Energistyrelsen

NORTH SEA ENERGY ISLAND

Framework for the coming draft plan to be used for the strategic environmental assessment

Office/department
Centre for Energy Islands

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Contents

Introduction

The *Climate agreement for energy and industry etc.* of 22 June 2020, and later supplementary agreements, commit Denmark to building the world's first energy islands – one in the North Sea and one on Bornholm. The energy island in the North Sea is to be built in phases, as electricity consumption rises and the energy island is connected to other countries. It has been decided that the North Sea Energy Island must be realised with at least 3 GW of offshore wind power by 2033 (phase one), and that the offshore wind capacity must be expanded to at least 10 GW as soon as possible thereafter, with 2040 as the aim (phase two), depending on the necessary international connections being in place.

In relation to the strategic environmental assessment (SEA) of the North Sea Energy Island, it is assumed that it must include establishment in two phases:

- A first phase in which at least 3 GW of offshore wind power will be established, but with the possibility of up to 12 GW within the same area if the power per km^2 is increased
- A second phase in which a total of at least 10 GW of offshore wind power is established (phase one and two), but with the possibility of establishing a total of up to 40 GW (phase one and two) within the same area if the power per km^2 is increased
- The North Sea Energy Island will thus comprise at least 3 GW of offshore wind power in 2033, and a total of at least 10 GW offshore wind power with 2040 as the target time frame, with the possibility of establishing total offshore wind power of up to 40 GW if the power per km^2 is increased.

The SEA will be broader than the political agreements, to ensure flexibility in the implementation of one of the largest construction projects seen in recent years. Both phase one and two must allow for Power-to-X (PtX) plants[1] and other innovation.

The aim of the energy islands is to ensure that Denmark can electrify more areas of society in the coming years, and to help ensure that the electricity consumption of all Danish households and businesses is met by green electricity. Energy from the energy islands can be exported to neighbouring countries and contribute to the green transition across Europe. It has to be possible to connect technologies which can store or convert electricity from renewable energy from the offshore wind turbines, for example into green fuels using PtX.

[1] Note that there is currently no legal framework for PtX plants, and that work is being done to establish the framework for the field.

Proposed plan for the Programme North Sea Energy Island

The purpose of the plan for Programme North Sea Energy Island is to set the framework for the Programme North Sea Energy Island. This framework applies to the SEA of the plan, and may extend beyond the political agreements in order to ensure political flexibility in relation to subsequent decisions. A SEA of the plan must be carried out, including all sub-elements of the Plan for Programme North Sea Energy Island. The SEA of the plan comprises two phases and must cover the establishment, operation and decommissioning phases of the sub-elements of the plan. The phases may overlap in time and spatially. The final draft of the plan and accompanying environmental assessment is expected to be complete and submitted for consultation in the second half of 2023.

The plan is expected to contain the following elements:

Phase one of the Programme North Sea Energy Island covers:

- a flexible artificial island[2] with associated platforms for transmission equipment,
- at least 3 GW of offshore wind power (but if the power per km^2 is increased, it will be possible to establish up to 12 GW within the same area), an internal cable network and submarine cables to the island,
- platforms for transmission equipment, including for electricity transmission and energy conversion,
- submarine cables to the west coast of Jutland,
- submarine cables (interconnectors[3]) abroad,
- the possibility of PtX plant on platforms/installations or the artificial island with associated pipelines to Jutland and/or abroad,
- the possibility of innovation plant (other than PtX) on platforms/installations or the artificial island,
- onshore plant in Jutland (underground cables and high-voltage substation, including HVAC/HVDC converter station).

Phase two of the Programme North Sea Energy Island covers:

- establishing a total of at least 10 GW offshore wind power (phase one and two) in line with the political agreements, but if the power per km^2 is increased, it will

[2] In line with the press releases of 5 July 2022 regarding a flexible island concept which makes it possible to combine an artificial island with electricity transmission and energy conversion on platforms near the island, but without limiting the possibilities for innovative activities (e.g. PtX) and flexibility on the island, within the applicable regulatory and safety frameworks.

[3] Cable connections that connect Denmark to other partner countries

be possible to establish up to 40 GW (phase one and two) within the same area, an internal cable grid and submarine cables to the island or platforms,
- platforms for transmission equipment, including for electricity transmission and energy conversion,
- the option of submarine cables to the west coast of Jutland,
- submarine cables (interconnectors) abroad,
- the possibility of PtX plant on platforms/installations or the artificial island with associated pipelines to Jutland and/or abroad,
- the possibility of innovation plant (other than PtX) on platforms/installations or the artificial island,
- the possibility of onshore facilities in Jutland (underground cables, a possible coastal switching station[4], a high-voltage substation, including any HVAC/HVDC converter substations),
- and the possibility of grid reinforcements.

[4] A 'switching station' is a high-voltage substation which transforms a number of cables into fewer cables at a higher voltage level. This is only relevant if the electricity from the artificial island is brought ashore as alternating current (HVAC).

Programme North Sea Energy Island – Phase one

Offshore construction sites

The flexible island concept and the offshore wind farms with associated submarine cables (area under the first point above) will be placed within the area in the North Sea indicated by green hatching in *Figure 1*. The area lies within the area for renewable energy and energy islands designated in the consultation draft for the Danish Marine Spatial Plan.

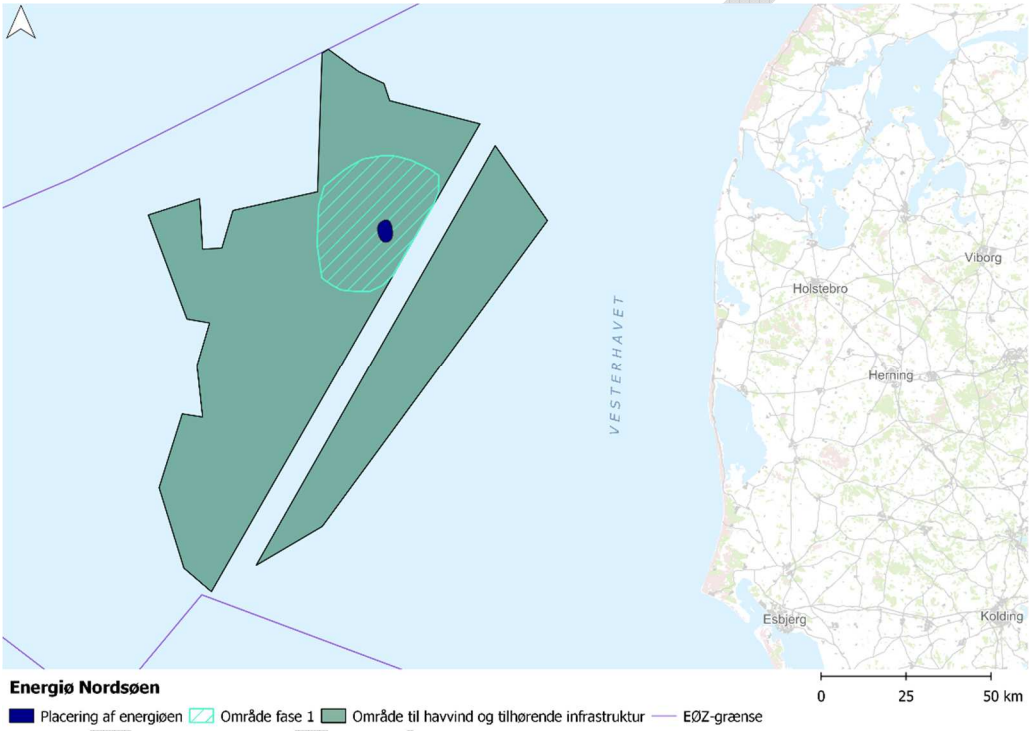

Figure 1 Areas in the North Sea designated for the Plan for Programme North Sea Energy Island.

Energiø Nordsøen	The North Sea Energy Island
Placering af energiøen	Location of the energy island
Område fase 1	Area phase one
Område til havvind og tilhørende infrastruktur	Area for offshore wind power and associated infrastructure
EØZ grænse	EEZ boundary

Flexible island concept

The flexible island concept will be placed within the 6.25 km^2 (2.5 x 2.5 km) area, which is a small part of the area for 'placement of energy island' shown in *Figure 1*. The area for 'placement of energy island' shown in *Figure 1* is approx. 23 km^2 in size. The island

is a development project of an unprecedented scale with a long time horizon. The size of the island has therefore not yet been finally decided. It is expected that the island may cover an area of up to 1 km^2 (area on the seabed).

The flexible island concept makes it possible to combine an artificial island with electricity transmission and energy conversion on platforms near the island, but without limiting the possibilities for innovative activities (e.g. PtX) and flexibility on the island, within the applicable regulatory and safety frameworks. The wind farms will be either connected directly to the artificial island, or to platforms for transmission equipment, which are in turn connected to the artificial island. It must also be possible to connect the North Sea Energy Island to several neighbouring countries. The final Plan for Programme North Sea Energy Island must therefore ensure that this future expansion is possible.

A range of construction models are available for the flexible island design, most of which involve the extraction of large volumes of sand for filling. However, the technical design of the island is still an open question, and will depend in part on market innovation and competition.

The exact design and size of the island will be decided at a later stage, but it is expected to potentially house elements such as:

- Electricity transmission plant and associated plant
  - HVAC plant[5]
  - HVDC switching plant (multi-terminal)
  - Cable laying systems
  - Control systems
  - Access or cable bridges or similar connections between the island and platforms

- Facilities for the operation of wind turbines and transmission services
  - Staff facilities (hotel, canteen, emergency room, leisure facilities, storage, offices, etc.)
  - Spare parts storage, office and workshop (outdoor storage area)
  - Control centre
  - Harbour, ship and support facilities
  - Helicopter, drones and support facilities
  - Storage of fuel for ships and helicopters, emergency supplies, etc.
  - Bridges to platforms for transmission equipment, innovation and PtX platforms/plant

- PtX and innovation plant with associated pipelines

[5] High-voltage alternating current plant

- Facilities for operation and maintenance of the flexible island
  - Water treatment plant and waste water management
  - Waste management for household waste, chemical waste, fuels, bulk waste, etc.
  - Electricity supply, incl. emergency supply
  - Fire station and pump systems
  - Emergency response facilities
  - Access and control systems
  - Maritime and air traffic control centre
  - Port facilities (cranes, forklifts, etc.)
  - Access and service roads

- Safety measures on the island
  - Monitoring and defence area (radar)
  - Vessel collision protection
  - Lighthouse (or other form of lighting for navigation safety)
  - Breakwaters (only in harbours)

Raw material extraction for the artificial island

The exact design and size of the island will be decided at a later stage, including the type of material to be used to construct the island. Note that the island may cover an area of up to 1 km^2 (area on the seabed). Possible materials include sand, gravel, lime, flint, granite or the like, for example from British/Scottish quarries or waste material from quarry runs, but this list is not exhaustive. In addition, steel and materials for any concrete production can be expected to be used.

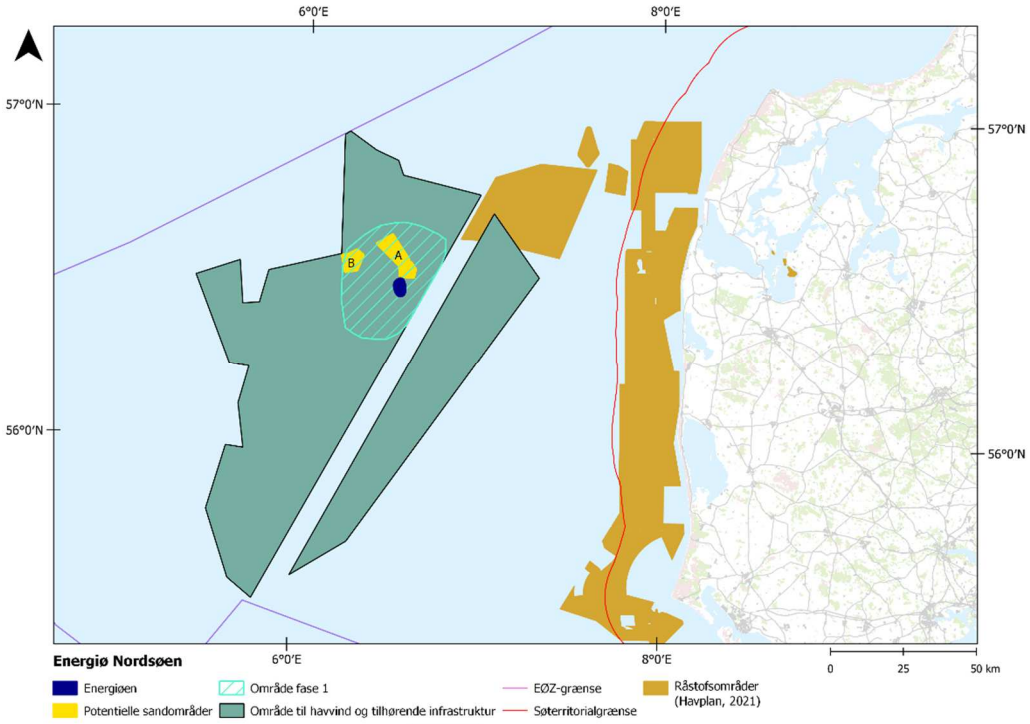

Figure 2 Potential resource extraction areas (yellow) within the Plan for North Sea Energy Island Programme, and resource extraction areas (brown) reported to the marine spatial plan.

Energiø Nordsøen	The North Sea Energy Island
Energiøen	Energy island
Potentielle sandområder	Potential sand areas
Område fase 1	Area phase one
Område til havvind og tilhørende infrasturktur	Area for offshore wind power and associated infrastructure
EØZ-grænse	EEZ boundary
Søterritorialgrænse	Boundary for territorial waters
Råstofsområder (havplan, 2021)	Resource areas (marine spatial plan, 2021)

If sand and/or gravel are to be used, resources can be extracted within the plan area or in other resource extraction areas. Note that the Danish Ministry of Environment is the planning and environmental authority for resource extraction areas. The designation of any areas for resource extraction is therefore not included in the Plan for Programme North Sea Energy Island, but needs to only be included as a parameter in connection with the assessment of any environmental impacts from the North Sea Energy Island. Two suitable resource extraction areas have been identified, which can be seen in *Figure 2* in yellow. If the island is constructed using sand/gravel, the resource consumption will not exceed 45 million m^3 for a 1 km^2 island (area on the seabed). It cannot be ruled out that material may need to be disposed of or temporarily deposited.

The disposal of material is under the jurisdiction of the Danish Environmental Protection Agency.

Navigation route to the artificial island

Within the area for offshore wind turbines, an area must be reserved for a navigation corridor, which will enable maritime traffic to the artificial island, in compliance with maritime safety rules. The navigation corridor is expected to be up to 10 km wide.

Offshore wind turbines and submarine cables

Phase one comprises at least 3 GW of offshore wind power, but with the possibility of up to 12 GW within the same area if the power per km^2 is increased. The offshore wind farms are expected to be placed within the area shown in *Figure 1* (light green shading), and at least 80 km from the west coast of Jutland. It will be possible to erect offshore wind turbines with a capacity of up to approx. 62 MW, a maximum height including blade tips of up to 500 metres, and a rotor diameter of up to 480 metres. Offshore wind farms may be constructed using various types of wind turbines with varying capacities. The offshore wind turbines are expected to be erected as anchored wind turbines, i.e. with monopile, gravitation or jacket foundations using either piles or suction buckets.

In phase one, it must be possible to place PtX and innovation plant on the artificial island, and on platforms/installations in the phase-one offshore wind farm areas, connected to the island or the offshore wind farms via submarine cables.

The final location of the offshore wind farms and individual turbines will be determined later in connection with the environmental impact assessment (EIA) for each specific project. The EIA for each specific offshore wind farm will be carried out by the successful bidder for each offshore wind turbine project.

During phase one, the individual offshore wind farms will be established using a grid of submarine cables that connect the individual turbines to the artificial island, or to a platform with transmission equipment which is connected to the artificial island. The final location of the cable routes will be determined later in connection with the EIA for each specific project.

Platforms for transmission equipment

The cables from the offshore wind farms run either directly to the island or to platforms with transmission equipment. The platforms with transmission equipment can be placed in the offshore wind turbine areas, and close to the island, and are connected to the island via a number of cables. It must also be possible to connect submarine cables for transporting electricity abroad on the platforms.

Platforms housing electricity transmission equipment may vary in size and appearance, and the types of foundations may also vary (e.g. monopiles, gravitation or jacket foundations with either piles or suction buckets).

The platforms must provide the option for residential facilities and special staff facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance so allows. The final location of the plant in the offshore wind power areas will be determined later in connection with the EIA for each specific project.

Submarine cables to Jutland

From the area for construction of the flexible island concept, a connection to the Danish electricity supply area must be established via the west coast of Jutland, so that part of the electricity generated can be transferred to the Danish transmission grid. It must be possible in phase one to establish a number of cable corridors with widths of up to 1,500 metres, that connect the artificial island to suitable locations for cable landing on the west coast of Jutland. Submarine cables can be laid in these corridors to transfer the electricity. It must also be possible to establish the necessary fibre cables in these corridors, and any cables or pipelines for other purposes that are deemed necessary. In phase one, the corridor for the fibre cable to Tuskær is 1,000 metres wide, and 50 metres wide close to Tuskær.

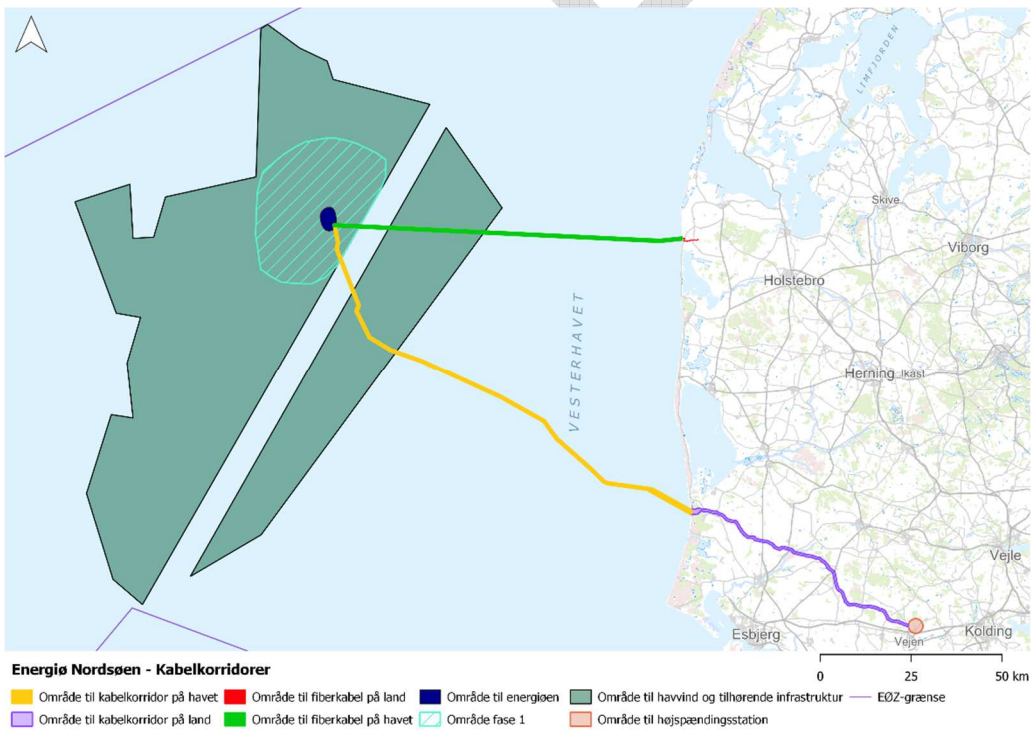

Figure 3 Submarine cables to Jutland.

Energiø Nordsøen - kabelkorridorer	North Sea Energy Island – cable corridors
Område til kabelkorridor på havet	Area for offshore cable corridor
Område til fiberkabel på land	Area for onshore fibre cable
Område til energinøen	Area for the energy island

Område til havvind of tilhørende infrastruktur	Area for offshore wind power and associated infrastructure
Område til kabelkorridor på land	Area for onshore cable corridor
Område til fiberkabel på havet	Area for offshore fibre cable
Område fase 1	Area phase one

Submarine cables abroad

From the area for construction of the artificial island, a number of cable connections abroad must be established to transport the electricity generated to partner countries. The cable connections will be established in corridors up to 3,000 metres wide, which may contain more than one submarine cable to partner countries in Danish waters and up to, for example, existing cable corridors in German waters .

In phase one, 2 GW of submarine cables are expected to be established to partner countries. The submarine cables must run from the energy island in the North Sea, in a southerly direction along the Danish continental shelf towards the Danish/German border, where they must intersect corridors for cables in German waters. Cables from Denmark may only use the GN13-GN14, GN12-GN15, GN11-GN16, GN10-GN17, GN9-GN18 and GN8-GN19 corridors when crossing German waters, *see Figure 4*. The exact route for the submarine cables in the Danish area has not been finally determined, other than having to intersect with the German corridors, but work is currently being done with the GN9-GN18 and GN8-GN19 corridors in German waters.

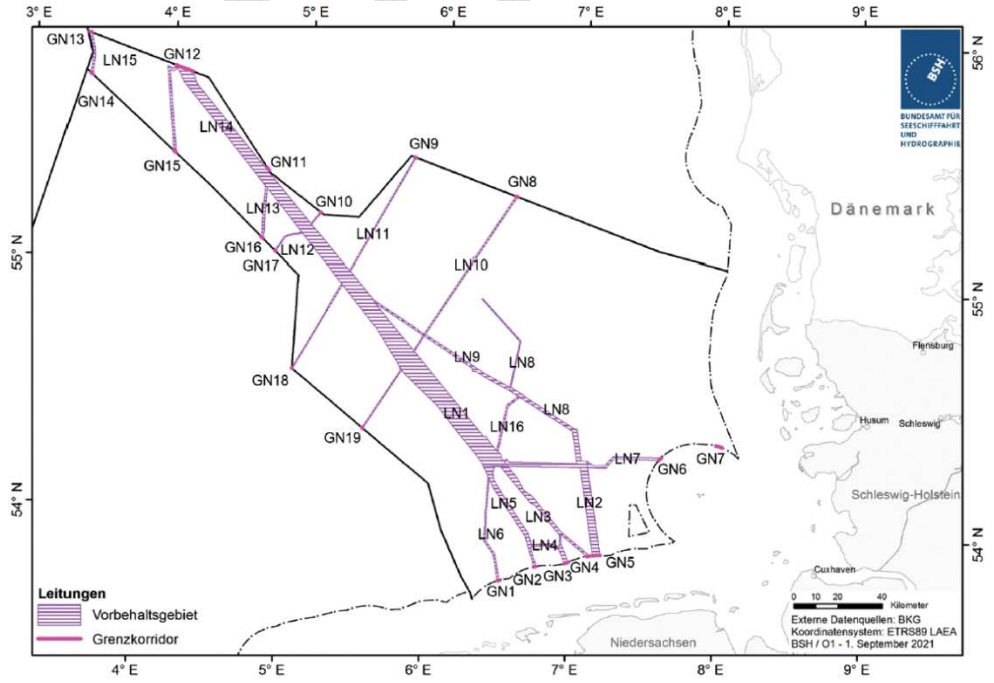

Figure 4 Cable corridors in German waters in the North Sea (BSH).

PtX and innovation plants

The electricity from the offshore wind turbines can be converted into other energy carriers, which can be stored and used by ships, vehicles and aeroplanes – known as Power-to-X (PtX). In phase one, it must be possible to utilise some of the electricity for applications such as PtX. This means that it must also be possible to install pipelines to the platforms/plants or to the artificial island.

Offshore PtX production at sea can take place on the island or on separate platforms/plants in the wind farms or in offshore wind turbines. The plants will be connected to the wind farms or the island via submarine cables or pipes. The energy carriers produced can either be collected by ship and transported to Denmark or abroad, or via pipelines. In connection with the export of PtX products it will be necessary to establish compressors and/or pumps. No decision has been made, beyond the 2 GW to partner countries and 1.4 GW to Denmark, concerning how large a share of the power from the energy island can be allocated to PtX.

The PtX platforms/plants may vary in size, appearance and type, and the types of foundations may also vary (e.g. monopiles, gravitation or jacket foundations with either piles or suction buckets). It cannot be ruled out that PtX plants could be established as floating plants or underwater installations (subsea installation), and may also include storage. The platforms (floating and fixed) may need temporary residential facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance and safety factors so allow.

It must also be possible to establish innovation technology other than PtX in connection with the North Sea Energy Island, which can utilise the electricity generated. Other innovation technology could include data centres and batteries for storing electricity. Innovation facilities can be established on the artificial island, platforms, underwater installations (subsea installation) or floating structures in immediate proximity to the artificial island and in the offshore wind turbine areas.

Innovation plants may vary in size, appearance and purpose, and the types of platform foundations may also vary (e.g. monopiles, gravitation or jacket foundations with either piles or suction buckets). Plants not placed on the artificial island will be connected to the artificial island, the wind farms, or the offshore wind turbines via submarine cables/pipelines. The platforms or floating structures must provide the option for residential facilities and special staff facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance so allows.

Pipelines in connection with PtX

It must be possible to establish pipelines from any PtX plants, either to the west coast of Jutland or abroad in corridors. The final placement of corridors for the pipelines will be decided later in connection with the EIA for the specific PtX projects.

Onshore sites for installations

Landing cable connections

When submarine cables are brought ashore on the west coast of Jutland, they must be joined with onshore cables. The corridor for bringing submarine cables ashore in phase one is shown in *Figure 5* and is up to 1,500 metres wide at the coast and for the first 3 km onshore. It may also be possible to land submarine cables for other purposes. Energinet is responsible for the placement of the landfall area. The final location of the cables in phase one will be determined later in connection with the EIA for each specific project.

Figure 5 Bringing submarine cables ashore, land cable corridor and area for expansion of Revsing substation.

Energinø Nordsøen - Ilandføring	North Sea Energy Island – cable landing
Område til kabelkorridor på land	Area for onshore cable corridor
Område til højspændingsstation	Area for high-voltage substation
Område til kabelkorridor	Area for cable corridor

High-voltage substations for grid connection

In phase one, Revsing in the Municipality of Vejen has been chosen as the point of connection, where the existing substation will be expanded, *see Figure 6*. In line with usual practice, the area for the substation has been selected by Energinet.

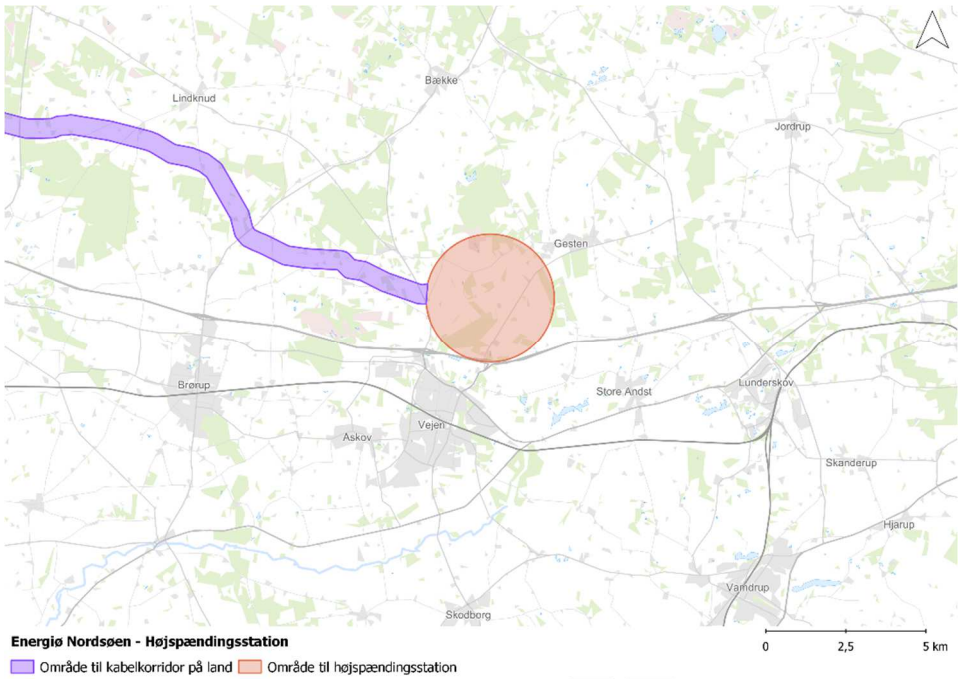

Figure 6 Area for cable corridor and the selected area at Revsing in the Municipality of Vejen.

Energiø Nordsøen - Højspændingsstation	North Sea Energy Island – High-voltage substation
Område til kabelkorridor på land	Area for onshore cable corridor
Område til hæjspændingsstation	Area for high-voltage substation

The area for expansion of such a facility is expected to be approx. 40 ha, and will be located at a distance of up to 4,000 metres from the chosen existing high-voltage substation.

Land cables

The landfall area point and high-voltage installations for grid connection must be connected by cables. Corridors for laying cables will be approx. 600 metres wide and are show in *Figure 5*.

North Sea Energy Island – Phase two

Offshore construction sites

Flexible island concept

The energy island is expected to be completed in phase one, but may be expanded in phase two, including by connecting platforms to the island, adding further edge protection to the island, or establishing piers connected to platforms located close to the island. Installations, facilities and buildings may also be constructed on the island in phase two. Note that there may also be a need to protect the edge of the island and for activities in connection with maintenance of the island during the operation phase.

Raw material extraction for the artificial island

Raw material extraction for the artificial island in phase two and during the operation phase cannot be ruled out, for example due to the need for sand replenishment due to erosion by the sea. It cannot be ruled out that there may be a need for disposal in phase two, which is under the jurisdiction of the Danish Environmental Protection Agency.

Offshore wind turbines and submarine cables

The area shown in green in *Figure 1* covers establishment of a total of at least 10 GW offshore wind power (phase one and two) in line with the political agreements, but with the possibility of establishing up to 40 GW (phase one and two) within the same area if the power per km^2 is increased. In phase two, the offshore wind turbines are expected to be located at least 50 km from the west coast of Jutland.

It will be possible to erect offshore wind turbines with a capacity of up to approx. 62 MW, a maximum height including blade tips of up to 500 metres, and a rotor diameter of up to 480 metres. The offshore wind turbines are expected to be erected as anchored wind turbines in water depths of less than 50 metres, i.e. with monopile, gravitation or jacket foundations using either piles or suction buckets. In the southern part of the green area in *Figure 1* the water depth may be more than 50 metres, and floating foundations may therefore be necessary.

In phase two, it must also be possible to place PtX and innovation plant on the island, and on platforms/installations in the phase-one and phase-two offshore wind farm areas, connected to the island or the offshore wind farms via submarine cables or pipelines.

The final location of the offshore wind farms and individual turbines in phase two will be determined later in connection with the EIA for each specific project.

During phase two, the individual offshore wind farms will be established using a grid of submarine cables that connect the individual turbines to the island, or to a platform which is connected to the artificial island. The final location of the cable routes will be determined later in connection with the EIA for each specific project.

Platforms for transmission equipment

In the phase-two offshore wind turbine areas, the distance is too large for the submarine cables to be routed directly to the island using the technology available today, and separate platforms for transmission equipment (electricity transmission and energy conversion) will be required in the wind farms. The platforms with transmission equipment can be placed in the offshore wind turbine areas, and close to the artificial island, and will be connected to the island via a number of cables. It must also be possible to connect submarine cables for transporting electricity abroad on the platforms, where these are connected to the island.

It is expected that platforms may need to be constructed for transmission equipment, which may vary in size and appearance, and the types of foundations may also vary (e.g. monopiles, gravitation or jacket foundations with either piles or suction buckets).

The platforms must provide the option for residential facilities and special staff facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance so allows. The final location of the plant in the offshore wind power areas in phase two will be determined later in connection with the EIA for each specific project.

Submarine cables to Jutland

In phase two a number of corridors may be needed that connect the artificial island to the west coast of Jutland. The corridors may be used to lay submarine cables, fibre cables, cables for other purposes and pipelines in connection with PtX platforms/plants.

Submarine cables abroad

The distribution of electricity from phase two has not yet been decided, but the plan must include the possibility of distributing abroad via additional submarine cables to partner countries from the artificial island or platforms in Danish waters.

PtX and innovation plants

During phase two, it must also be possible to place PtX platforms/plant and innovation plant on the island, in the phase-one and phase-two offshore wind turbine areas, and close to the artificial island, with respect for safety factors. It must be possible to establish pipelines in connection with the facilities.

Offshore PtX production can take place on the island and/or on separate platforms/plants in the wind farms or in offshore wind turbines. The plants will be connected to the wind farms or the island via submarine cables. The energy carriers produced can either be collected by ship and transported to Denmark or abroad, or via pipelines from the wind farms and the flexible island concept. In connection with the export of PtX products it will be necessary to establish compressors and/or pumps. No decision has been made as to how large a share of the electricity from phase two can be allocated to PtX.

The PtX platforms/plants may vary in size, appearance and type, and the types of foundations may also vary (e.g. monopiles, gravitation or jacket foundations with either piles or suction buckets). It cannot be ruled out that PtX plants could be established as floating plants or underwater installations (subsea installation), and may also include storage. The platforms (floating and fixed) may need temporary residential facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance so allows.

It must also be possible in phase two to establish innovation technology other than PtX in connection with the North Sea Energy Island, which can utilise the electricity generated. Other innovation technology could include data centres and batteries for storing electricity. Innovation facilities can be established on the artificial island, platforms, underwater installations (subsea installation) or floating structures in immediate proximity to the artificial island and in the offshore wind turbine areas, and can vary in size and appearance. Platform foundations can vary, and could include monopile, gravitation or jacket foundations using either piles or suction buckets. The platforms or floating structures must provide the option for residential facilities and special staff facilities, a helipad, ship access, or a bridge connection to the artificial island, if the distance so allows.

Pipelines in connection with PtX

It must be possible to establish pipelines from any PtX plants, either to the west coast of Jutland or abroad in corridors. The final placement of corridors for the pipelines will be decided later in connection with the EIA for the specific PtX projects.

Onshore construction sites

Landing cable connections

When cables are brought ashore on the west coast of Jutland, offshore cables must be joined with onshore cables. There are several sites along the west coast of Jutland where submarine cables could be brought ashore in phase two. The final location of sites for cable connections in phase two will be determined by Energinet later in connection with the EIA for each specific project.

Coastal switching stations

When power is brought ashore from the artificial island, it may be advantageous or necessary to establish coastal plant where the power brought ashore is combined in fewer cables and converted to a higher voltage. Compensation reactors are installed at the same location. The final location of sites for coastal switching stations in phase two will be determined later in connection with the EIA for each specific project.

High-voltage substations for grid connection

There may be a need to establish additional high-voltage installations in phase two to convert and transform grid voltage to match the electricity transmission grid. Such a

high-voltage facility may be established either as a new substation, an expansion to an existing high-voltage substation or as a linked high-voltage facility as close to the existing high-voltage substation as possible. The final location of sites for high-voltage substations in phase two will be determined by Energinet later in connection with the EIA for each specific project. The EIA process will explore, if applicable, how environmental impacts can be minimised, including any inconvenience to citizens.

Land cables

There may also be a need to lay additional cables in phase two, and to designate additional corridors. The final location of the corridors in phase two will be determined later in connection with the EIA for each specific project.