms	(*Halicryptus spinulosis*)

Animals that live on top of the seabed, so-called epifauna, can also be present but are expected to have a much smaller spread due to the fact that the bottom is dominated by soft soil.

The oxygen conditions in the Neptunus energy farm are. according to SMHI’s measurements, good with a smaller spread of oxygen-poor areas in the south-western part of the farm, see section 4.3 (SMHI, 2019; SMHI, 2020). In general, the number of benthic species at the site is low and strongly correlated with the oxygen concentration at the seabed. Due to any oxygen-poor and anaerobic bottoms that may occur at the Neptunus energy farm, the spread of bottom fauna is expected to be low in these areas. The bottom fauna in the area is expected to consist of species that are common in this part of the Baltic Sea.

Red algae are the group of algae with the largest depth distribution and have been observed as far down as 38 metres in the Baltic Sea (Kågesten, et al., 2020). As the deepest point of the site exceeds this depth, along with a dominance of soft and sandy bottoms, no vegetation is expected to occur in the area.

4.5.2. *Fish*

The Baltic Sea is a brackish sea, with periodic inflows of salt water via the Danish Straits and continuous supply of fresh water via rivers and watercourses that flow into the northern parts of the sea. Due to this, the fish fauna in the south-west of the Baltic Sea is dominated mainly by salt-water species, while the north-east consists of a combination of both salt and freshwater species

A distribution of demersal (bottom-living) fish species can be expected but is probably limited due to the oxygen-poor/anaerobic bottoms (see section 4.3). In the Neptunus, the fish fauna is dominated by sprat (*Sprattus sprattus)*, in addition to herring (*Clupea harengus*) and cod (*Gadus morhua*) (ICES DATRAS, 2023). Demersal fish are relatively rare due to the oxygen-poor areas, but are represented, among others, by flounder (*Platichthys flesus*) and plaice (*Pleuronectes platessa*) (ibid.). In addition, the farm site is located just above the eastern cod's largest and most important spawning area for the population's survival, the Bornholm Deep, see Figure 22 (ICES, 2019; ICES, 2020; HELCOM, 2022). Cod spawn throughout almost all of the year, but its most intense spawning season occurs in June–August in the Bornholm Deep (Bleil, et al., 2013). In addition to cod, it is likely that sprat and flounder also spawn in the Bornholm Deep and thus also in the Neptune energy farm, see Figure 23 and Figure 24 (HELCOM, 2022).

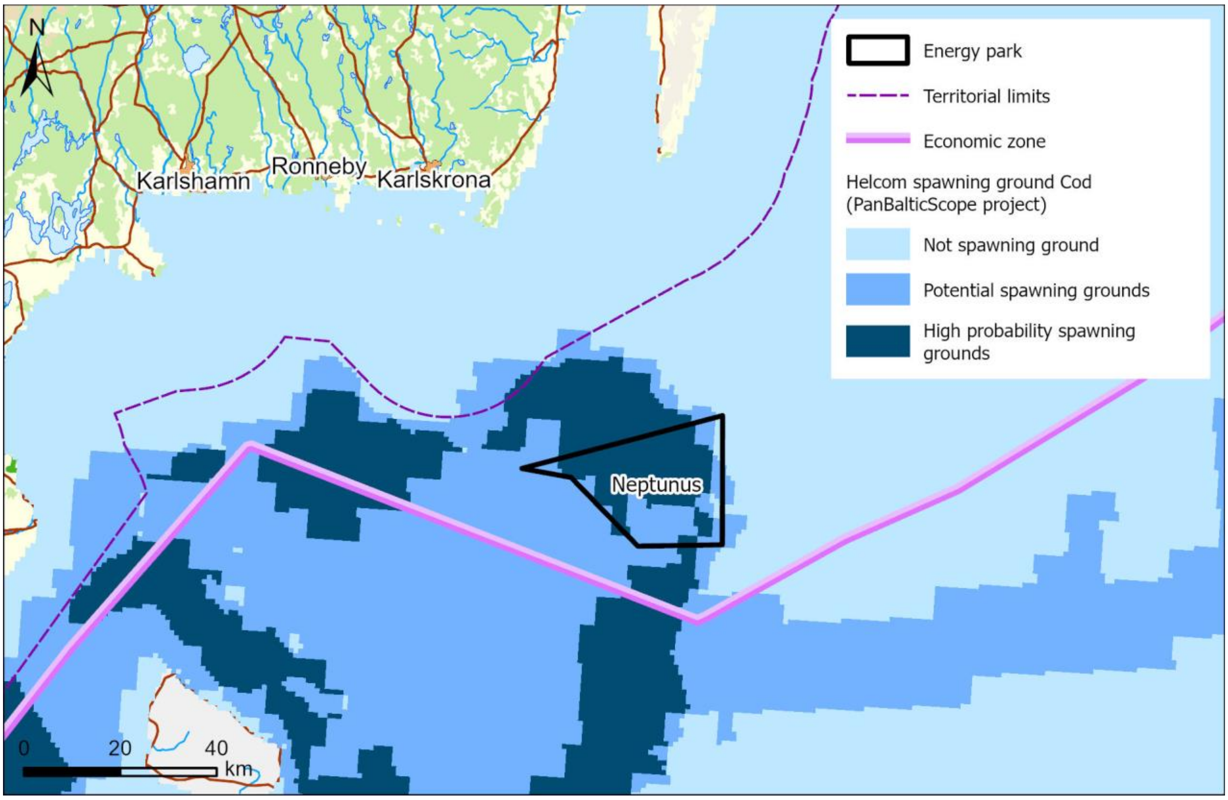


Figure 22. Map of the probability of cod spawning grounds within Neptunus. The Bornholm Deep is located south-west of the marked farm area. © [National Land Survey] 2023, [Document: HELCOM] 2022

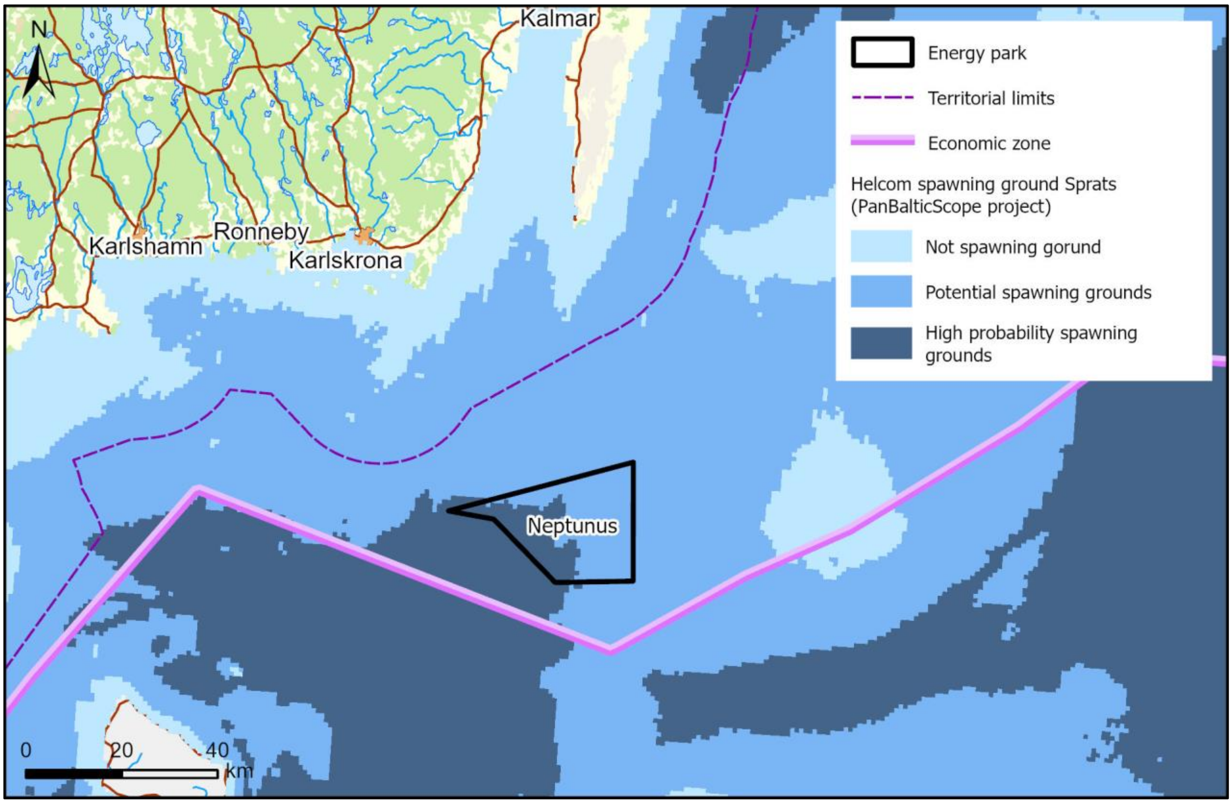


Figure 23. Map of the probability of sprat spawning grounds within Neptunus. The Bornholm Deep is located south-west of the marked farm area. © [National Land Survey] 2023, [Document: HELCOM] 2022

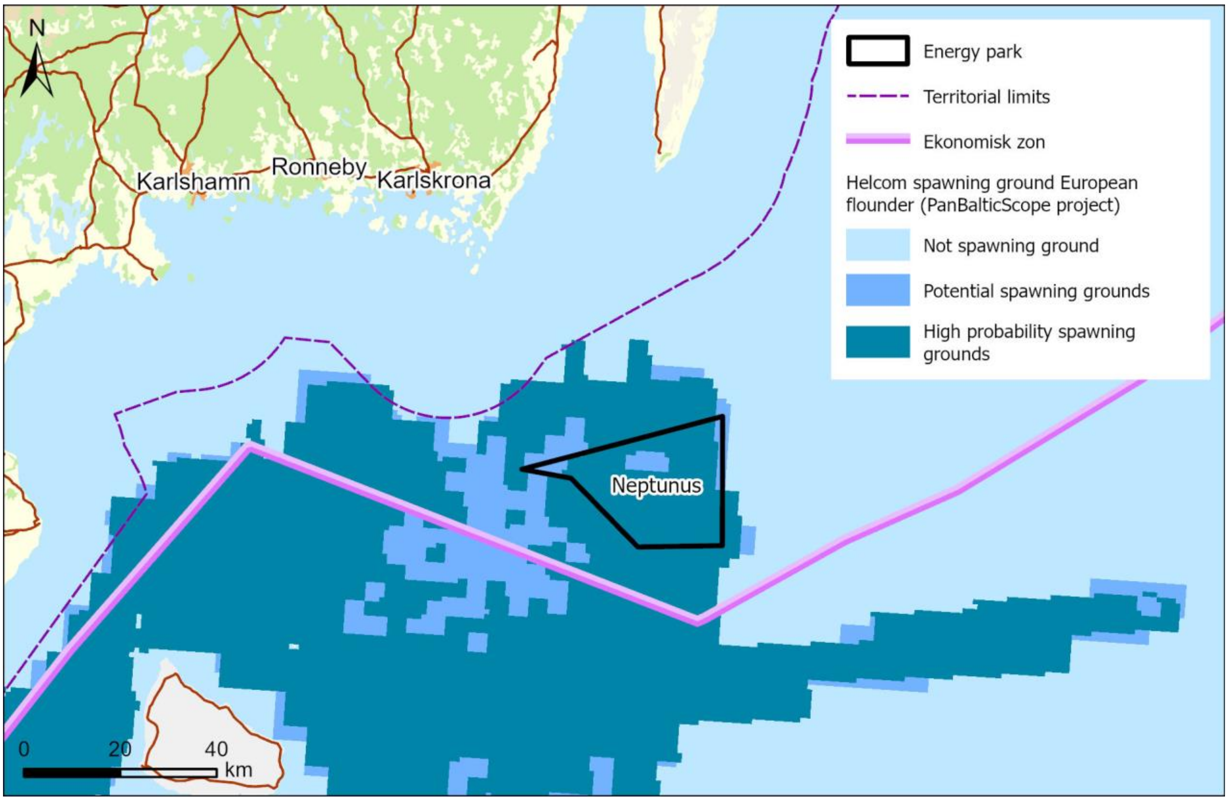


Figure 24. Map of potential flounder spawning grounds. The Bornholm Deep is located southwest of the marked farm area. © [National Land Survey] 2023, [Document: HELCOM] 2022

4.5.3. *Birds*

The waters of the Baltic Sea are home to several species of seabirds as both overwintering, breeding and foraging areas. The area's seabird fauna includes eider ducks, long-tailed ducks, velvet scoter, common scoter, and various species of auks, loons and gulls.

The Natura 2000 area of the Hoburgs bank and Midsjöbankarna, bordering on Neptunus in the east, is an important overwintering area for seabirds in the Baltic Sea, see Figure 25. The offshore banks are of particular importance for the highly endangered northern European and Russian populations of long-tailed duck . (Larsson, 2016; Larsson, 2018).

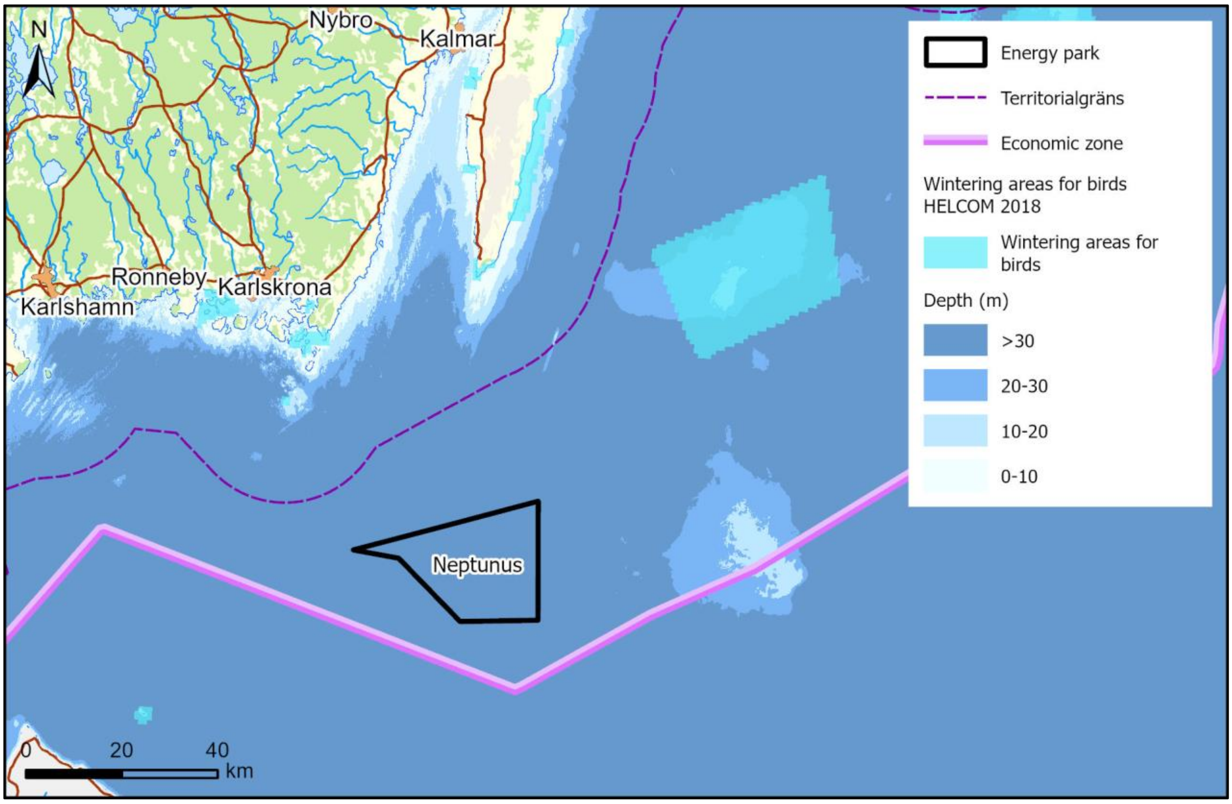


Figure 25. Map of bird overwintering areas in the vicinity of Neptunus, together with the offshore banks. © [National Land Survey] 2023, [Document: HELCOM] 2022

When reviewing data reported to the species portal (SLU Species Information Centre), the information shows that the general migration runs close to the coast. On the other hand, the Baltic Sea is an important migration corridor between northern Russia and north-western Europe. Consequently, due to the migration corridor, a large number of birds pass widely through the Baltic during the migration periods in spring and autumn. The main migration corridor runs in a north-east-south-west direction between south-eastern Skåne and Öland

and does not overlap with the Neptunus site, see Figure 26. However, birds could pass sites adjacent to the energy farm In connection with their migration.

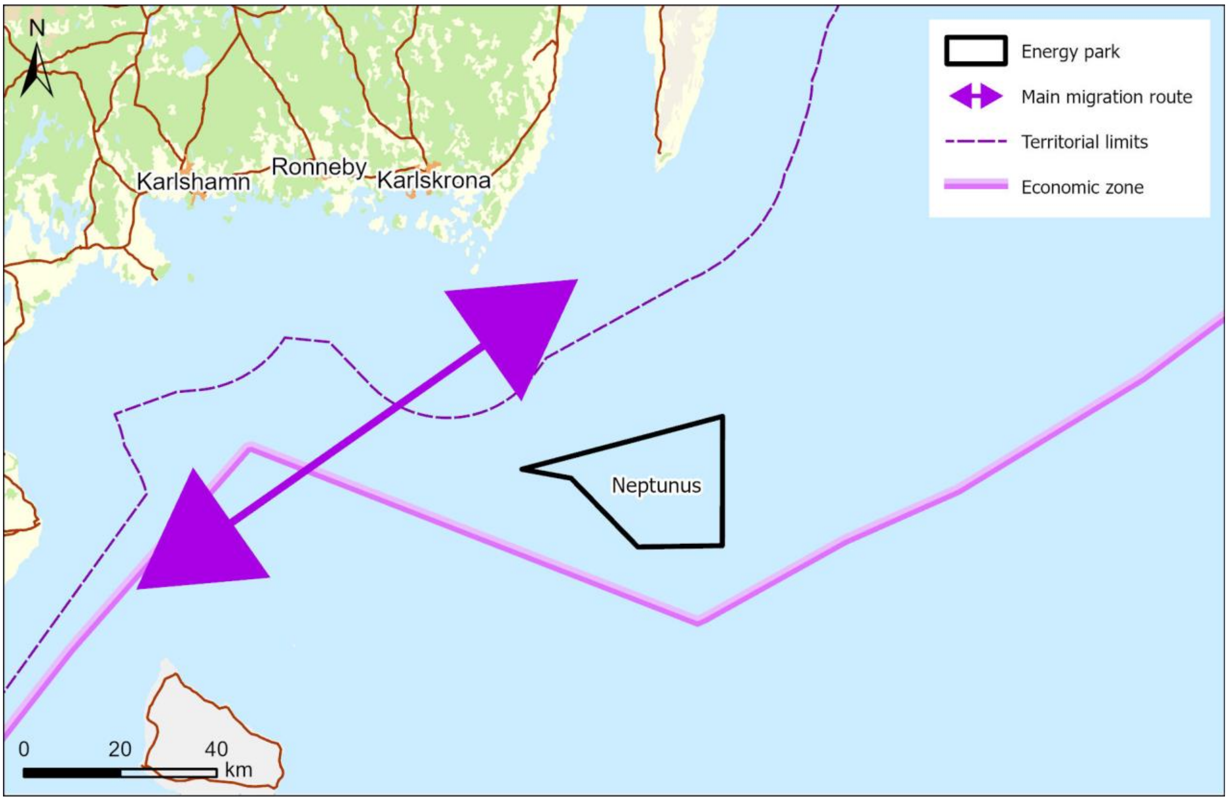


Figure 26. The energy farm and the main bird migration corridor. © [National Land Survey] 2023

4.5.4. *Marine mammals*

4.5.4.1. Porpoises

Porpoises from the Baltic Sea population area also present within the Neptunus energy farm and are also a designated species in the nearby Natura 2000 area of the Hoburgs bank and Midsjöbankarna.

Studies of the presence of the porpoises in the Baltic Sea show that they are mainly present around the offshore banks in the Baltic Proper during May – October, while they disperse more during November – April, see Figure 27, Figure 28 and Figure 29 (Carlén, et al., 2018). The density of porpoises is very low within Neptunus and despite the fact that the area borders on Hoburgs bank and Midsjöbankarna Natura 2000 area, the annual incidence of porpoises is estimated to be between 0 and 0.0002 individuals per square kilometre (SAMBAH, 2016). Very low porpoise densities are also confirmed by a count carried out by AquaBiota with porpoise detectors (F-PODS) within the Neptunus energy farm site.

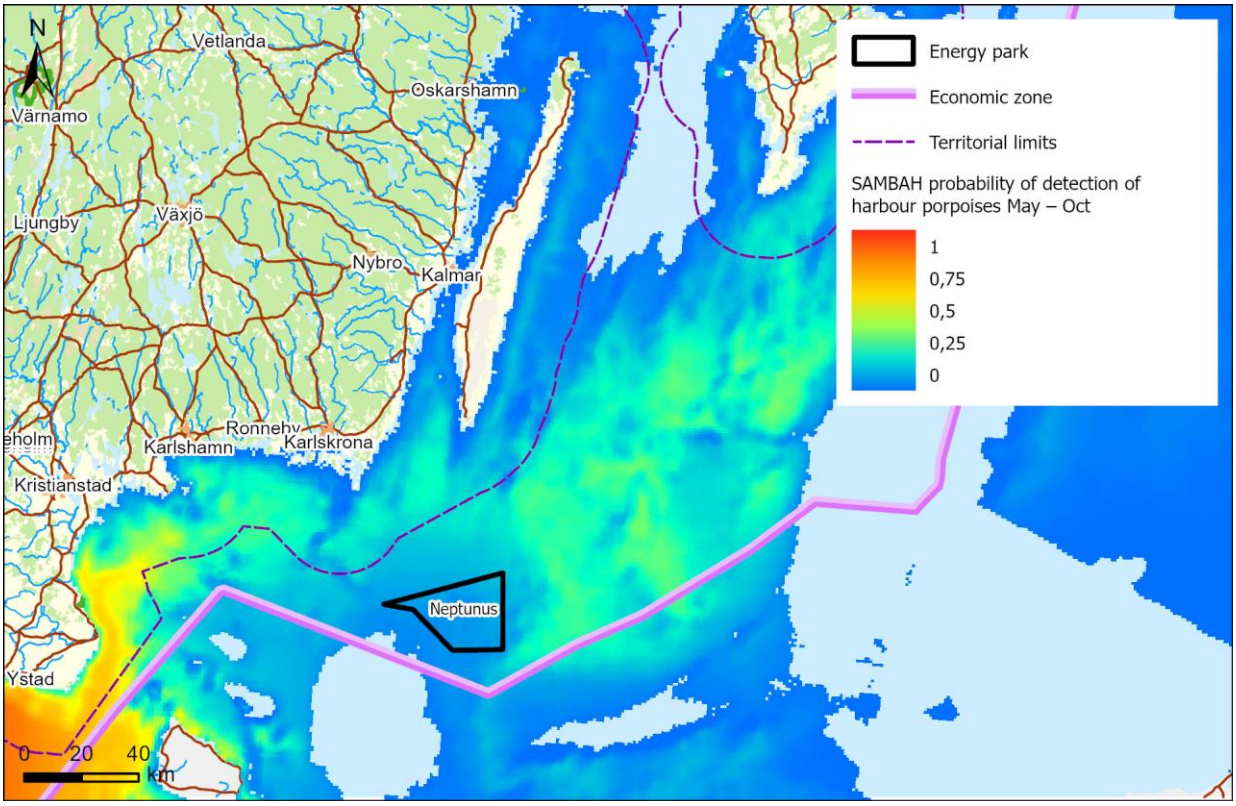


Figure 27. Expected porpoise distribution during the May-October period. Probability of detection shows the modelled mean values (in a grid consisting of 1x1 km squares) for the months of May-October, based on the SAMBAH surveys, which was a project focused on preserving the Baltic Sea's porpoise population and estimated porpoises densities and numbers (Carlén, et al., 2018). © [National Land Survey] 2023, [Document: HELCOM]

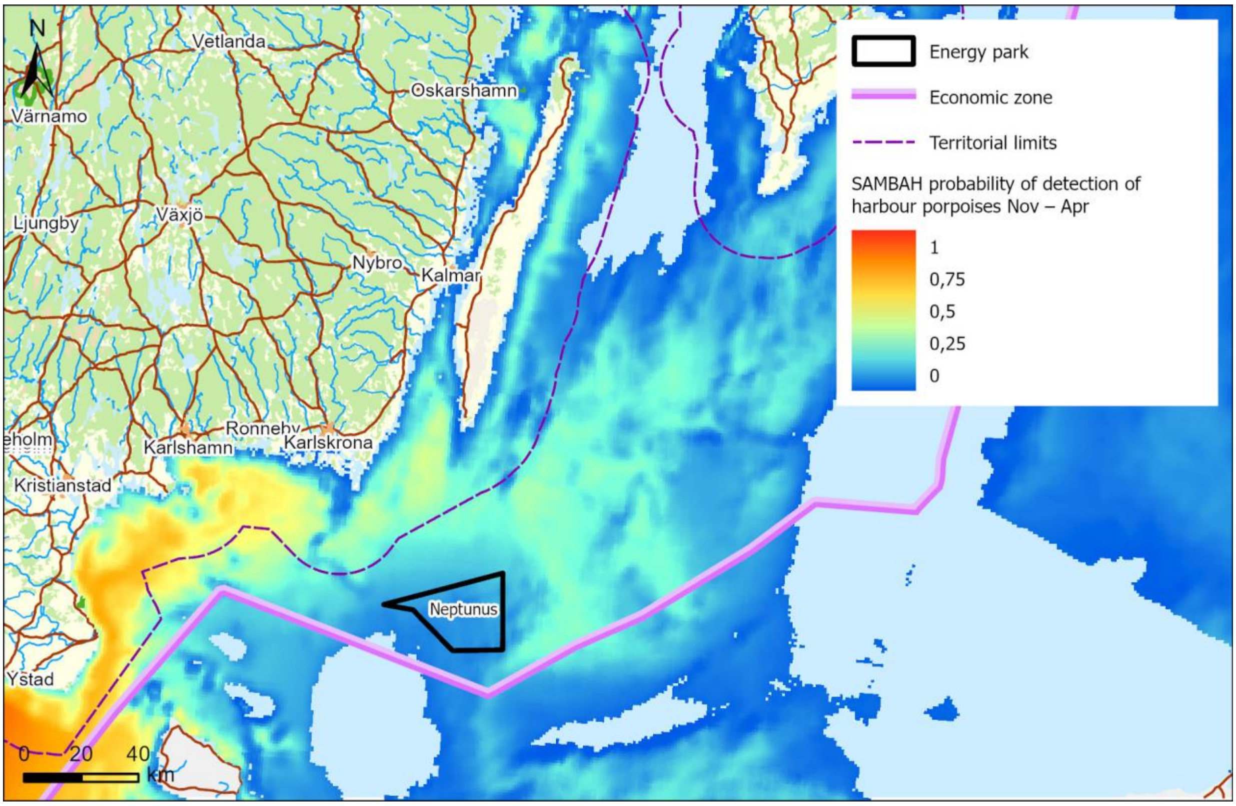


Figure 28. Expected porpoise distribution during the November- April period. Probability of detection shows the modelled mean values (in a grid consisting of 1x1 km of squares) for the months November-April, based on the SAMBAH surveys (Carlén, et al., 2018). © [National Land Survey] 2023, [Document: HELCOM]

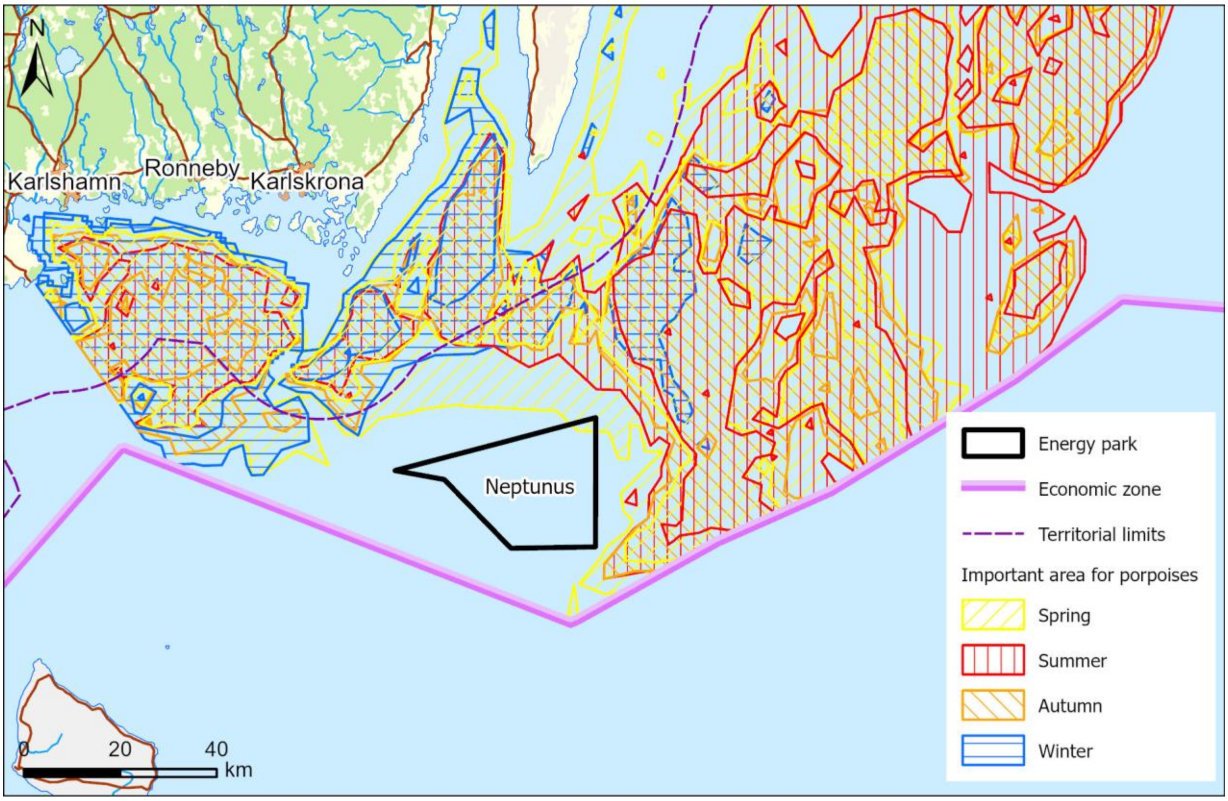


Figure 29. Important areas for porpoises in the Baltic Sea. © [National Land Survey] 2023 document: [HELCOM] 2021

The numbers of the Baltic Sea porpoises decreased sharply during the last century – mainly due to by-catches in net fishing but probably also due to discharges of environmental toxins that affected fertility. The Baltic Sea population currently consists of only an estimated 500 individuals[1] (SAMBAH, 2016). The biggest threats today are by-catches in fishing, environmental toxins, underwater noise and a reduced supply of prey. The Baltic Sea population is classified as critically endangered in the National Red List of the Species Information Centre, which means that it is very sensitive to further disturbances (SLU ArtDatabanken, 2020; SAMBAH, 2016).

4.5.4.2. Seals

Common seals are found in Swedish and Danish waters and are divided into four subpopulations in Limfjord, Kattegat, southern Baltic and Kalmarsund (HELCOM, 2018b). The Kalmarsund population is the population that could possibly be present in the Neptunus energy farm area (SAMBAH, 2016) and amounts to about 2,000 individuals. Based on head count data between 2003 and 2016, the Kalmarsund population has increased annually by 7.9

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[1] Confidence interval of 100 – 1000.

per cent (HELCOM, 2018a). The population usually stays in the strait or near the south-eastern coast of Öland. The seals' important basking places, so-called "haul-out sites", are also found here, see Figure 30.

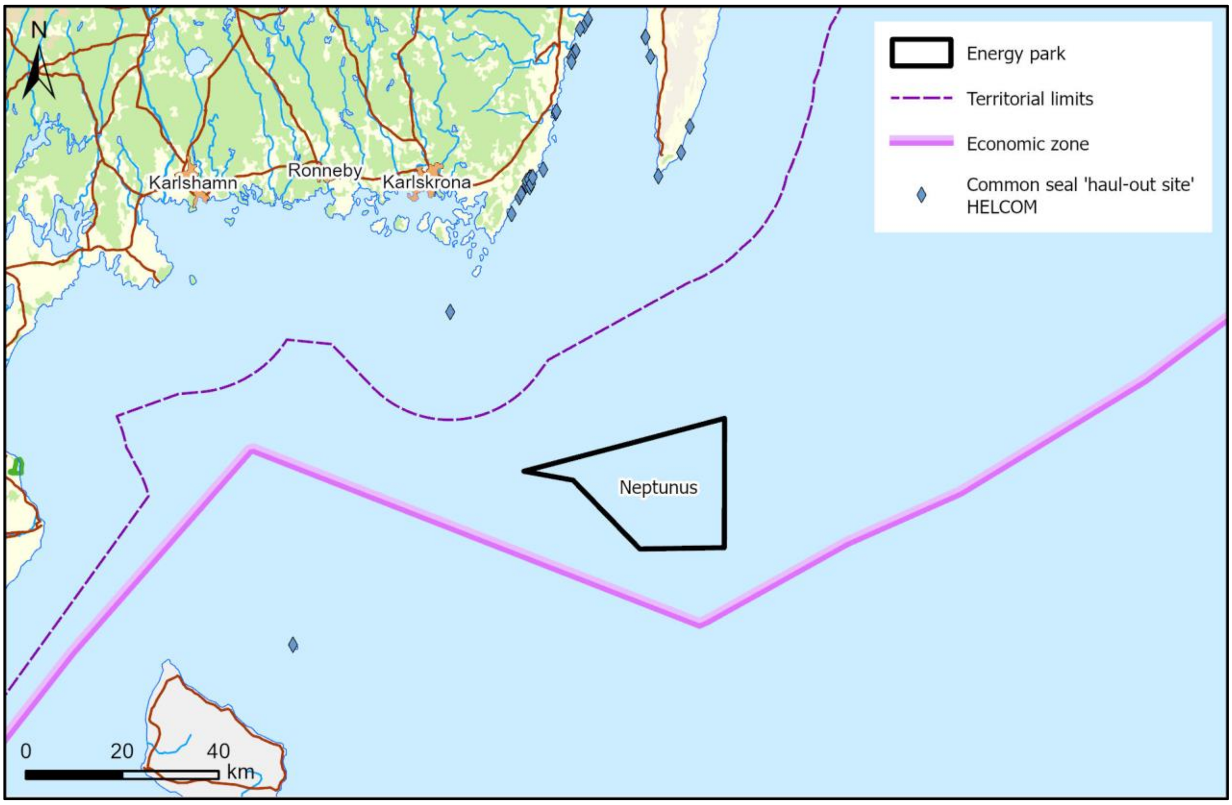

Figure 30. Important areas for common seals in the Baltic Sea. © [National Land Survey] 2023, [Document: HELCOM] 2021

The grey seal is the most common seal species in the entire Baltic Sea and the species can move across large areas of the sea. Based on a survey of grey seals carried out in 2014, the population was estimated at about 40,000 individuals (HELCOM, 2015). The population is therefore assessed as viable according to the Swedish Red List and has reached a good status (HELCOM, 2018a). The haul-out site closest to Neptunus is located in the Blekinge archipelago, about 38 kilometres from the energy farm site (HELCOM, 2018b).

Both of the species, grey seals and common seals, are protected under Annexes 2 and 5 of the EU's Species and Habitat Directive. Grey seals and common seals feed mainly in shallow areas with depths down to 40 metres (Tollit, et al., 1998; Sjöberg & Ball, 2000). The need for shallow areas makes the offshore banks potentially important foraging areas (Naturvårdsverket, 2010). However, due to the significant depth within Neptunus, 50–80 metres, the energy farm site is probably not of particular importance for seals.

4.5.5. *Bats*

Due to the large distance to land, it is unlikely that the farm area is used by bats for foraging or to form breeding colonies. However, it is possible that bats could pass through the farm area during migration to and from the continent. For example, there is a known migration point at Öland’s southern tip where bats have been observed to migrate straight south, which could potentially mean that these bats pass through the farm area during migration (Ahlén, et al., 2009). There are also recorded observations of bats arriving in the spring from the south to Öland’s southern tip (ArtDatabanken, 2020).

Observations have shown that bats do not migrate in concentrated groups, but are scattered in time and over large areas (Ahlén, et al., 2009). It has been observed that migrating bats may start hunting if they encounter large concentrations of insects above or at the surface of the water (Ahlén, et al., 2009).

In a bat count carried out within Neptunus on August 26 and 27, 2021, three audio files of the genus *Eptesicus sp*. were detected. However, in this case it was not possible to determine the species more closely based on the recordings, but it has been considered that the recording is probably of the northern bat (*Eptesicus nilssonii)* or the closely related serotine bat (*Eptesicus serotinus).* As the northern bat is not a migrating species (Ahlén, et al., 2009), it is more likely that it is the partially migrating serotine bat that has passed the ultrasound detector at a long distance (Bogdanowicz, et al., 2013; Ahlén & Baagøe, 2013; Moussy, et al., 2015).

4.6. Ecosystem services and green infrastructure

An ecosystem service refers to a product or service that natural ecosystems provide to man and that contributes to our well-being and quality of life. Examples of this include natural water regulation, nature experiences and natural resources. Green infrastructure is defined as ecologically functional networks of habitats, structures and natural areas, as well as the factors contributing to the provision of various ecosystem services.

Based on the Swedish Agency for Marine and Water Management’s report (2015:12)) on ecosystem services from Swedish seas and influencing factors, the following ecosystem services have been assessed to be relevant to the Neptunus energy farm:

- **Supportive:** Maintenance of the dynamics of the food web, maintenance of habitats, maintenance of biodiversity
- **Providing:** Provision of raw ingredients for the production of food
- **Regulatory:** Retention of sediment, regulation of toxic substances

- **Cultural**: Non-material benefits that people get from ecosystems through, for example, experiences in nature, such as outdoor pursuits.

Because the Neptunus site is far from land, has a significant depth of water with poor oxygen conditions, the area itself is not expected to be of great importance for supportive or cultural ecosystem services.

4.6.1. *Biodiversity*

Biodiversity is the range of ecosystems, species and genuses in nature (SLU, 2021). The latest research ranking from the United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES, describes a worrying loss of biodiversity. Climate change is already one of the five main drivers of biodiversity loss, and its impact is expected to increase (IPBES, 2019). At the same time, loss of nature and biodiversity itself has an impact on the climate as nature's ability to absorb carbon dioxide and store carbon deteriorates as a consequence of, among other things, logging, agriculture and acidification of the sea and lakes (Umeå universitet, 2021).

OX2 aims to ensure that all of its wind and energy farms that are being developed will be nature-positive by 2030. In its development of the farms, OX2 has therefore designed a way of working that is guided by hierarchical consideration. This means that the work is carried out in a structured way in order to avoid and minimise the impact on nature through location, detailed design and planning of construction activities for the farms. In parallel, during all project phases, opportunities for restoring natural environments and/or implementing other measures with a positive impact on biodiversity will be identified. In the case of the Neptunus energy farm, this has involved OX2 investigating the possibility of oxygenating bottom water with by-product oxygen from offshore hydrogen production.

4.6.2. *Oxygenation*

The general biodiversity in the Baltic Sea has deteriorated in recent decades, along with some species of fish, birds and marine mammals, as well as habitats that are in an unsatisfactory state of health. Contributing factors to the current poor status of the Baltic Sea are the spread of anaerobic areas and poor oxygenation of bottom water as a result of, among other things, irregular supply of salt and oxygen-rich water from the North Sea, climate change and eutrophication. The Baltic Sea is naturally sensitive to oxygen deficiency because a strong salinity layer, a so-called halocline, separates the deep water from the less salty surface water.

So the development over time for bottoms with oxygen-stressed and anaerobic in the Baltic Proper in Figure 31.

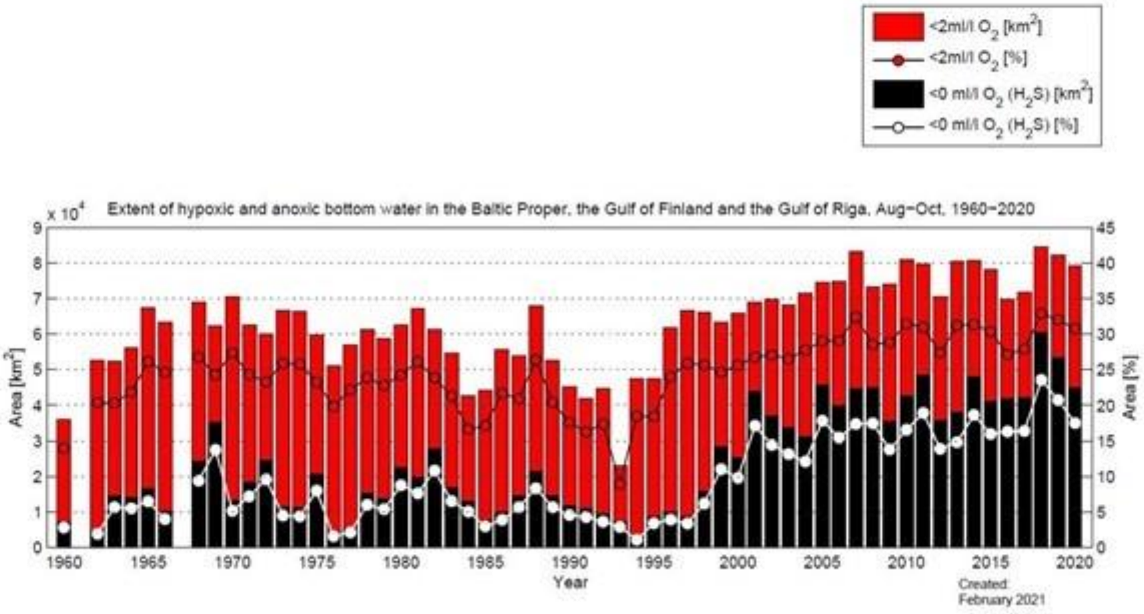

Figure 31. Development over time for bottoms with oxygen-stressed and anaerobic conditions in the Baltic Proper. (Stigebrandt, 2021)

OX2 is currently investigating, together with IVL Svenska Miljöinstitutet, the conditions for combining hydrogen production with an oxygenation stage, in which oxygenated water or oxygen gas is diverted to bottom waters. The forthcoming Espoo report will describe the consequences of oxygenation on the marine environment of the Baltic Sea.

4.7. Landscape scenery

Landscape scenery can be defined as a person’s visual impression of the landscape. The planned site of Neptunus lies far out at sea and is dominated by wide expanses of open sea. An analysis of the impact on the landscape will be presented in the forthcoming Espoo report.

4.8. Natural resource management

4.8.1. *Fishing*

Commercial fishing in the Baltic Sea is mainly focused on a few species. Cod, Herring and sprat account for up to 95 cent of total catches (ICES, 2018). Pelagic fishing, mainly using floating trawls, takes place throughout the Baltic Sea and is mainly focused on herring and sprat. (Jordbruksverket & Havs- och vattenmyndigheten, 2016). It is this fishery that contributes the largest catches in terms of tonnage in the Baltic (Havs- och vattenmyndigheten, 2018). The most important demersal trawling is bottom trawling aimed at cod and flatfish, dwarfed by flounder and plaice, which is concentrated in the southern and western Baltic, but not in the Neptunus area. Other species of local and seasonal economic importance are salmon, dab, brill, turbot, pike-perch, pike, perch, whitefish, eels and sea trout.

Neptunus is located within the ICES (International Council for the Exploration of the Sea), so-called statistical rectangle 40G6 and part into rectangle 40G5. This is an international area in which landings from commercial fishing are recorded (ICES, u.d.). Poland accounts for most of the fishing, followed by Sweden, Germany, Lithuania and Denmark. The reported catch tonnages for Latvia, Finland and Estonia are, in comparison, very small.

The Swedish Fisheries Monitoring Unit, which monitors the Swedish fishing fleet in real time (Havs- och vattenmyndigheten, 2013), shows that relatively little fishing takes place in the Neptunus area, with some occurrence of floating trawling in the north-east of the energy farm, see Figure 32. Neptunus is also located in a marine area with a so-called “closed period” meant to protect the cod spawning. The closure period for the area to which Neptune belongs extends from May 1 to August 31. During the closed season, only some types of pelagic fishing are allowed (Havs- och vattenmyndigheten, 2021a).

Data from Vessel Monitoring System (VMS) show that almost all fishing activities in the vicinity of Neptunus in 2019 had the form of trawling in the mid-depth waters, i.e. with floating trawls, see Figure 32. As a result, fishing in these areas is likely to focus on herring and sprat (Havs- och vattenmyndigheten, 2021b). Bottom trawling also takes place to the west of Neptunus.

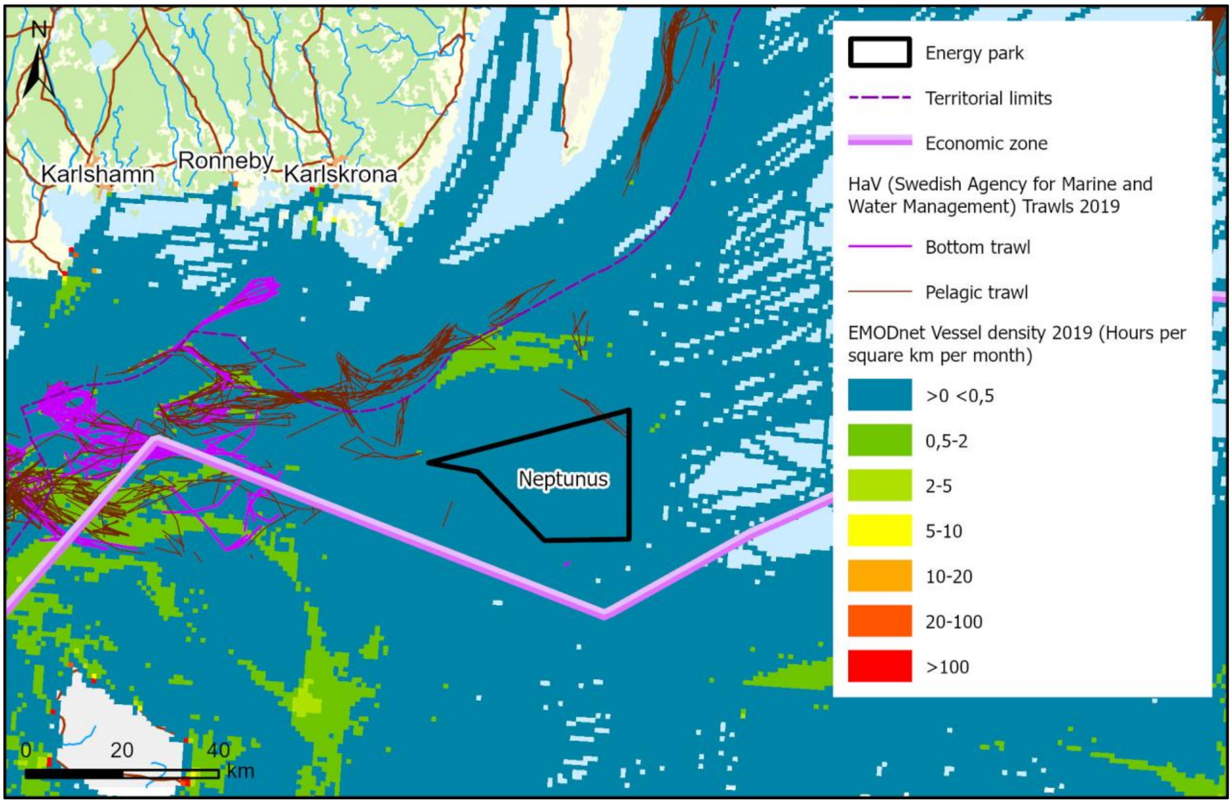

Figure 32. Commercial fishing in the area in 2019. Trawls from Swedish trawlers. Vessel density is displayed in hours per km^2 per month. © [National Land Survey] 2023, [Document: Swedish Marine and Water Management Agency, EMODnet] 2022

4.9. Climate

An increased amount of carbon dioxide in the atmosphere and increases in temperature as a result of the rising levels of carbon dioxide and other greenhouse gases affects the climate. An increase in the global average temperature has impacts that include changing precipitation patterns and wind conditions, changing extent of ice and snow cover, rising sea levels and warmer seas, etc. (Bogren, et al., 2019). These impacts have an impact on both natural ecosystems on land and in the sea, as well as on human society. For example, warmer seas create conditions for more extensive algal blooms, affect species composition in different areas and contribute to increased acidification of the sea. Furthermore, there is a marked increase in the number of natural disasters in the world, due to climatological, hydrological and meteorological factors. Regardless of the measures currently being taken to mitigate climate change, in the future the climate will look different from today’s climate.

The planned Neptunus energy farm is part of the extensive energy transition in both Sweden and the rest of Europe from fossil-dependent power sources to energy production entirely based on renewable, green and sustainable technologies.

4.10. Infrastructure and planning conditions

4.10.1. *Maritime activities*

Three areas of national interest for shipping are adjacent to the Neptunus energy farm; the shipping route *Gedser-Svenska Björn*, which is a deep-water route adjacent to the northern border of Neptunus and is designated by the international body IMO, *Bornholmsgatt – Klaipeda* which is a new area of national interest for shipping that overlaps with the southern part of Neptunus and the shipping route *Karlskrona – Gdynia*, which is a small shipping route that passes within the northeast part of Neptunus. See these Figure 33 (Havs- och vattenmyndigheten, 2022). A slight amount of vessel traffic also passes outside the designated shipping routes within the energy farm, see Figure 34. The movements of a large number of number of vessels such as cargo, container, fishing passenger, service and tanker vessels, etc. have been tracked using the Automatic Identification System(AIS). AIS data from 2017 and 2018 show that these types of vessels pass along the energy farm on their way into and out of the Baltic Sea. The movement pattern of fishing vessels is more spread out as the fishing areas differ according to the target species.

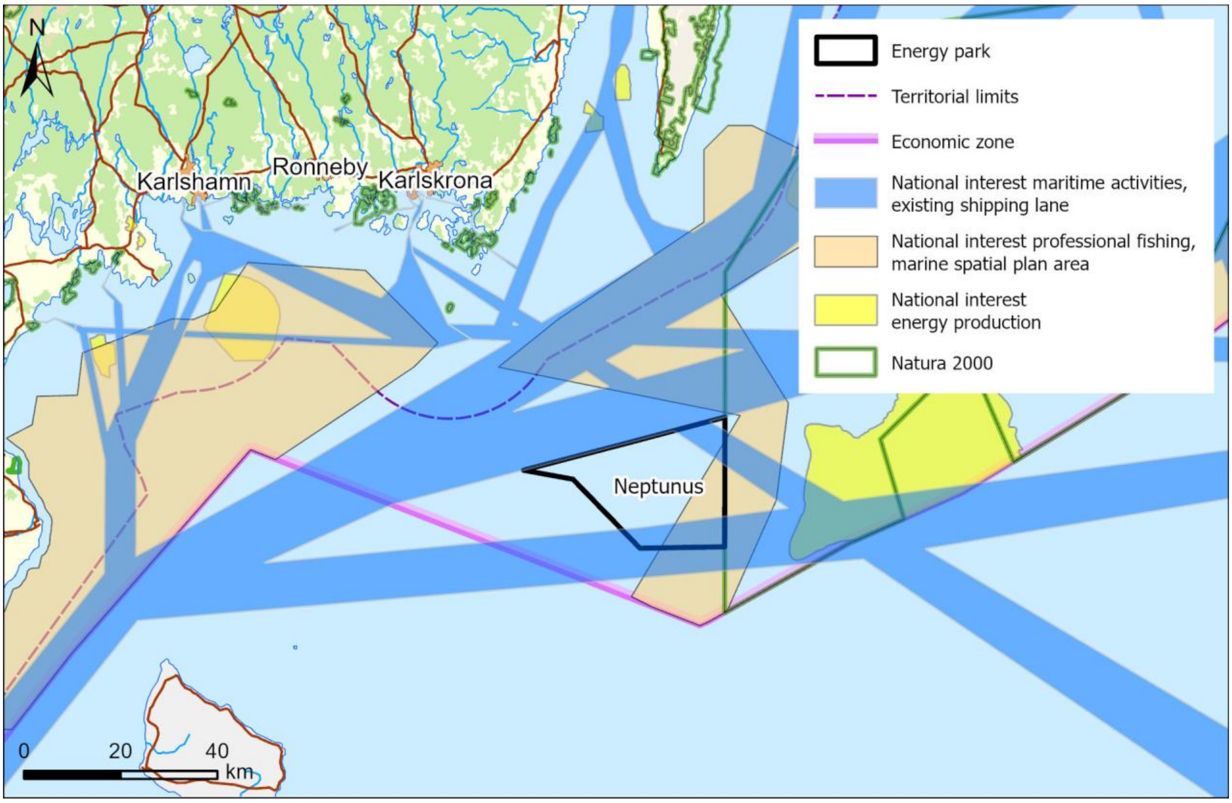

Figure 33. Energy farm and national interest shipping in the Baltic Sea. © [National Land Survey] 2023, [Document: Swedish Marine and Water Management Agency] 2022

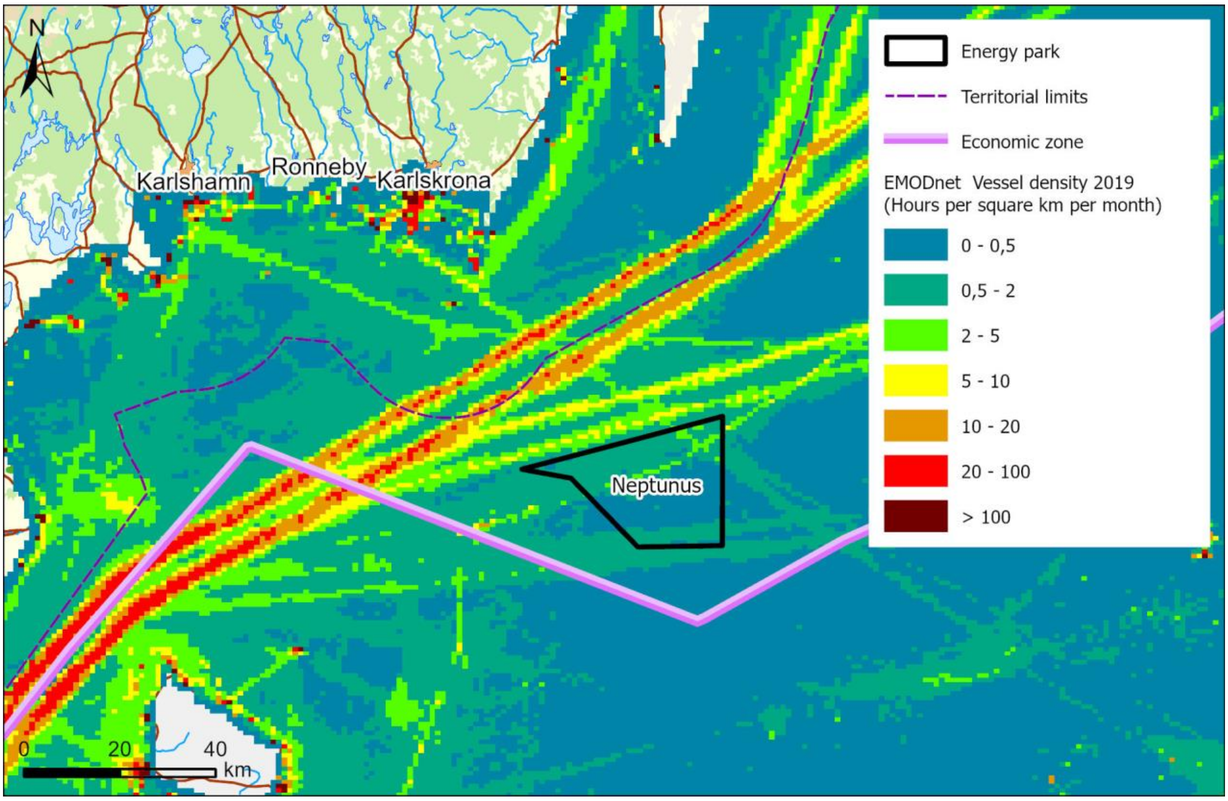

Figure 34. Energy farm and vessel density in the Baltic Sea. © [National Land Survey] 2023, [Document: EMODnet] 2021

4.10.2. *Aviation*

A Minimum Sector Altitude (MSA) for an airport is a circle with a 55 kilometres radius from the airport's landing aid devices. The area is divided into four sectors for which the minimum flight height is 300 metres above each sector's highest physical barriers. In other words, aircraft have a safety margin of 300 metres to the highest object in each sector (Trafikverket, 2014). The Neptunus Energy farm does not overlap any airport MSA area.

4.10.3. *Military areas*

The Neptunus energy farm is adjacent to an area designated for underwater exercises used by the Swedish Armed Forces and by the corresponding authorities in Denmark and Germany (EMODnet, 2022), see Figure 35.

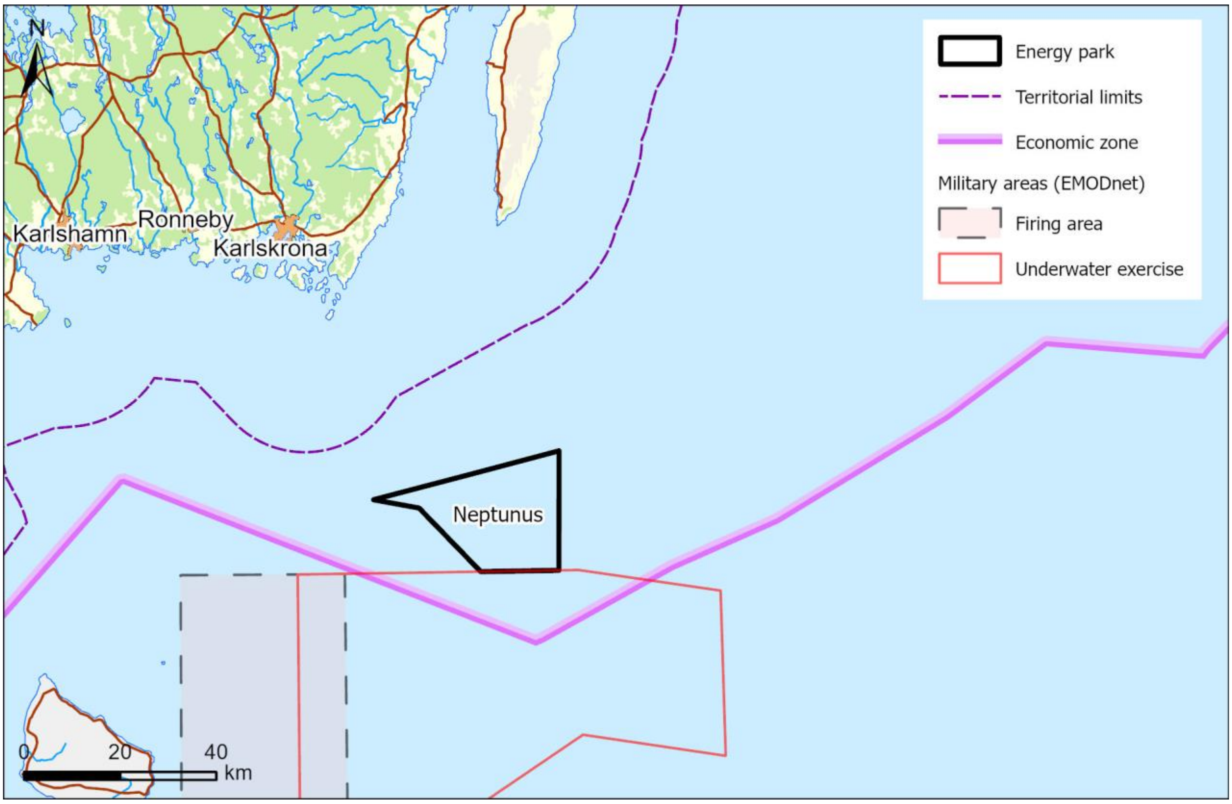

Figure 35. Significant international military exercise areas. © [National Land Survey] 2023, [Document: EMODnet]

4.10.4. *Environmentally hazardous objects and dumping areas*

After World War II, large quantities of chemical and conventional weapons were dumped into the Baltic Sea, to such an extent that the Baltic Sea today is probably the sea in the world that contains the highest concentration of mines, munitions and chemical weapons (Havet.nu, 2018). Many of these objects are still dangerous to come into contact with and a number of high-risk areas with a particularly high density of dumped munitions have been established (Försvarsmakten, u.d.). Dumped hazardous objects may also be present outside marked areas because they may have been dumped incorrectly or moved, for example having been towed by trawling vessels (Havet.nu, 2018).

The Neptunus energy farm is adjacent to a hazardous area for dumped objects, including dumped ammunition and mustard gas, see Figure 36.

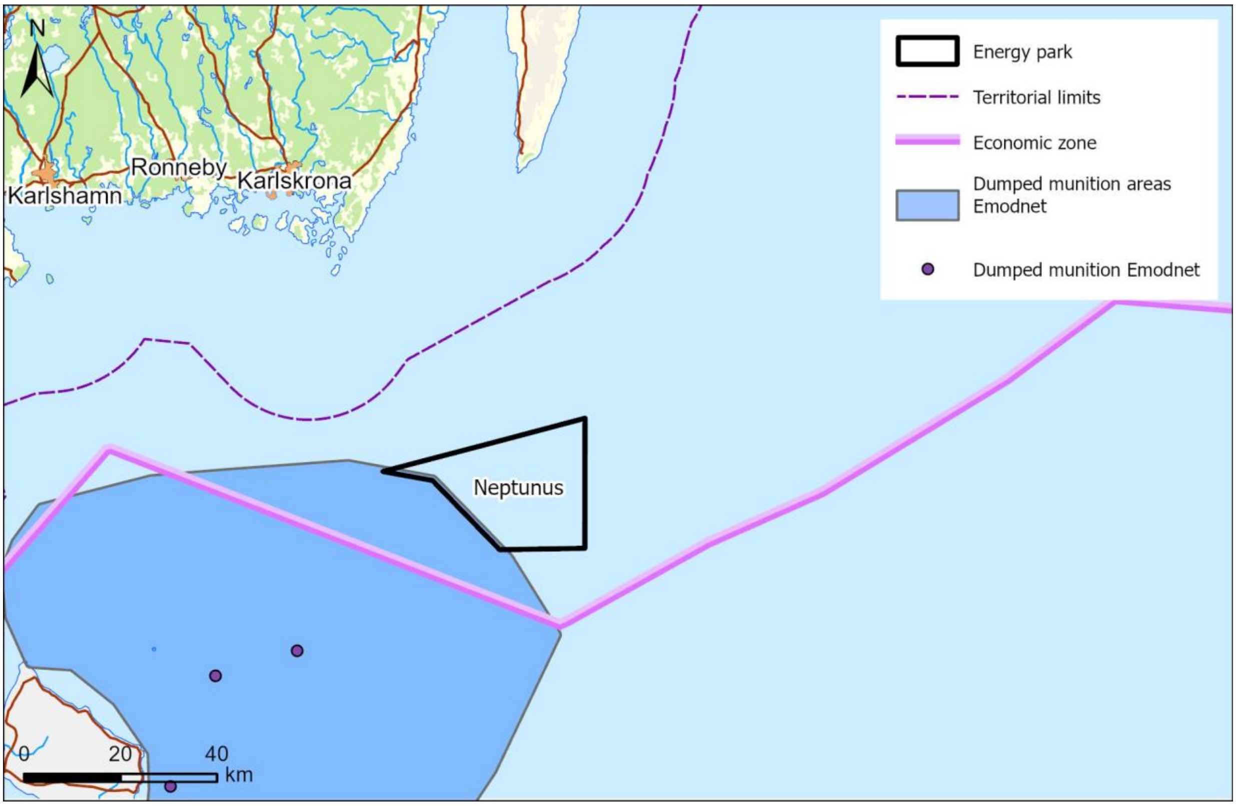

Figure 36. Neptunus energy farm and dumped ammunition areas as well as sites of dumped ammunition. © [National Land Survey] 2023, [Document: EMODnet] 2021

4.10.5. *Other activities*

There are currently no existing wind farms near the Neptunus energy farm site. However, there are several farms in the planning stages nearby, see those marked in Figure 37 and briefly described in Table 4. In addition, the Swedish wind farms and the closest Polish and Danish wind farms are described in more detail below.

Table 4. Planned and existing activities close to the Neptunus energy farm.

Project name	Country	Output	Status
Södra Victoria	Sweden	2000 MW	Early planning stage
Aurora	Sweden	5500 MW	Early planning stage
Cirrus	Sweden	2550 MW	Early planning stage
Södra Östersjön 1	Sweden	-	Early planning stage

Project name	Country	Output	Status
Södra Östersjön 2	Sweden	-	Early planning stage
Beta	Sweden	3340 MW	Early planning stage
Baltic Central offshore wind farm	Sweden	4000 MW	Early planning stage
Ymer	Sweden	2,400 – 2,800 MW	Early planning stage
Bornholm Bassin øst	Denmark	1500 MW	Early planning stage
Bornholm Bassin syd	Denmark	1500 MW	Early planning stage
Baltic power	Poland	1200 MW	Early planning stage
BC-Wind	Poland	399 MW	Early planning stage
FEW Baltic II	Poland	350 MW	Early planning stage
MFW Baltyk II	Poland	720 MW	Early planning stage
MFW Baltyk III	Poland	720 MW	Early planning stage
Baltica 1	Poland	896 MW	Early planning stage
Baltica 2	Poland	1498 MW	Early planning stage
Baltica 3	Poland	1045.5 MW	Early planning stage
Baltyk I	Poland	1560 MW	Early planning stage

OX2 is planning another wind farm in the Baltic Proper, east of Öland and south-west of Gotland. The proposed area of the wind farm is 1,045 square kilometres and is marked with black dashed lines in Figure 37. In 2022, a licence application was submitted for SEZ, KSL and a licence application for the Natura 2000 area of Hoburgs bank and Midsjöbankarna.

The company Njordr Offshore Wind is planning a wind farm which will overlap the southern part of the Neptunus project site, named Beta. The proposed area of the wind farm is 570 square kilometres and is marked in dark red in Figure 37. The SEZ consultation was carried out on 9 January 2022 (Njord Offshore Wind, 2022).

A further wind farm. Södra Victoria, is being planned for the Södra Midsjöbanken by RWE Renewables, 100 kilometres from the Swedish coast, on the border with Poland. See the area marked in dark green in Figure 37. The licence application for Natura 2000 was submitted on 10 June 2022 and provided the necessary licences have been granted, the wind farm is expected to go stream in around 2027 (RWE Renewables, u.d.). RWE is also planning the Ymer wind farm, which partially overlaps the western part of the Neptunus project site, the area marked in red in Figure 37.

The company Baltic C AB (Örsted) is also planning a project, the Baltic Central offshore wind farm, which partly overlaps Neptunus. See the area marked in dark orange in Figure 37. Their application for a survey licence was submitted on 14 November 2022. (Örstedt, 2023)

Freja Offshore is designing a wind farm called Cirrus, which partially overlaps the Neptune site, see Cirrus marked in light blue in Figure 37. The Cirrus wind farm has a farm size of 456 square kilometres with a total output of about 2,550 megawatts. Consultations were held in spring 2022.

Blekinge Offshore is also planning a wind farm, called Blekinge Offshore, about 15 kilometres from the Swedish coast. See the area marked with light purple. The wind farm was rejected in 2016 because of Swedish National Defence interests. The farm has now been modified and consultations were carried out in the summer of 2022.

On October 25, 2022, 4C Offshore announced that the company is developing various offshore wind projects in Denmark in partnership with Örsted. Bornholm Bassin Øst and Bornholm Bassin Syd in the Baltic are two of these, see the areas marked with yellow and mint green in Figure 37 (Offshore, 2023).

The energy company, Wind Power A/S is planning two wind farms near Neptunus: Södra Östersjön 1, which partly overlaps Neptunus, and Södra Östersjön 2, which will be located 12 kilometres north-east of Neptunus. See these areas marked with dark blue and pink in Figure 37.

There are two Polish planned wind farms further east from Neptunus: Baltyk 1, located about 34 kilometres from Neptunus, and Baltica 1, located about 53 kilometres from Neptune. See these areas marked with blue and light green in Figure 37. In addition to these, there are still a number of Polish wind farms planned to be to the south of the energy farm, see Figure 37.

In addition to the planned wind farms, the Nord Stream 1 and Nord Stream 2 gas pipelines will also pass through the project site.

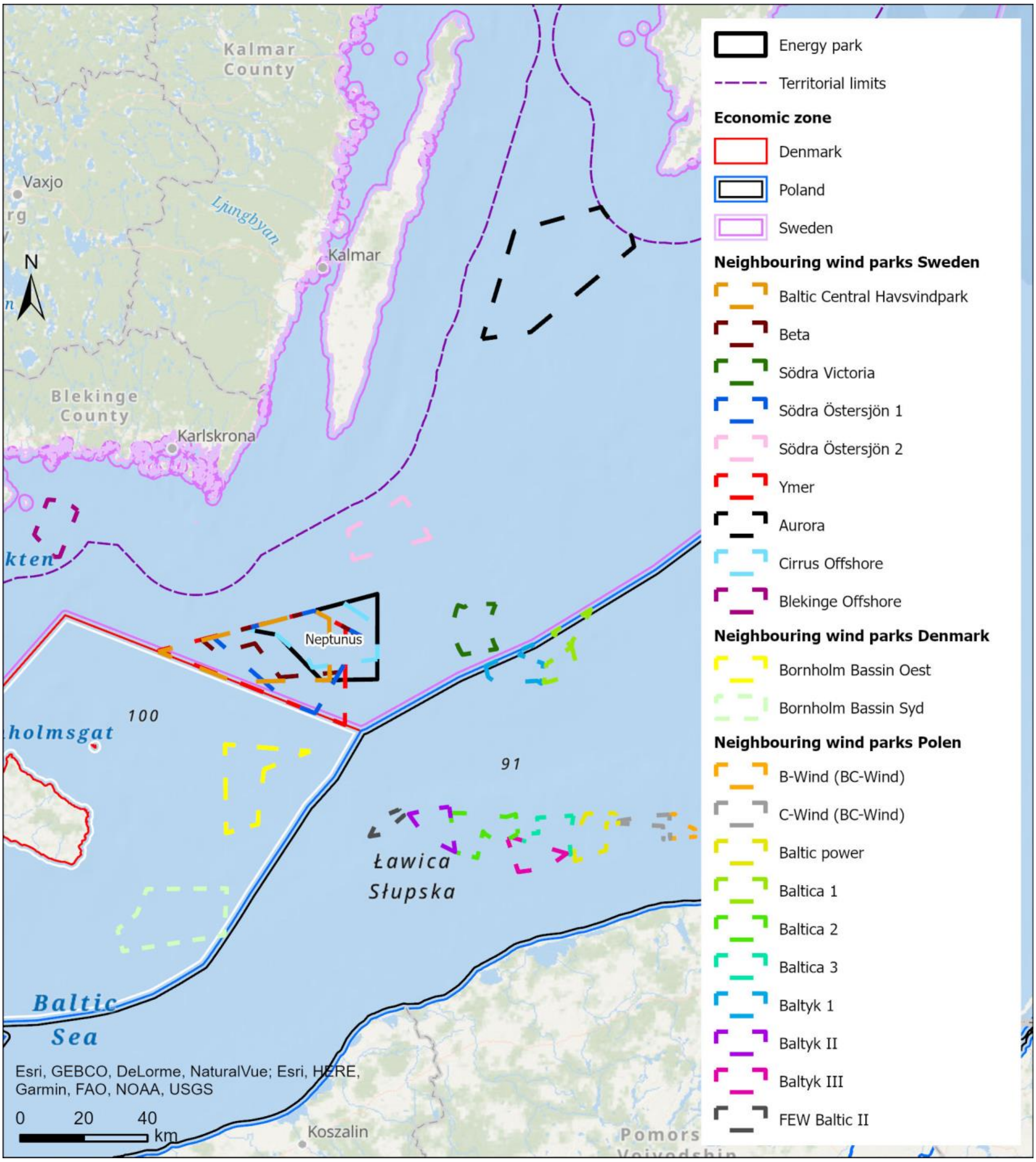

Figure 37. Planned and existing activities close to the Neptunus energy farm. [documentation: EMODnet, Länsstyrelsen] 2022

5. Risk and safety

5.1. General risk and safety associated with the energy park

Construction of an offshore energy farm places high demands on safety, which means that this will be a priority issue during all phases of the project. The risks from a large-scale wind power project and hydrogen and oxygen production can be divided into risks to human health, risks to the environment and risks to individual or public property.

Risks to human health must be considered in relation to, for example, work carried out at height, work involving heavy lifting or work involving the handling of electrical equipment. Risks to the environment may consist of the discharge of oil or other chemical products and the spread of bottom sediments that have been disturbed during construction work. Risks of damage to public or private property may arise, for example, during vessel movements in the project site or when handling heavy components. Ammunition or other weapons pose a particular risk, which means that the possible presence of these objects in the project site must first be identified by geophysical surveys.

The general management of risks can be described in the form of a so-called action hierarchy. In the first instance, the risk must be eliminated by completely avoiding the hazardous moment or by replacing it with a less risky one. The next step is to use technical or administrative measures to reduce the likelihood and impact of a hazardous event and to be prepared for action if the hazard occurs.

Risk analyses will be carried out continuously throughout all phases of the project. An identified risk must always be accompanied by an action. Procurement processes must ensure that suppliers comply with the project’s high requirements for safety and risk minimisation. Risks will be described in more detail in the forthcoming Espoo Report.

5.2. Risk and safety associated with hydrogen and oxygen production

The planned operations will produce and transport large quantities of the gasses hydrogen and oxygen, which can lead to risk of accidents. Design of the energy farm will focus on safety aspects and special attention will be paid on accident prevention in the farm’s design. A survey of risks and an assessment of necessary risk mitigation measures to minimise risks to the environment and health is ongoing.

The risks that are considered relevant to the energy farm from a Seveso perspective, that is, with regard to serious consequences in the event of an accident, are considered to be those associated with the handling of hydrogen and oxygen. Depending on the final engineering of hydrogen and oxygen production, which can be decentralised or centralised, there are various risks associated with handling within the energy farm.

Pipelines and buffer tanks within the energy farm could be exposed to, for example, shipping traffic, extreme weather and earthquakes. This could lead to hydrogen and/or oxygen leaks which could result in major accidents. Figure 33 illustrates potential shipping routes that expose the energy farm to risks from shipping traffic and the presence of passenger ships and cargo ships, including cargo ships carrying dangerous goods. If hydrogen is stored in tanks on dedicated platforms, the energy farm may require additional vessel traffic for loading, operation and maintenance, which may entail a somewhat heightened risk of accidents in the area due to an increased risk of allisions with the wind turbines.

A rough risk analysis has been carried out to identify risks within the energy farm. The risk scenarios that have been assessed to be relevant for hydrogen handling are primarily jet flames, gas cloud fires and explosions due to leakage ignited by an external or internal source of ignition. The main relevance for oxygen are mainly underlying effects resulting from other environmental accidents. In addition, fire and physical damage to ships and wind turbines with persons on board have been identified as relevant risk scenarios – mainly in connection with maintenance work or in the event of an allision[2]. Events that may lead to the identified accident scenarios are primarily related to allision risks, loading, operation and maintenance, extreme weather or some type of aggressive threat.

Initial assessments argue that gas cloud fires and explosions are the dominant risk factors for people in the energy farm’s vicinity because these can have impacts over long distances. A jet flame usually affects its direct proximity (a couple of hundred metres in the worst case scenario) and the effect is mainly in the direction of the jet flame, while gas cloud fires and explosions can have an affect in several directions.

As the site is located about 50-70 kilometres from the nearest mainland and inhabited islands , the third party risk for people on land is considered negligible. However, there are risks to operating personnel as well as to passing cargo and/or passenger vessels. For this reason, the energy farm must be planned in such a way that the risks to passing cargo and/or passenger vessels are low by introducing safety distances and/or other risk mitigation measures. It will be ensured that operational personnel who will work in the energy farm have

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[2] Impact between a moving vessel and another stationary object, such as a ship or wind turbine. Other collisions that are, in contrast, between two objects, both of which are in motion.

good knowledge of the risks and receive the necessary training on, among other things, how to act in the event of an accident.

Furthermore, the risk of discharges and emissions of environmentally hazardous substances to the Baltic Sea has been identified as a possible secondary effect as a result of allisions. No large amounts of environmentally hazardous substances will be handled within the energy farm. However, establishment of an energy farm may lead to an increased risk of allisions. An allision between a vessel and a wind turbine could result in the release of environmentally hazardous substances carried by the ship and/or turbine oil discharges from the wind turbine. A fire within the facility could also result in the release of environmentally hazardous substances. Furthermore, a non-ignited leak is also a risk. An accident in which environmentally hazardous substances leak into the Baltic Sea could have major consequences for the local environment.

The preliminary and overall risk mitigation measures proposed include reduced production of hydrogen near shipping lanes, safety distances between wind turbines within the energy farm and, in particular, approved hydrogen tanks, fire protection measures and good operating and maintenance procedures. There are no other Seveso facilities in the surrounding area that could affect, or be affected by, the energy farm. Accidents in connection with the passage of ships carrying dangerous goods could create domino effects, which will be taken into account in further work on accident risks.

An internal emergency plan will be developed in consultation with the relevant authorities as part of the safety report. Close cooperation with the Swedish Maritime Administration and the Swedish Coast Guard is foreseen, where OX2 provides support with the measures that are relevant to complementing potential actions in the event of an accident. Within the framework of the safety report, the risk assessment will also comprehensively report the requirements for the design of the installation pursuant to the Act on flammable and explosive goods.

Accident risks with an impact on the environment and health and planned safety measures will be reported in future applications. In addition, the prevention of serious chemical accidents resulting from operations and limited in a risk assessment will be described, as part of the safety report.

As the higher level of requirements in SevesoI legislation is reached, the licence application must include an action programme that includes the operational principles governing internal safety work, and a safety report describing risk identification, risk assessment and proposals for possible risk mitigation measures.

6. Preliminary environmental impact

The impact of the energy farm may be felt at all of the project's three different phases as described in the operation description in section 3.3 and covers the construction phase, the operating phase and the decommissioning phase. In addition, environmental impacts can occur in the event of accidents linked to the energy farm, see section 5.

This section deals with the potential environmental impact of the Neptunus energy farm and so must be taken into account in the forthcoming process. The potential transboundary impacts are presented in the following section 7. The forthcoming Espoo report will describe the environmental impacts and their consequences and assessed them in more detail. The assessments of the environmental impacts and its consequences will be based on a worst case- scenario for each recipient group. For example, the effects on marine mammals in terms of noise will be assessed on the basis of the foundation type that generates the highest sound levels in connection with its construction.

6.1. Geology and depth conditions

The main environmental impact on geology and seabed conditions that could occur from the establishment of the energy farm is the loss of existing substrates and the replacement with hard substrates and hard structures for the construction of foundations. The extent of this impact depends mainly on the choice of foundation.

During the construction phase and in connection with facility surveys there will be physical impact on the seabed through geotechnical surveys such as drilling, vibrocorers and cone pressure testing. However, only a very small part of the seabed surface is affected, which is why the potential impact on geology and bottom conditions is considered to be negligible.

The various types of foundations all require tethering to the seabed and therefore also require erosion protection, which leads to an impact on the geology in the vertical direction. The duration of the change in the seabed surface depends partly on the useful life of the energy farm and partly on whether the foundations are removed or left in connection with decommissioning. During the operational and decommissioning phases the impact on geology and seabed conditions is expected to be negligible, as the size of the total seabed surface affected by the foundations is very small.

6.2. Hydrography

Several studies of hydrography have been carried out in connection with the construction of marine structures in Sweden, for example for the Lillgrund wind farm and for the Öresund Bridge (Øresundkonsortiet, 2000; Møller & Edelvang, 2001; Karlsson, et al., 2006). The changes in wave and current patterns observed around the foundations for the wind turbines have been marginal and are not expected to affect the hydrogaphy (Hammar, et al., 2008). As platform foundations are of the same nature as those for the wind turbines, the impact is expected to be the same as for the turbine foundations. However, when seawater is pumped up for electrolysis and oxygen and hot brine is then returned to the sea during hydrogen production, this may affect the hydrography locally. Potential impacts will be investigated and described in more detail in the Espoo Report.

As Neptune is located in the open sea far from the coast and with a significant bottom depth, the impact on hydrography during the construction, operation and decommissioning phase is expected to be negligible.

6.3. Natural environment

6.3.1. *Bottom flora and bottom fauna*

The impact that may occur on the existing natural environments caused by the facility surveys is limited to the sampling points for the geotechnical surveys, where a certain proportion of the existing flora and fauna could be removed or damaged, and to the sediment spread that may occur during the surveys.

The effects on bottom the demersal flora and fauna during the construction phase are mainly due to the physical disturbances to the seabed caused by the installation of foundations, erosion control and internal pipelines. In addition to the risk of direct harm to sessile animals, i.e. the animals that live attached to a surface), the construction of the foundation of the wind can cause the temporary spread of suspended particles. The sediment spread and subsequent sedimentation are largely controlled by existing bottom substrates, water currents and the type of foundation and the installation technology used in their establishment. Drilled piles are an example of the type of foundation that can give rise to sediment spread.

The species that are present in Neptunus are common and are found in large quantities in this part of the Baltic Sea, such as segmented worms and crayfish (DHI, 2016). These species are not expected to be adversely affected by an increase in suspended particles or an increase in sedimentation when living in the sediment. There are also indications of anaerobic conditions at the seabed at the farm site, which means a lack of demersal fauna (Gogina, et al., 2016; Josefsson, et al., 2020). As the distances to the Polish economic zone and the Danish economic zone are about 10 km, no transboundary impact of sediment suspension is expected.

Sediment spread models will be developed to estimate the distribution pattern in connection with the construction of the energy farm. The sediment spread models will serve as a basis for deeper analysis of the effects of sedimentation on demersal flora and fauna in the forthcoming Espoo report.

During the operational phase, the primary impact on demersal organisms is expected to be disturbance and loss of habitats where excavation of the seabed has taken place, foundations and erosion protection have been installed and have replaced existing habitats. The amount of habitat loss depends on the design of the farm, i.e. the the size, design of the hydrogen plans and number of wind turbines and foundations.

A possible change in water temperature and salinity, due to the release of hot brine from hydrogen production, could result in the displacement of cold water and fresh-brackish water species. It could also benefit the infiltration of alien species and their spread in the Baltic Sea. However, this impact is expected to be highly local in centralised hydrogen production, while decentralised hydrogen production is not expected to produce any demonstrable effect except at the discharge sites. Hydrogen production also creates oxygen. OX2 will potentially use this oxygen to oxygenate the bottom water, which could enable demersal animals to be established in places that are currently oxygen-poor or anaerobic. Demersal animals are an important source of food for cod, herring and flatfish, which in turn provide food for birds, other fish and marine mammals. Due to the significant depth, however, no establishment of flora is expected to take place on the seabed despite oxygenation. Potential impacts and potential mitigatory measures to minimise the potential impact of hydrogen production will be analysed in more detail in the forthcoming Espoo report.

Oil spills from ships can occur in various forms of accidents, such as collisions. Wind turbines and transformer/inverter machinery, as well as plant parts for the production, storage and distribution of hydrogen, contain oils and other chemical products that could be released in the event of accidents. Various forms of mitigatory measures will be taken in order to limit the risk of contamination of the sea in the event of such an accident.

Some sediment spread may occur during the decommissioning of foundations and the inter-array, but not to the same extent as during installation. There is otherwise no impact expected on demersal flora and fauna.

6.3.2. *Fish*

Some construction surveys during the construction phase may lead to temporary evasive behaviour of certain species, such as cod, in the vicinity of the survey vessel. Construction surveys will cause noise emissions and sediment spread. However, since the construction surveys are carried out over a short period and the noise emissions around the vessels carrying out these operations take place in a negligible part of the site, the surveys are not expected to cause any significant disturbance.

During the construction phase, increased sedimentation may have an impact on fish, especially roe and larvae as suspended particles can under certain conditions get caught in gills, cover and weigh down roe, disturb foraging behaviour and in total result in poorer conditions for survival. The construction stage is a relatively short phase and the content of suspended material from drilling, for example, can be reduced in various ways, for example by the release of the material suspended at the seabed and not in the upper layers of water. The effect is then that suspended sediment decreases in amount and duration above the halocline. However, Neptune overlaps an important area for the reproduction of the eastern cod population and spreading via currents can mean that a larger area is at risk of being affected. Where necessary, technical or other precautionary measures may be taken to minimise the effect of suspended sediment on cod.

During the construction phase, elevated noise levels may also occur, which could mean physiological effects such as TTS, PTS and internal damage, which in turn can affect fishes' orientation, prey location, communication and recruitment. Noise from the construction phase is considered to have the greatest impact on cod during the spawning period, which is at its most intense from June to August but can extend into September ((Hammar, et al., 2014; Bleil, et al., 2009). Where necessary, technical or other precautionary measures may be taken to minimise the impact of subsea noise.

During the operational period, subsea noise is emitted from the turbines which may cause certain behavioural reactions in fish and mask fishes' own sounds (Popper & Hawkins, 2019). Båmstedt et al. (2009) could not, however, show any clear behavioural changes in fish as a result of the operating noise from wind turbines. However, accumulations of fish observed around foundations following establishment of wind power facilities indicates that the potential impact of noise during the operating phase is negligible.

Construction of foundations can lead to habitat changes that can have a positive effect on the composition of fish communities through the creation of a reef effect. The energy farm could, to some extent, protect fish populations in the area by reducing fishing, in addition to the regulation of cod fishing that already exists (Naturvårdsverket, 2011c).

During the operating phase, electromagnetic fields occur around the inter-array cables that could affect fish such as eels during the migration (Öhman, et al., 2007; Rølvåg, et al., 2020).

OX2 is investigating whether oxygen as a result of hydrogen production may be added to the bottom water. This could potentially oxygenate the deep anaerobic and oxygen-poor bottom waters of the Neptunus energy farm, which occur mainly during the summer period. This in turn could benefit the recruitment of cod from the eastern stock in the energy farm area, as cod needs an oxygen content of over 2 mg/l to spawn (Bergström, et al., 2015). Salinity and temperature may also change, but probably to a limited extent. The impact of hydrogen production will be analysed in the forthcoming Espoo report.

Some sediment spread may occur during the decommissioning of the foundations, inter-array and the internal pipeline network, but not to the same extent as during the construction phase.

6.3.3. *Birds*

During the construction phase, birds may be temporarily displaced by increased vessel traffic and noise-generating work that may take place in the area, such as in connection with construction surveys, installation of wind turbines and hydrogen production platforms. If floating wind turbines are to be installed, installation is likely to take place at port. However, the disruption associated with installation of fixed foundations is limited in time and will take place in smaller sub-areas, which means that large areas without displacement activities will be available throughout the process.

It is mainly during the operational phase that there is a potential risk of an impact on birds. The effects of wind power on birds during operation can be divided into three main factors: displacement effects, barrier effects and collision risks.

Displacement effects mean that a species avoids the energy farm or its surroundings. The impact of displacement effects varies between species where, for example, long-tailed ducks have been shown to avoid wind farms to a large extent, while other seabird species seem unaffected (Nilsson & Green, 2011; Fox & Petersen, 2019). For the auks, guillemots and razorbills, the general situation is for them to avoid a wind farm to some extent in the first few years after its establishment (Dierschke, 2016). It can therefore be expected that the planned wind farm will cause some habitat loss for the auks as their foraging area becomes smaller. However, the counts carried out indicate that sea areas south-west of the survey area, closer to Christiansø, are of greater importance as a foraging area for auks than the energy farm area, see Figure 38. The Erteholmene archipelago, within which Christiansø is located, is a Danish Natura 2000 area.

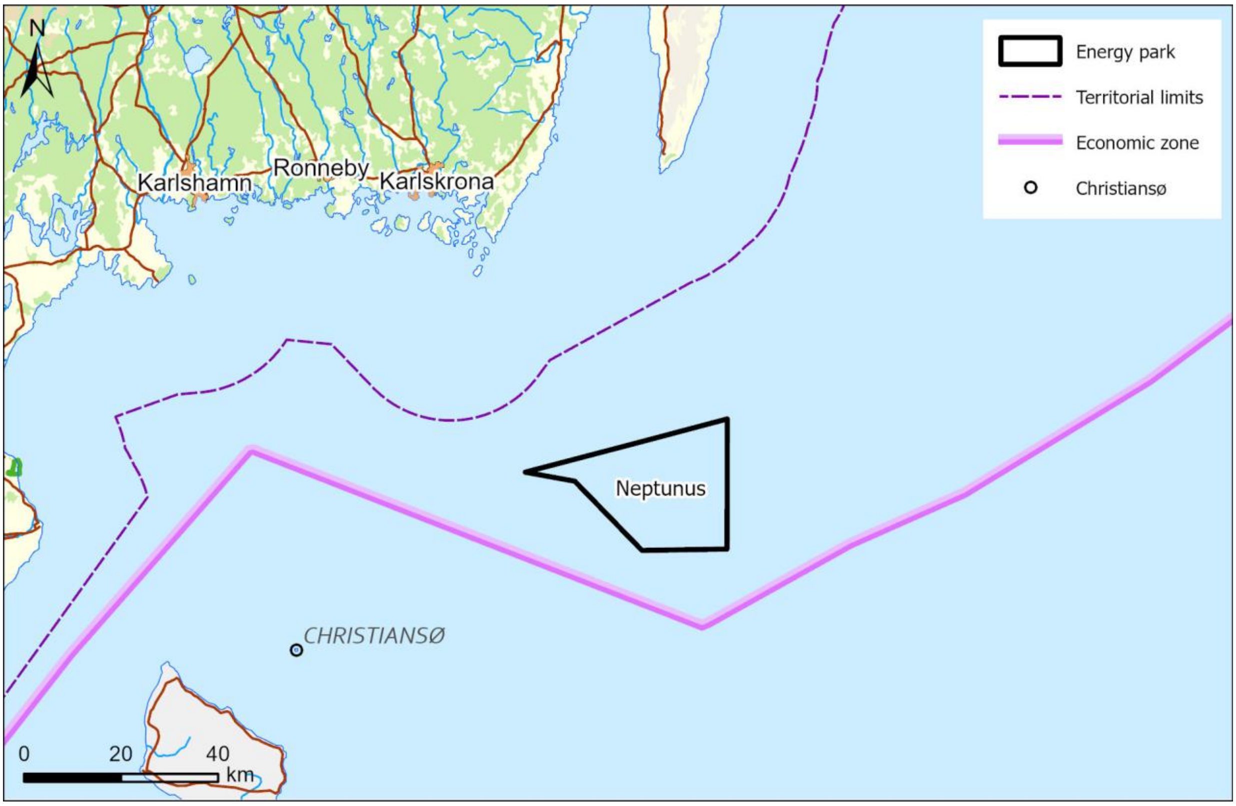

Figure 38. The energy farm site and the island of Christiansø. © [National Land Survey] 2023

Red-throated loon, which have been noted in the Neptunus area, also exhibit avoidance behaviour for offshore wind turbines (Fox & Petersen, 2019). However, it is not clear what the importance of the area for red-throated loon is. As the depth of the energy farm exceeds the depth that at which red-throated loon usually forage, i.e. deeper than 30 metres, the establishment of the energy farm is not expected to have a significant impact on the species.

Collision risk means that birds are injured or killed as a direct result of colliding with the turbine blades or the turbulence that occurs behind the blades. An important factor in assessing the risk of collision is the flight height of the different species. Marine divers and auks normally fly at low altitudes, thus avoiding collisions. In general, the risk of seabirds, such as auks, colliding with wind turbines is small, as they plan flight routes at a safe distance from wind farms. Furthermore, species such as red-throated loon (Petersen, et al., 2014; Mendel, et al., 2019; Vanermen & Stienen, 2019) and long-tailed ducks (Petersen & Nielsen, 2011) avoid flying into wind farms, which also reduces the risk of collisions. However, a collision investigation will be carried out for the Neptunus energy farm.

The third factor of influence is the barrier effect, which means that the energy farm is an obstacle to passing birds. Although this effect reduces the risk of collision, it increases the energy consumption of birds because they risk having to change their flight route to avoid the farm. The possible additional distance can be considered negligible in relation to the total migration route during the autumn and spring (Marsden, et al., 2009).

The main migration corridor does not pass through Neptunus. However, birds could pass sites adjacent to the energy farm In connection with their migration. Actually, most seabirds avoid collisions with wind turbines by either flying around the wind farm or by flying between rows of turbines inside the farm (Fox & Petersen, 2019). In addition, many seabirds fly low above the water surface during the migration. Avoiding flying through the farm means only a very small detour in relation to the total length of the migration of the seabirds passing Neptunus. Furthermore, Neptunus does not obstruct any known routes on which birds fly back and forth during foraging, for example from Christiansø.

The decommissioning of foundations, cables and pipelines may cause noise emissions and some displacement effect may occur due to increased presence of vessels, but not to the same extent as during installation. There is otherwise no impact expected on demersal flora and fauna during the decommissioning phase.

6.3.4. *Marine mammals*

Underwater noise is the influence factor that can principally affect marine mammals in connection with the construction, operation and decommissioning of the Neptunus energy farm. Its impact depends on a number of factors such such intensity and frequency of sound, whether the sound is in the form of impulses or continuous, the salinity of water, bottom conditions, the distance to the sound source, and the hearing spectrum and sensitivity of the animals. High noise levels can mask communication and cause avoidance behaviour in marine mammals. If animals do not avoid the area and are, instead, continuously exposed to high noise levels, they are at risk of temporary hearing loss and then permanent hearing loss.

Some construction surveys, such as seismic surveys with sub-bottom profiles and mini airguns, can affect marine mammals in the form of underwater noise. The sound levels may mean that porpoises and seals avoid an area around the survey vessel where the sound levels are elevated. The impact can be minimised if mitigatory measures are imposed. Survey vessels can carry observers in order to ensure that no marine mammals are present in the immediate vicinity when conducting surveys that emit noise. Subsequently, soft start methods can be used for seismic surveys. The soft start ensures that the animals have time to remove themselves from the vicinity before the surveys are run at full power.

During the construction of foundations for the Neptunus energy farm, principally piling noise may displace marine mammals from the area at which piling takes place. This entails a temporary loss of habitat for the marine mammals. However, the work will be carried out for a limited time, in small sub-areas, which means that large areas without displacing activities will be available throughout the entire construction phase. Porpoises' well-developed sense of hearing makes them susceptible to noise interference. This is especially true of loud impulse noise, such as piling sounds. To minimise interference, several mitigatory measures such as sound damping techniques can be applied to limit the spread of noise during pile-driving work. In order to reduce the impact on porpoises during their most sensitive period, it is also proposed to impose a time restriction with regard to the impact on the Hoburgs bank and Midsjöbankarna Natura 2000 area where the porpoises gather during the summer to feed their calves and mate. With protective measures in place, no significant impact on porpoises is expected.

Seals are less sensitive to underwater noise than porpoises (Kastelein, et al., 2013) Unlike porpoises, seals can also keep their hearing organs above water, which means that they can temporarily escape loud underwater sounds. However, noise from the construction phase can have a displacing effect (Edrén & Andersen, 2010; Brasseur, et al., 2012; Havs- och vattenmyndigheten, 2012; Thompson, et al., 2013). However, the haul-out sites of grey seals and common seals, where they shed fur and breed pups, are not located near Neptunus. The distance from Neptune to the nearest location is about 38 kilometres, so the risk of impact on seals during the construction phase is expected to be very small.

During the operational phase, wind turbines emit low frequency continuous noise to air and water. In four out of the five wind farms studied by Vallejo et al. (2017), porpoises returned in the same numbers as before during the operational phase. According to Tougaard et al. (2009), porpoises need to be within about 100 metres of the turbine to perceive the operating noise. This is because porpoises have relatively poor hearing in the lower frequency ranges that cover the noise from the wind turbines (Kastelein, et al., 2017). In some cases, porpoise density has been higher in the farm area during operation than before, probably due to an increased supply of food because the foundations attract fish (Scheidat, et al., 2011). Reduced vessel traffic can also lead to increased porpoise density. Overall, this indicates that porpoises return to the farm area and that no significant impact on porpoises is expected during the operational phase.

Seals can produce and hear sounds down to 0.1 kilohertz, and are able to hear the noise generated by wind turbines in operation (Kastelein, et al., 2009). Low frequency sounds from artificial sources could therefore interfere with seal communication (Sills, et al., 2015). However, studies of common seals at Nysted and Rødsand II in the western Baltic Sea showed that seals’ movement patterns were not affected by wind turbines in operation (McConnel, et al., 2021). However, studies at the German wind farm Alpha Ventus showed clear indications that common seals are attracted to the foundations of wind turbines, probably due to food availability due to increased biological production at the foundation’s hard substrate (Russel, et al., 2014).

The activities during the decommissioning phase will also lead to noise emissions, for example in connection with cutting when foundations and wind turbines are removed and in connection with the removal of inter-array cabling and pipeline networks. However, the impact on marine mammals during the decommissioning phase is expected to be more limited than during the construction phase.

Prior to the production of the environmental impact assessment, the impact of noise on marine mammals will be investigated further using sound modelling.

6.3.5. *Bats*

The impact on bats during the construction surveys will be limited to the presence of ships and the possible displacement effect that ships may have.

During the construction phase, bats may be temporarily displaced by increased vessel traffic and noise-generating work that may take place in the area, such as installation of wind turbines and hydrogen production platforms. However, the disruption will be limited in time and will occur in smaller areas.

Bats can migrate over water (Hatch, et al., 2013) and the area around Neptunus can potentially be used for migration routes. An important factor in the impact on migratory bats over the sea is flight altitude. Studies have shown that migrant bats across the Baltic Sea fly relatively low, which minimises the risk of collision with the rotor blades of the wind turbines (Ahlén, et al., 2009).

6.4. Ecosystem services and green infrastructure

Several different forms of ecosystem services can be expected to develop around energy farms. The formation of reefs around the foundations leads to the establishment of filtering organisms (Andersson & Öhman, 2010), which could locally create a potentially regulating ecosystem service in the form of locally improved water quality (McLaughlan & Aldridge, 2013). The increase in filtering and photosynthetic organisms around the foundations can contribute to an aggregation of fish, that could benefit the fishing industry, thereby making up a supply ecosystem service (Grove, et al., 1989).

Access to the area will be somewhat restricted during construction of the energy farm. This can have an impact on supply ecosystem services such as the fishing industry and cultural ecosystem services such as recreational fishing and boat trips. Better habitats for commercial species combined with reduced trawling would benefit fishing, which could also provide an important cultural ecosystem service for the local area. Areas around Neptunus are regularly used for commercial fishing, and reduced trawling as a result of the energy farm could probably lead to the recruitment of commercially important species. In the long run, this could lead to a spill-over effect that benefits commercial fishing (Stobart, et al., 2009).

If oxygenation of the bottom water is achieved, the conditions for new habitats will be created, for example by improving access to food for fish. The biodiversity of this part of the Baltic Sea could benefit in the long term due to reduction of the oxygen-poor bottom water in the area. Through this, ecosystem services linked to the organisms can also be generated in the area. This would, for example, benefit fishery in the area around the energy farm further.

6.5. Landscape scenery

Neptunus is located out at sea far from living environments and other settlements. The planned turbines have a potential maximum height of 420 metres and the wind turbines can thus be seen from large distances away in the surrounding seascape. Furthermore, wind turbines with a total height of more than 150 metres need to be marked with obstruction lighting, which can increase visibility for the turbines at night. Neptunus is estimated to be barely visible from the Swedish coast, about 50 kilometres from the energy farm. The coastlines and islands of other neighbouring countries are more than 50 kilometres away from the energy farm, which is why the farm’s visibility is considered to be even less than from the coast of Sweden.

Visualisations and photo-montages have been created from several vantage points in Sweden in order to demonstrate the expected seascape view after the establishment of Neptunus.

6.6. Fishing

Fishing activity is relatively low in the Neptunus area (Havs- och vattenmyndigheten, 2013). Furthermore, cod fishing in the project area is regulated. The impact on fishing will be investigated further in the forthcoming Espoo report.

The Neptunus energy farm may create a so-called reef effect and there are several research studies that have shown that protecting an area from fishing can lead to both an increase in fish biomass and, in the long term, increased income for the fishing industry (Roberts, et al., 2001; Gell & Roberts, 2003; White, et al., 2008; Lester, et al., 2009; Gaines, et al., 2010). National marine plans have also indicated that, for several sea areas, use, energy extraction and nature can co-exist with commercial fishing.

It cannot be excluded that individual fishermen may be affected by the planned energy farm. A worst case scenario for fishing means that commercial fishing will not be possible within the energy farm. The worst case is conservative, as parts of the planned wind farm will probably continue to be able to be used for some types of commercial fishing. However, the existence of foundations, erosion protection, seabed cables and any tethering lines must be taken into account in the event of continued commercial fishing in the wind farm. A conflict of interest cannot, therefore, be excluded, and will be discussed further in the future Espoo report.

6.7. Climate

The construction of the wind farm will have a certain climate impact in the form of new production of the various components of the wind farm and other installations, transport and installation work. The decommissioning phase also involves a certain climate footprint linked to vehicle operation and so on. These activities will be limited in time and scope. During the operational phase, Neptunus will instead contribute with fossil-free energy. Energy production in the farm would have a capacity about 13–15 TWh, which is equivalent to the capacity to supply up to 3 million Swedish households with renewable energy. In other words, the energy farm would play a central part in limiting future climate change and switching to a renewable electricity system.

6.8. Infrastructure and planning conditions

6.8.1. *Maritime activities*

During the construction phase, marine activities may be affected due to the increase in vessel traffic and limited access within the construction site. However, the disruptions will be temporary and limited to the specific area where the construction work is carried out and to the time it is carried out.

Establishment of an energy farm may lead to an increased risk of allisions. An allision between a vessel and a wind turbine could have consequences for the environment in the area. A nautical risk analysis will be carried out and presented in the forthcoming Espoo report.

The production of hydrogen entails a risk of fire and explosion during operations, see section 5.2. Such an explosion may affect approaching passing vessels, such as ships passing through the shipping lanes through the energy farm. However, the risk of this type of accident is minimised by implementing safety distances from the wind turbines in the spatial planning.

6.8.2. *Aviation*

New obstructions in an MSA area can have consequences on aviation traffic and require a revision of flight altitudes in the relevant airspace. Neptunus does not overlap with any MSA airspace and is not expected to affect aviation.

6.8.3. *Military areas*

Neptunus borders on an area for subsea exercises for Sweden, Denmark and Germany. A dialogue will be conducted with the Swedish Armed Forces regarding the minimisation of any impact in this area.

6.8.4. *Environmentally hazardous objects and dumping areas*

Neptunus borders on a hazardous area for dumped chemical weapons. A desk study has been carried out to investigate the potential level of risk in the Neptunus energy farm. The study shows that there are no previously dumped weapons or similar in the energy farm site.

6.9. Cumulative effects

Cumulative effects refer to the effects of other activities or measures that may have environmental effects within the impact area of the project in question. Cumulative effects can occur when several different effects interact with each other– both by the fact that a different types of effects from one and the same activity interact or by the fact that a effects from different activities interact. The Espoo report will identify and assess cumulative effects from existing and licensed activities in the area. Cumulative effects may include, for example, impacts on birds, fish and marine mammals from various types of activity within a geographical area.

There are currently no existing wind farms or other facilities covered by SevesoI legislation in the vicinity of Neptunus. There are, however, plans for other wind farms in the Baltic Proper (4COffshore wind, 2022), which– depending on whether they have obtained a license at the time of the environmental impact assessment– can and should be taken into account when assessing cumulative effects.

In addition, the Espoo report will include potential cumulative effects from other activities in the area, such as those from shipping, cables and pipelines.

7. Potential transboundary impacts

The future Espoo report that is prepared in accordance with Article 4 of the Espoo Convention, will assess and describe the expected transboundary impact. The main transboundary impact that could arise is set out in this chapter.

7.1. Birds

The potential impact on birds described in section 6.3.3 may extend beyond the Swedish EEZ, inter alia in view of the fact that certain species of birds move over very large areas and are therefore found within the maritime territories and zones of several different countries . For example, the area around Christiansø, about 70 kilometres south-west of Neptunus, is of importance to birds, including auks. The impact on birds in the Swedish EEZ is expected to be limited, which means that the potential transboundary impact can also be expected to be limited. The impact on birds will be described in the future Espoo report.

7.2. Marine mammals

Porpoises, grey seals and common seals are identified species in several Swedish, Polish, German and Danish Natura 2000 sites. The potential impacts described in section 6.3.4 may extend beyond the Swedish border, since the areas these species occur in may comprise parts of the territory of several countries. The impact on marine mammals in the Swedish EEZ is expected, given the application of mitigatory measures, to be limited, which means that the potential transboundary impact can also be expected to be limited. The impact on marine mammals will be described in the future Espoo report.

7.3. Landscape scenery

The possible effects on the landscape described in section 6.5 may potentially have a transboundary impact as well. Neptune is located at sea, about 50 kilometres from the Swedish mainland and about 70 kilometres from the Danish island of Christiansø. Distances are longer to other countries. The effect on landscape scenery in the Swedish EEZ is expected to be limited, which means that the potential transboundary impact can also be expected to be limited.

7.4. Fishing

The potential impact on fishing described in section 6.6 may also include commercial fishermen from other countries. The impact on fishing within Sweden’s economic zone is expected to be limited, although it cannot be excluded that individual fishermen may be affected by the planned energy farm. This means that the potential transboundary impact can also be expected to be limited. The impact on fishing will be described in the future Espoo report.

7.5. Maritime activities

The potential impact described in section 6.8.1 may also have a transboundary impact, mainly in the form of possible temporary effects on the maritime traffic in the area due to increased boat traffic and possible closures in the construction area. Three areas of national interest for shipping border on the Neptunus energy farm; the shipping route *Gedser-Svenska Björn* (deep water route and designated by the international body IMO), *Bornholmsgatt – Klaipeda*, which is a new area of national interest for shipping and the shipping route *Karlskrona – Gdynia*.

There is a risk of impact on shipping in the form of increased allision risk and accidents linked to the production of hydrogen gas. A nautical risk analysis will be carried out and presented in the forthcoming Espoo report.

7.6. Military areas

As Neptune borders on an area for subsea exercises, dialogue with the Swedish Armed Forces will be conducted to avoid any impact. This will also be discussed in the forthcoming Espoo Report.

7.7. Cumulative effects

The possible cumulative effects described in section 6.9 may potentially have a transboundary impact as well. The cumulative effects in the Swedish EEZ are expected to be limited, which means that the potential transboundary impact can also be expected to be limited. The cumulative effects will be described in the future Espoo report.

10. References

4COffshore wind, 2022. *4Coffshore wind kartverktyg.* [Online]
Available at: https://www.4coffshore.com/offshorewind/index.aspx?lat=56.495&lon=-2.196&wfid=UK54 .

Ahlén, I. & Baagøe, H. J., 2013. *Bats and wind power- investigations required for risk assessment in Denmark and Sweden.* Stockholm, s.n., pp. 5-7.

Ahlén, I., Baagøe, H. J. & Bach, L., 2009. Behavior of Scandinavian bats during migration and foraging at sea. *Journal of Mammalogy 90,* pp. 1318-1323.

Andersson, M. H. & Öhman, M. C., 2010. Fish and sessile assemblages associated with wind-turbine constructions in the Baltic sea. *Marine and Freshwater research,* Volume 61, pp. 642-650.

ArtDatabanken, 2020. *Rödlistade arter i Sverige 2020,* Uppsala: SLU.

Benke, H. et al., 2014. Baltic Sea harbour propoise populations: Status and conservation needs derived from recent survey results. *Marine Ecology Progress Series,* Volume 495, pp. 275-290.

Bergström, L. et al., 2012. *Vindkraftens effekter på marint liv - En syntesrapport,* s.l.: Vindval.

Bergström, U. et al., 2015. *Genetisk undersökning av torsk från Ålands hav,* s.l.: SLU.

Bleil, M., Oeberst, R. & Urrutia, P., 2009. Seasonal maturity development of Baltic cod in different spawning areas: importance of the Arkona sea for the summer spawning stock.. *Journail of Applied Ichtyology,* Volume 25, p. 10.17.

Bleil, M., Oeberst, R. & Urrutia, P., 2013. Seasonal maturity development of Baltic cod in different spawning areas: importance of the Arkona sea for the summer spawning stock. *Journal of applied ichtyology,* Volume 25, pp. 10-17.

Bogdanowicz, W. et al., 2013. Population genetics and bat rabies: a case study of Eptesicus serotinus in Poland. *Acta Chiropterologica,* 15(1), pp. 35-56.

Bogren, J., Gustavsson, J. & Williams, M., 2019. *Klimatförändringar - Naturliga och antropogena orsaker,* s.l.: s.n.

Brandt, M. J. et al., 2018. Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. *Marine Ecology progress series,* Volume 596, pp. 213-232.

Brasseur, S. M. J. M. et al., 2012. *Habitat preferences of harbour seals in the Dutch coastal area: analysis and estimate of effects of offshore wind farms.,* s.l.: Report C043-10.

Båmstedt, U. et al., 2009. *Effekter av undervattensljud från havsbaserade vindkraftsverk på fisk från bottniska viken. Rapport 5924,* s.l.: Naturvårdsverket.

Carlén, I. et al., 2018. Basin-scale distribution of harbour porpoises in the baltic Sea provides basis for effective conservation actions. *Biological Conservation,* Volume 226, pp. 42-53.

CMEMS, 2020. *Baltic Sea Hindcast,* s.l.: s.n.

DHI, 2016. *Infauna Report for Swedish Waters 2015,* s.l.: Nord Stream 2 project No 150814.

DHI, 2016. *Infauna Report for Swedish Waters in 2015. Environmental Baseline Survey of Seabed Sediments, Hydrological Conditions, Benthic Bottenfauna and Chemical Warfate Agents in Sweden and Denmark. Nordstream 2. Project No.:150814,* s.l.: s.n.

Diaz, R. J. & Rosenberg, R., 2008. Spreading dead zones and consequences for marine ecosystems. *science,* 321(5891), pp. 926-929.

Dierschke, V. F. R. o. G. S., 2016. *Seabirds and offshore wind farms in European waters: Avoidance and attraction. Biological Conservation 202,59-68,* s.l.: s.n.

Durinck, J. S. H. J. F. &. P. S., 1994. *Important marine areas for wintering birds in the Baltic Sea – EU DG XI Research Contract no. 2242/90-09-01. Ornis Consult Report 1994, 110 pp.,* s.l.: s.n.

Edrén, S. & Andersen, S., 2010. *The effect of large danish offshore wind farm on harbor and gray seal haul-out behavior,* s.l.: s.n.

EMODnet, 2022. *EMODnet.* [Online]
Available at: https://www.emodnet.eu/

Energimyndigheten & Havs och vattenmyndigheten, 2023. *Samexistens mellan havsbaserad vindkraft, yrkesfiske, vattenbruk och naturvård,* s.l.: s.n.

Energimyndigheten, 2021. *Energiindikatorer 2021 Uppföljning av Sveriges energipolitiska mål, ER 2021:10,* s.l.: Energimyndigheten.

European Environment Agency, 2022. *Natura 2000 data - the European network of protected sites.* [Online]
Available at: https://www.eea.europa.eu/en/datahub/datahubitem-view/6fc8ad2d-195d-40f4-bdec-576e7d1268e4

Europeiska kommissionen, 2020. *Communication from the commisson to the European parliament, the council, the European economic and social committee and the committe of the regions. A hydrogen strategy for a climate-neutral Europe,* Brussels: European Commission.

Florén, K., Hansson, P. & Skoglund, S., 2017. *Vegetationsklädda bottnar i Gävleborgs läns kustvatten - Trendövervakning 2016,* s.l.: Länsstyrelsen Gävleborg, Rapport 2017:5. 58 pp.

Fox, A. D. & Petersen, I., 2019. Offshore wind farms and their effects on birds. *Dansk Ornitologisk Forenings Tidskrift,* Volume 113, pp. 86-101.

Försvarsmakten, n.d. *Riskområden.* [Online]
Available at: https://www.forsvarsmakten.se/sv/information-och-fakta/for-dig-som-privatperson/upphittad-ammunition/riskomraden/

Gaines, S. D., White, C., Carr, M. H. & Palumbi, S. R., 2010. Designing marine reserve networks for both conservation and fisheries management. *proceedings of the National Academy of Sciences ,* Volume 107, pp. 18286-18293.

Gell, F. R. & Roberts, C. M., 2003. Benefits beyond boundaries: the fishery effects of marine reserves. *Trends in ecology & evolution,* 18(9), pp. 448 - 455.

Gogina, M. et al., 2016. The Baltic Sea scale inventory of benthic faunal communities. *ICES Journal of Marine Science,* 73(4), pp. 1196-1213.

Grove, R. S., Sonu, C. J. & Nakamura, M., 1989. Recent Japanese trends in fishnig reef desing and planning. *Bulletin of Marine Science,* Volume 44, pp. 984-996.

Hammar, L., Andersson, S. & Rosenberg, R., 2008. *Miljömässig optimering av fundament för havsbaserad vindkraft,* s.l.: Naturvårdsverket. Vindval rapport 5828.

Hammar, L., Wikström, A. & Molander, S., 2014. Assessing ecological risks of offshore wind power of Kattegat cod. *Renewable energy,* Volume 66, pp. 414-424.

Hatch, S. K. et al., 2013. *Offshore observations of eastern red bats (Lasiurus borealis) in the mid Atlantic Unites States using Multiple Survey methods,* s.l.: PLoS ONE 8, e83803.

Havet.nu, 2018. *Ammunition och kemiska stridsmedel.* [Online]
Available at: https://www.havet.nu/ammunition-och-kemiska-stridsmedel

Havs- och vattenmyndigheten, 2012. *Nationell förvaltningsplan för gråsäl (Halichoerus grypus) i östersjön,* s.l.: Havs- och vattenmyndigheten.

Havs- och vattenmyndigheten, 2013. *Geografisk spårbarhet av Fiskefartyg - VMS - Fiske och handel,* s.l.: Havs- och vattenmyndigheten.

Havs- och vattenmyndigheten, 2018. *Fångstdata Östersjön, 2009-2018. Utdrag från Havs- och vattenmyndighetens databas,* s.l.: s.n.

Havs- och vattenmyndigheten, 2021a. *Villkor för fiske under vissa fredningsperioder i Östersjön.* [Online]
Available at: https://www.havochvatten.se/arkiv/nytt-om-fiskeregler/2021-04-22-villkor-for-fiske-under-vissa-fredningsperioder-i-ostersjon.html

Havs- och vattenmyndigheten, 2021b. *Fisk och skaldjursbestånd i hav och sötvatten 2020, Resursöversikt,* s.l.: Rapport 2021:6. ISBN 978-91-89329-05-8.

Havs- och vattenmyndigheten, 2022. *Havsplaner för Bottniska viken, Östersjön och Västerhavet,* s.l.: Havs- och vattenmyndigheten.

HELCOM, 2015. *Core indicator report - Population trends and abundance of seals.* [Online]
Available at: http://helcom.fi/Pages/search.aspx?k=seal%20monitoring.

HELCOM, 2018a. *Population trends and abundance of seals.* [Online]
Available at: https://helcom.fi/media/core%20indicators/Population-trends-and-abundance-of-seals-HELCOM-core-indicator-2018.pdf

HELCOM, 2018b. *Distribution of Baltic seals. HELCOM core indicator report.* [Online]
Available at: https://helcom.fi/media/core%20indicators/Distribution-of-Baltic-seals-HELCOM-core-indicator-2018.pdf

HELCOM, 2022. *Helcom map and data service.* [Online]
Available at: http://maps.helcom.fi/website/mapservice/

ICES DATRAS, 2023. *ICES Database on Trawl Surveys (DATRAS),* Copenhagen, Denmark: ICES.

ICES, 2014a. *Database of Trawl Surveys (DATRAS),* Copenhagen. Updated: 2021: ICES.

ICES, 2014b. *Manual for the Baltic Interational Trawl Surveys (BITS),* s.l.: Series of ICES Survey protocols. SISP 7 - BITS.

ICES, 2018. *ICES fisheriess overviews - Baltic sea ecoregion,* s.l.: s.n.

ICES, 2019. *Expert group reports, benchmark workshop on Baltic cod stocks (WKBALTCOD2),* s.l.: ACOM. 5/27/2019 3:02 PM, Lise Cronne.

ICES, 2020. Baltic fisheries assessment working group (WGBFAS). *ICES Scientific Reports,* 2(45), p. 643.

ICES, n.d. *ICES statistical rectangles.* [Online]
Available at: https://www.ices.dk/data/maps/Pages/ICES-statistical-rectangles.aspx

IPBES, 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services,* Bonn, Germany: IPBES Secretariat.

Jordbruksverket & Havs- och vattenmyndigheten, 2016. *Svenskt yrkesfiske 2020 - Hållbart fiske och nyttig mat.,* s.l.: Havs- och vattenmyndigheten.

Josefsson, S., Larsson, O. & Törnqvist, O., 2020. *Fosfor och andra grundämnen i kust- och utsjösediment,* s.l.: SGU-rapport 2020-05. Dnr 35-1243/2019.

Karlsson, A., Liungman, O. & Lindow, H., 2006. *Överslagsberäkning av vertikalblandning vid Skottarevet vindpark,* s.l.: SMHI.

Kastelein, R. A., Gransier, R. & Hoek, L., 2013. Comparative temporary treshold shifts in a harbour porpoise and harbor seal, and severe shift in a seal. *The journal of the Acoustical Society of America,* Volume 134, pp. 13-16.

Kastelein, R. A. et al., 2009. Underwater detection of tonal signals between 0,125 and 100 kHz by harbor seals (Phoca vitulina). *Journal of the Acoustical Society of America,* Volume 125, pp. 1222-1229.

Kastelein, R., Helder-HOEK, L. & Van de Voorde, S., 2017. Hearing Treshold of a male and a female harbour porpoises. *Journal of the Acoustical Society of America,* 142(2).

Kullander, S. O., Nyman, L., Jilg, K. & Delling, B., 2012. *Nationalnyckeln till Sveriges flora och fauna. Strålfeniga fiskar. Actinopterygii,* Uppsala: ArtDatabanken, SLU.

Kågesten, G., Baumgartner, F. & Frejre, F., 2020. *High-resolution benthic habitat mapping of Hoburgs bank, Baltic sea,* s.l.: SGU-rapport 2020:34.

Lara, A., Peters, D., Fichter, T. & Guidehouse, 2021. *The role of gas and gas infrastructure in Swedish decarbonisation pathways 2020-2045. Energiforsk report 2021:788,* s.l.: Energiforsk.

Larsson, K., 2016. *Sjöfart och naturvärden vid utsjöbankar i centrala Östersjön,* s.l.: s.n.

Larsson, K., 2018. *Sjöfåglars utnyttjande av havsområden runt Gotland och Öland: betydelse av amrint områdesskydd.,* s.l.: Länsstyrelsen i Gotlands län, rapport 2018:2.

Lennerhag, O., Bollen, M., Ackeby, S. & Rönnberg, S., 2014. *Spänningsvariationer och intermittent produktion. Elforsk rapport 14:42,* s.l.: Elforsk.

Lester, S. E. et al., 2009. Biological effects within no-take marine reserves: a global synthesis.. *Marine Ecology Progress Series,* Volume 384, pp. 33-46.

Länsstyrelsen, 2021. *Bevarandeplan för Natura 2000-området SE0330308 Hoburgs bank och Midsjöbankarna.,* s.l.: Länsstyrelsen Gotlands län och Kalmars län.

Länsstyrelserna, 2022. *Geodatakatalogen.* [Online]
Available at: https://ext-geodatakatalog.lansstyrelsen.se/GeodataKatalogen/

Madsen, P. T. et al., 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs.. *Marine Ecology progress series,* Volume 309, pp. 279-295.

Marsden, E. A. et al., 2009. Barriers to movement: impacts of wind farms on migrating birds. *ICES Journal of Marine Science,* Volume 66, pp. 746-753.

McConnel, B., Lonergan, M. & Dietz, R., 2021. *Interaction between seals and offshore wind farms,* s.l.: The Crown Estate, 41 pp.

McLaughlan, C. & Aldridge, D. C., 2013. Cultivation of Zebra mussels (Dreissena polymorpha) within their invaded range to improve water quality in reservoirs.. *Water research,* Volume 47, pp. 4357-4369.

Mendel, B. et al., 2019. Operational offshore wind farms and associated ship traffic cause profound changes in distribution patterns of Loons (Gavia spp). *Journal of Environmental Management,* Volume 231, pp. 429-438.

Miljödepartementet, 2020. *Sweden's long-term strategy for reducing greenhouse gas emissions,* s.l.: Miljödepartementet.

Moussy, C. et al., 2015. Population genetic structure of serotine bats (Eptesicus Serotinus) across Europe and implications for the potential spread of bar rabies (European bat lyssavirus EBLv-1). *heredity,* 115(1), pp. 83-92.

Møller, A. L. & Edelvang, K., 2001. *Lillgrund vindpark. Assessment of effects to the zero solution in Öresund,* s.l.: DHI.

Naturvårdsverket, 2006. *Inventering av marina naturtyper på utsjöbankar,* Stockholm: Naturvårdsverket. Rapport 5576.

Naturvårdsverket, 2010. *Undersökning av utsjöbankar,* Stockholm: Naturvårdsverket. Rapport 6385.

Naturvårdsverket, 2010. *Undersökning av Utsjöbankar. Inventering, modellering och naturvärdesbedömning,* s.l.: Rapport 8365.

Naturvårdsverket, 2011a. *Rev, EU-kod 1170. Vägledning för svenska naturtyper i habitatdirektivets bilaga 1 NV-04493-11,* s.l.: s.n.

Naturvårdsverket, 2011b. *Sandbankar, EU-kod 1110. Vägledning för svenska naturtyper i habitatdirektivets bilaga 1 NV-04493-11,* s.l.: s.n.

Naturvårdsverket, 2011c. *Reglering av fiske i skyddade havsområden,* s.l.: Projektrapport. Rapport 6416.

Naturvårdsverket, 2014. *Biogena rev. Beskrivning och vägledning för biotopen biogena rev i bilaga 3 till förordningen (1998:1252) om områdesskydd enligt miljöbalken m.m.,* s.l.: Naturvårdsverket.

Naturvårdsverket, 2020. *Sveriges arter och naturtyper i EU:s art- och habitatdirektiv.,* s.l.: Resultat från rapportering 2019 till EU av bevarandestatus 2013-2018. naturvardsverket.se/publikationer.

Nilsson, L., 2016. Changes in numbers and distribution of wintering Long-tailed ducks Clangula hyemalis in Swedish waters during the last fifty years. *ORNIS SVECIA,* Volume 26, pp. 162-176.

Nilsson, L. & Green, M., 2011. *Birds in southern Öresund in relation to the windfarm at Lillgrund. Final report of the monitoring program 2011-2011,* s.l.: Rapport från Biologiska institutionen, Lunds universitet..

Njord Offshore Wind, 2022. *Project Beta samrådsunderlag,* s.l.: Njordr Offshore Wind AB.

Norling, P. & Kautsky, N., 2007. Structural and functional effects of Mytilus edulis on diversity of associated species and ecosystem functioning. *Mar Ecol Prog Ser,* Volume 351, pp. 163-175.

Näslund, J. B. J., Fyhr, F. & Isaeus, M., 2019. *Kartering av naturvärden på Hoburgs bank,* s.l.: Havs- och vattenmyndighetens rapport 2019:XX.

Offshore, 4., 2023. *Baltic Central Offshore Wind Farm Floating Wind Farm.* [Online]
Available at: https://www.4coffshore.com/windfarms/sweden/baltic-central-offshore-wind-farm-sweden-se1j.html

Offshore, 4., 2023. *Bornholm Bassin Öst Floating Wind Farm.* [Online]
Available at: https://www.4coffshore.com/windfarms/denmark/bornholm-bassin-%C3%B8st-denmark-dk2c.html

Perrow, M. R., 2019. *Wildlife and wind farms, conflicts and solutions. Volume 4 Offshore: monitoring and mitigation. Pelagic Publishing, Exeter, UK,* s.l.: s.n.

Petersen, I. K., Nilesen, R. D. & Mackenzie, M. L., 2014. *Post-construction evaluation of bird abundances and distributions in the Horns Rev 2 offshore wind farm area, 2011 and 2012.,* s.l.: Report commissioned by DONG energy, Aarhus university, DCE- Danish centre for environment and energy. 51 pp.

Petersen, I. & Nielsen, R., 2011. *Abundance and distribution of selected waterbird species in Danish marine areas,* s.l.: Report commissioned by Vattenfall A/S. National Environmental Research Institute, Aarhus university, Denmark. 62 pp..

Popper, A. N. & Hawkins, A. D., 2019. An overview of fish bioacoustics and the impacts of antropogenic sounds on fishes.. *Journal of Fish Biology,* 94(5), pp. 692,713.

Regeringskansliet, 2022. *Nationell strategi för elektrifiering - en trygg, konkurrenskraftig och hållbar elförsörjning för en historisk klimatomställning, en sammanfattning,* s.l.: s.n.

Riksantikvarieämbetet, 2016. *Vision för kulturmiljöarbete till 2030,* s.l.: s.n.

Riksantikvarieämbetet, 2019. *Fornsök Fartyg och båtlämning.* [Online]
Available at: https://app.raa.se/open/fornsok/lamning-query

Roberts, C. M. et al., 2001. Effects of marine reserves on adjacent fisheries. *Science,* Volume 294, pp. 1920-1923.

Russel, D. F. et al., 2014. Marine mammals trace anthropogenic structures at sea.. *Current Biology,* Volume 24, pp. 638-639.

RWE Renewables, n.d. *Utvecklingsprojekt Söda Midsjöbanken.* [Online]
Available at: https://sodra-midsjobanken.rwe.com/

Rydell, J. O. R. P. S. &. G. M., 2017. *Vindkraftens påverkan på fåglar och fladdermöss. Uppdaterad syntesrapport 2017. Rapport 6740,* s.l.: Naturvårdsverket.

Rølvåg, T., Hagen, A. B., Hagen & T, B., 2020. *Shark attacks on offshore streamer cables,* s.l.: Enginering failure analysis 110, 104403.

SAMBAH, 2016. *Static acoustic monitoring of the Baltic sea harbour porpoise (SAMBAH),* s.l.: Final report under the LIFE+ project LIFE08 NAT/S/000261. Kolmårdens Djurpark AB SE-618 92 Kolmården, Sweden. 81 pp.

Scheidat, M. et al., 2011. *Harbour porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea. ,* s.l.: Environmental Research Letters 6: 025102.

SGU, 2021. *Geologiska förutsättningar för koldioxidlagring.* [Online]
Available at: https://www.sgu.se/samhallsplanering/ccs-koldioxidlagring/geologiska-forutsattningar-for-koldioxidlagring/

Sills, J. M., Southall, B. L. & Reichmuth, C., 2015. Amphibious hearing in ringed seals (Pusa hispida): underwater audiograms, aerial audiograms and critical ratio measurements.. *Journal of experimental biology,* 218(14), pp. 2250-2259.

Sjöberg, M. & Ball, J. P., 2000. Grey seal, Halichoerus grypus, habitat selection around halout sites in the Baltic sea: bathymetry or central-place foraging?. *Canadian Journal of Zoology,* Volume 78, pp. 1661-1667.

Skov, H. et al., 2011. *Waterbird populations and pressures in the Baltic sea,* s.l.: TemaNord 2011:550. Nordic Council of Ministers, Copenhagen.

SLU ArtDatabanken, 2020. *Rödlistade arter i Sverige 2020,* Uppsala: SLU.

SLU, 2021. *Om biologisk mångfald.* [Online]
Available at: https://www.slu.se/centrumbildningar-och-projekt/centrum-for-biologisk-mangfald-cbm/biologisk-mangfald/om-biologisk-mangfald/

SMHI, 2019. *Oxygen Survey in the Baltic Sea 2019 - Extent of Anoxia and Hypoxia. Report No. 67, 2019,* s.l.: SMHI.

SMHI, 2020. *Oxygen Survey in the Baltic Sea 2020 - Extent of Anoxia and Hypoxia. Report No. 70, 2020,* s.l.: SMHI.

SMHI, 2021. *Oxygen survey in the Baltic Sea 2021 - Extent of Anoxia and Hypoxia, 1960 - 2021.,* s.l.: Report Oceanography No. 72, 2021.

SMHI, 2022a. *Framtida medelvattenstånd,* https://www.smhi.se/klimat/stigande-havsnivaer/framtida-medelvattenstand-1.165493: s.n.

SMHI, 2022b. *Havsis - Isobservationer.* [Online]
Available at: https://www.smhi.se/data/oceanografi/havsis

Stigebrandt, A., 2021. *Vårt gemensamma innanhav : finskt och svenskt kring Östersjön.,* s.l.: Kungl. vetenskaps- och vitterhets-samhället..

Stobart, B. et al., 2009. Long-term and spillover effects of a marine protected area on an exploited fish community.. *Marine Ecology Progress series,* Volume 384, pp. 47-60.

Thompson, P. M. et al., 2013. Framework for assessing impacts of pile-driving noise from offshore wind farm construction on a harbour seal population. *Environmental Impact Assessment Review,* Volume 43, pp. 73-85.

Tollit, D. J. et al., 1998. Variations in harbour seal Phoca vitulina diet and dive-depths in relation to foraging habitat.. *Journal of Zoology,* 244(2), pp. 209-222.

Tougaard, J., Henriksen, O. & Miller, L. A., 2009. Underwater noise from three offshore wind turbines: estimation of impact zones for harbor porpoises and harbor seals.. *Journal of the Acoustical Society of America,* Issue 125, pp. 3766 - 3773.

Tougaard, J. & Mikaelsen, M., 2018. *Effects of large turbines for the offshore wind farm at Krieger's Flak, Sweden. Assessment of impact on marine mammals,* s.l.: Scientific report No. 286. Aarhus University, NIRAS.

Trafikverket, 2014. *Vindkraft och civil luftfart- en modell för prövning av vindkraftverk i närheten av flygplatser.,* s.l.: Trafikverket publikationsnummer 2014:045.

Umeå universitet, 2021. *Växters upptag av koldioxid riskerar minska.* [Online]
Available at: https://www.forskning.se/2021/04/06/vaxters-upptag-av-koldioxid-riskerar-att-minska/#

Vallejo, G. C. et al., 2017. Responses of two marine top predators to an offshore wind farm.. *Ecology and evolution,* 7(21), pp. 8698-8708.

Vanermen, N. & Stienen, E. W. M., 2019. *Seabirds: displacement.,* s.l.: 174-205 Perrow, M, R (ed) 2019. Wildlife and wind farms, conflict and solutions. Volume 3 offshore: potential effects. Pelagic Publishing, Exeter, UK.

Villnäs, A. et al., 2013. The role of recurrent disturbances of ecosystem multifunctionality. *Ecology,* 94(10), pp. 2275-2287.

White, C. et al., 2008. Marine reserve effects on fishery profit.. *Ecology letters,* Volume 11, pp. 370-379.

Öhman, M. C., Sigray, P. & Westerberg, H., 2007. Offshore windmills and the effects of electromagnetic fields on fish.. *Ambio,* Volume 36, pp. 630-633.

Øresundkonsortiet, 2000. *Environmental impact of the construction of the Øresund fixed link,* s.l.: Copenhagen 96 pp.

Örstedt, 2023. *Baltic Central Havsindpark.* [Online]
Available at: https://orsted.se/havsbaserad-vindkraft/vara-projekt