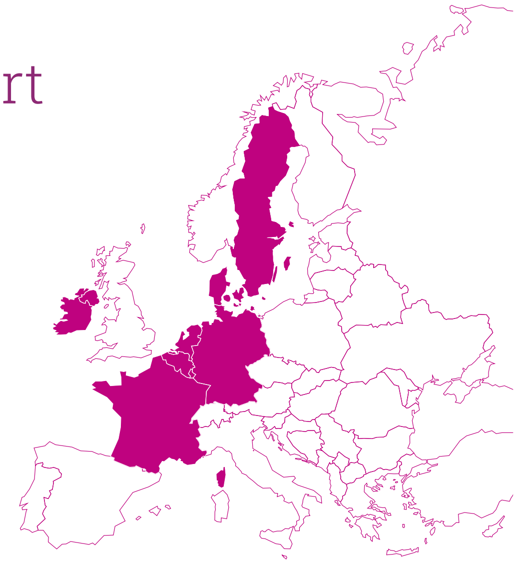
TYNDP 2024

Sea-Basin ONDP Report

TEN-E Offshore Priority Corridor: Northern Seas Offshore Grids



January 2024

15 YEARS OF entsoe ELECTRIFYING EUROPE

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The **40 member TSOs**, representing 36 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the inter-connected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources. ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with climate objectives and **social welfare** in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility**.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its **legally mandated tasks**, ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- Assessment of the adequacy of the system in different timeframes;
- Coordination of the planning and development of infrastructures at the European level (**Ten-Year Network Development Plans, TYNDPs**);
- Coordination of research, development and innovation activities of TSOs;
- Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

TYNDP 2024

Sea-Basin ONDP Report

TEN-E Offshore Priority Corridor: Northern Seas Offshore Grids

January 2024

How to use this interactive document

To help you find the information you need quickly and easily we have made this an interactive document.

Home button
This will take you to the contents page. You can click on the titles to navigate to a chapter.

Glossary
You will find a link to the glossary on each page.

Arrows
Click on the arrows to move backwards or forwards a page.

Hyperlinks
Hyperlinks are highlighted in bold text and underlined throughout the report. You can click on them to access further information.

ENTSO-E ONDP interactive data visualisation platform

Questions?

Contact us as at **tyndp@entsoe.eu**

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Executive Summary: Key Messages for the Sea Basin Northern Seas Offshore Grid (NSOG)

The Northern Seas region faces major changes and challenges in the energy system in the coming decades. At both European and national level, the Energy and Climate policies have set ambitious non-binding targets to decarbonise the entire energy system by 2050. For 2030, the EU climate law enforces a cut of greenhouse gas emissions by at least 55 % (compared to 1990 levels), and for 2050 the EU should be climate neutral.

The Offshore Network Development Plan (ONDP) is a follow-up of requirements from the revised TEN-E regulation (EU-reg. 2022/869), where ENTSO-E is entrusted with the planning of the offshore network development. ENTSO-E has developed and now publishes this first ONDP for the Northern Seas Sea Basin. For this plan, the Ministries of the involved countries have delivered expected levels of offshore Renewable Energy Sources (RES) generation for the years 2030, 2040 and 2050, based on which ENTSO-E has developed a view on the offshore infrastructure needed. The related necessary onshore infrastructure needs will be investigated under the framework of the Ten-Year Network Development Plan (TYNDP) 2024 system needs study.

ENTSO-E aims to ensure a holistic planning of a more complex but integrated onshore and offshore system. There is a need to consider different sectors, onshore and offshore infrastructure needs, interoperability, sustainability and development of an efficient market design. Both ENTSO-E and the Transmission System Operators (TSOs) have a key position in this development.

For the Northern Seas Region, the large increase of offshore renewable generation and the decrease of thermal capacity will result in a weather-dependent energy mix to cover electricity demand. This will change the utilisation of the electricity system and more flexibility will be necessary. Sector integration and demand response will provide some of the flexibility to always balance the energy system. The key messages for the Northern Seas Region can be summarised as:

1. Esbjerg- and Ostend-declaration – huge political offshore ambitions;

2. Goals: 119 GW by 2030, 333 GW by 2050;

3. 2030 – Faster speed needed – Radial connection and first offshore hybrid elements;

4. 2040 – First interlinked offshore clusters, further increasing towards 2050;

5. Offshore network infrastructure – High costs, high benefits; and

6. Huge challenges ahead – supply chain, ports, flexibility, infrastructure.

Esbjerg – and Ostend-declaration – huge political offshore ambitions

At the time of writing, Europe is recovering from an energy crisis. The price for energy carriers was already high and became even higher when Russia invaded Ukraine. The geo-political development is forcing Europe to be independent from Russian gas, which two years ago represented approximately 1,500 TWh of Europe's energy-balance. In addition, the de-carbonisation and the electrification of the demand will greatly increase electricity requirements in the years to come. Offshore wind is expected to be an important part of the solution to cover the potential lack of energy. Hence, the current developments are accelerating the political measures to achieve the green transition and have led to increased countries' ambitions.

RES are the fundamental tools to decarbonise the energy system and, in all TYNDP-scenarios, the installed capacity grows considerably. A large part of the European offshore RES goals will be met through offshore wind, and much of this is likely to be located in the Northern Seas region. In May 2022, the four governments of Belgium, the Netherlands, Denmark and Germany, through the **Esbjerg-declaration**, agreed to establish 65 GW of offshore RES by 2030 and 150 GW of offshore RES by 2050. In 2023 this was followed up by the **Ostend-declaration**, now involving five additional countries (Great Britain, Ireland, France, Luxembourg and Norway). In the Ostend-declaration, the 9 countries confirm the ambitious targets for offshore wind, aiming for 120 GW by 2030 in the Northern Seas region. In addition, the countries state that they aim to more than double the 2030-capacity of offshore wind to at least 300 GW by 2050. Through this declaration, the 9 countries show full political support for the European offshore goals. The Ostend-declaration was also in line with the **"Non-binding agreement on goals for offshore renewable generation in 2050 with intermediate steps in 2040 and 2030 for priority offshore grid corridor Northern Seas offshore grids (NSOG)"**, published by all the Member States (MSs) in January 2023 for the purpose of this ONDP.

Goals: 119 GW by 2030, 333 GW by 2050

The Northern Seas are often referred to as "the European green powerhouse". With lots of shallow waters and high wind speeds, the Northern Seas region, consisting of the North Sea, the English Channel, the Irish Sea, the Celtic Sea, Skagerrak and Kattegat, have huge potential for offshore wind and can fulfil a large amount of the European Offshore wind capacity target of 300 GW, as mentioned in the European offshore RES strategy from November 2020.

All countries have rather high ambitions and expectations regarding the offshore development. Most of the planned projects are expected to be developed in the southern part of the North Sea and on the UK coast. There are also some first floating wind farms being developed; these are technically and financially more challenging and might require additional support. Costs are, however, expected to decrease considerably and several analysts predict profitability by 2040.

Offshore Wind Development 2030–2050

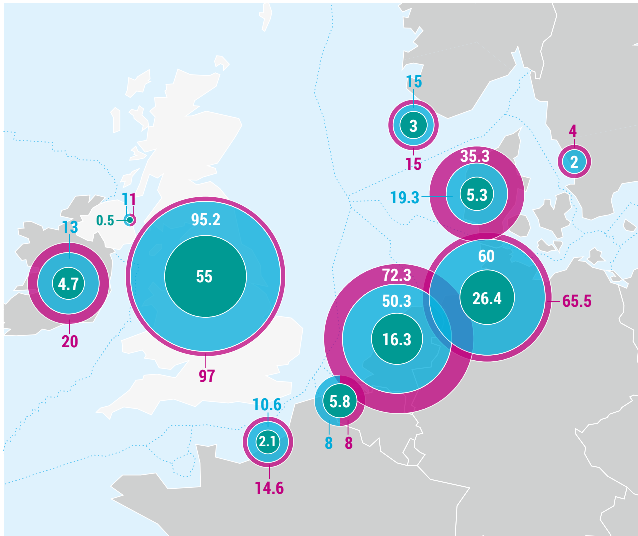


Figure 1 – Offshore wind capacities 2030, 2040, 2050 (Norwegian offshore goal is to open up for 30 GW, but only 15 GW has been modelled.).

2030 – Faster speed needed – Radial connection and first offshore hybrid elements

The rapid expansion of offshore RES requires huge investments in both offshore- and onshore infrastructure to transport the energy to the main demand centres. The total offshore wind capacity is, according to the goals of the Northern Seas countries, expected to be about 120 GW by 2030 (of which 58 GW in GB+NO). Today, the installed offshore wind capacity is about 27 GW in the Northern Seas area (of which 14 GW in GB+NO), thus an annual installation rate of 15 GW/year is needed with the same implications for infrastructure expansion, while the last 10 years' average rate was 2.5 GW/year. This translates to a necessary 6-fold increase in speed for the entire area, with 8 GW/year for European countries alone and 7 GW/year for GB+NO). Regarding infrastructure, an offshore route length of 7,020 km has been identified, translating into 1,200 km annually between 2024 and 2030. Depending on the technical solution, this can be multiplied by 2 or 3 to arrive at the cable length.

The offshore RES development is, among others, based on economic realities, which means that windy sites close to shore and most shallow waters are developed first. The areas west of Denmark, north of Germany/Netherlands/Belgium, northwest of France and to the east of England and Ireland are expected to be most developed at the 2030 horizon. This matches the fact that these areas cover the largest demand. While most of today's envisaged projects are radial connections, some offshore hybrid projects are already planned and will play an increasing role. These have dual functionalities, i.e. they combine the connection of offshore RES to an onshore system with the function of an interconnection, linking different countries or market zones, and providing for a more efficient integration of offshore renewables. In a nutshell: by 2030, the major offshore development is still expected to be based on radial connections, complemented by a small number of offshore hybrids.

2040 – First interlinked offshore clusters, increasing towards 2050

By 2040, the total offshore wind capacity is, according to the goals of the Northern Seas countries, expected to be about 274 GW, of which 110 GW are in GB+NO. Increasing numbers of offshore wind projects are then expected to be developed farther from shore, which means more complex construction requirements, more expensive projects and longer and more expensive connection of the wind farms to the onshore energy system. To ensure the construction and operation of these wind farms in a more cost-efficient manner, the concepts of energy islands and power hubs have been developed. A potential architecture of a 2040 first integrated offshore grid is shown in figure 3. This is the outcome of an economic assessment followed by a plausibility check from the national TSOs and shows interconnectors between offshore clusters with a positive cost/benefit.

The benefits of a more integrated offshore network and hybrid interconnectors are:

- Transports the energy to the demand-centres, which will also require onshore grid reinforcements;
- Increases energy security from offshore RES due to increased network redundancy. If one link/radial is lost, energy can be sent in another direction and thus reduce the potential energy-loss/curtailment;
- Increases the capacity/flexibility between different countries/synchronous areas by creating more interconnections; and
- Connects areas with different wind-profiles, hence can bring less-correlated RES across longer distances.

These benefits will be assessed and quantified in the next step based on the Commission guidance on cost-benefits and cost-sharing due in June 2024.

Offshore infrastructure transmission corridors of up to 21,000 km route length have been identified, translating into 2,100 km annually to be covered. The cable length is twice to three times that long. The infrastructure results as shown in Figure 2 and Figure 3 are based on the assumptions of the technical break-through of a high voltage direct current (HVDC) circuit breaker. The analyses show that the development of a HVDC-breaker results in a higher interconnection level between clusters and countries compared to a situation without this asset.

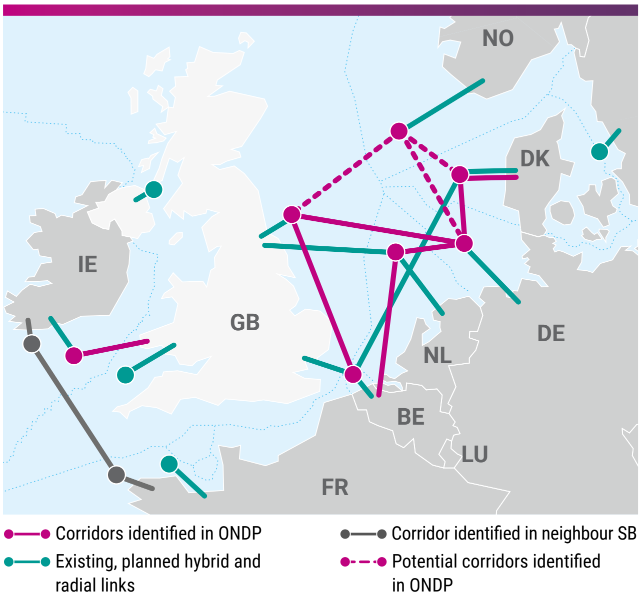


Figure 2 – By 2040, a more integrated offshore network might be realised.

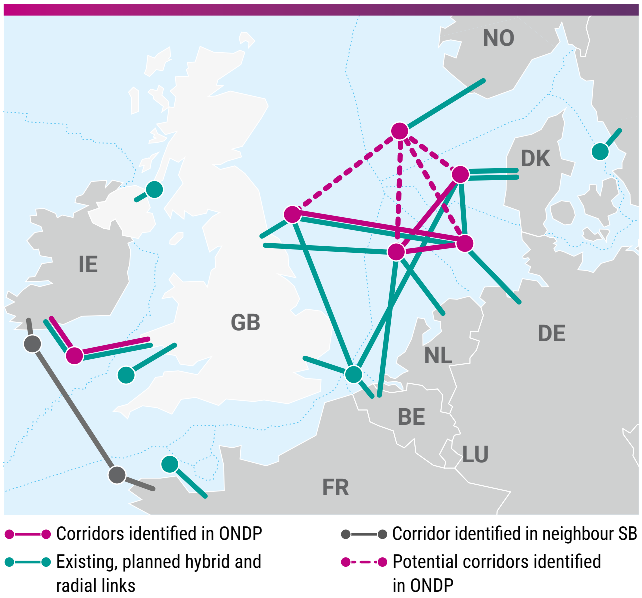


Figure 3 – By 2050, an even more integrated offshore network might be realised.

The breakthrough of the HVDC-circuit breaker technology means lower costs in interlinking offshore-nodes with each other as the extremely expensive offshore converter-stations are not needed for each extra node/hub. Chapter 6 explains the architectures resulting from the two main technical and cost setups. These two main configurations are with/without new HVDC-circuit breakers. Without HVDC-circuit breakers the additional interconnection level reached between offshore clusters adds 9.5 GW, while DC-circuit breakers allow up to an additional 30 GW to be added in addition to the TYNDP 2022 levels at an even slightly lower cost, although route length increases.

Towards 2050, the total offshore wind capacity will, according to the goals of the Northern Seas countries, reach levels beyond 330 GW, of which 112 GW are in GB+NO. Offshore RES locations will continue to move farther offshore. Figure 3 shows a potential architecture of a 2050 offshore network infrastructure, still based on the assumptions of the technical break-through of a HVDC-breaker. The architecture shown in Figure 3 is rather similar to the 2040 architecture shown in Figure 2 as the increase in offshore RES between 2040 and 2050 is less than in previous decades, and as we mainly observe a need to reinforce existing transmission corridors rather than a need to create new transmission corridors.

Offshore network infrastructure – High costs, high benefits

The cost of developing a more integrated offshore network infrastructure is expected to be high and in the same range as a less integrated infrastructure. The degree of integration, i.e. the existence of links between offshore nodes of different jurisdictions, depends on technology development. The more integrated it is, the higher the benefits will be. The benefits include having a more efficient onshore and offshore market, a more reliable transport of the energy from offshore sites to onshore demand, supplying non-correlated RES to longer distant customers, increased overall energy security of the European power system, better usage of offshore RES, decreased global emissions and a more sustainable energy system. Due to the complexity of quantifying many of these benefits, the first edition of the ONDP builds mainly on market-benefits (SEW).

This Offshore Network Development Plan shows the very first investigation of offshore network equipment needs and related costs. The first estimates of the cost of the interconnected offshore infrastructure shows costs towards 2030 of over 50 bn€, not counting the radial connections of the GB system. Between 2030 and 2040, the first estimates show the cost of the offshore infrastructure to be about 150 bn€. This cost is, by 2050, further increased by an additional 60 bn€. In total, the cost of the interconnected offshore infrastructure for the Northern Seas is about 260 bn€ (some of which relates to GB+NO). Most of the costs are seen in the North Sea, where clusters of different countries are closer to each other than in other NSOG waters. The architecture and resulting interconnection level very much depends on both the technical development (with or without a DC-circuit breaker), and assumptions on equipment costs. The results visualised in this report reflect the low-cost assumption higher levels. The choice of favourable conditions was made to get an idea of the potential upper range of the offshore network development.

In the ENTSO-E interactive online tool, the results for high-cost-assumptions are also shown.

In addition, it is important to note that beyond the cost-assumptions of this study, the offshore development is a long-term development that falls under the "class 5" category of AACE International's classification system (Association of Advanced Cost Engineering). This is usually performed during a conceptual stage of a project. Applying this class 5, an additional uncertainty range of –20 to + 100 % around the cost-sensitivities should be applied.

Huge challenges ahead – supply chain, ports, flexibility, infrastructure

One of the first challenges offshore wind projects face is procuring all the elements of the offshore wind farm (OWF), including offshore network infrastructure. Due to the significant increase in global demand, the market of the supply industry is tight. Most of the manufacturers of cables, converter stations, large transformers and offshore platforms, as well as large installation vessels, are currently operating at full capacity. This means that procuring and installing offshore infrastructures takes longer than it used to. The expected large increase in offshore projects has also led to manufacturers being more selective of the projects they bid on. This results in fewer competitive bids and higher associated costs. Furthermore, the availability of the ports is a key element of building the wind farms and all the infrastructure in an efficient manner. According to the North Seas offshore wind port study 2030 – 2050 presented to the NSEC ministries, currently the ports of the Northern Seas do not have the necessary size for the expected huge offshore wind development.

With the large changes in electricity generation, security of supply will be a challenge, compared to the classic energy system. Both the electricity production and demand become more variable due to much higher weather-dependency. For the Northern Seas, the increase of offshore wind generation will lead to a more variable and less controllable system from the production side. To increase the energy-system's flexibility, a variety of actions need to be taken. A tighter cooperation with other energy-sectors, such as the hydrogen sector, is expected to increase. Furthermore, the flexibility of the demand-side does have huge potential and will be important. In addition, the interconnector-capacity and cooperation between different synchronous areas and different countries needs to be strengthened. When the wind is blowing, or the sun is shining in one part of Europe, the situation might be different for other parts of Europe. This weather-dependency increases the need for new transmission capacity, including interconnectors.

The Offshore Network Development Plan Northern Seas shows potential solutions for the different challenges. In this especially, the potential offshore architecture is important.

1 Introduction to the Sea Basin Report Northern Seas Offshore Grid

On 3 June 2022, the revised TEN-E regulation (EU) 2022/869 entered into force, mandating ENTSO-E with the new task to develop offshore network development plans (ONDPs) for each sea basin by 24 January 2024.

Formally, the ONDPs are a separate part of ENTSO-E's Ten-Year-Network Development plan (TYNDP). The offshore plans must build on the joint Member States' (MSs') non-binding agreements on joint offshore Renewable Energy Sources (RES) goals for each sea basin. On 19 January, EU countries, with the support of the Commission, concluded regional non-binding agreements to cooperate on goals for offshore renewable generation to be deployed within each sea basin by 2050. These agreements include intermediate steps in 2030 and 2040[1].

The ONDPs deliver a high-level outlook on offshore generation capacities potential and the resulting offshore network infrastructure needs for each sea basin:

- Northern Seas Offshore Grids (NSOG), including North Sea, the Irish Sea, the Celtic Sea, the English Channel and neighbouring waters;
- Baltic Energy Market Interconnection Plan offshore grids (BEMIP offshore) including the Baltic Sea and neighbouring waters;
- South and West offshore grids (SW offshore) including the Mediterranean Sea, including the Cadiz Gulf, and neighbouring waters;
- South and East offshore grids (SE offshore) including the Mediterranean Sea, Black Sea and neighbouring waters; and
- Atlantic offshore grids (AOG) including the North Atlantic Ocean waters.

The sea basins and involved countries are laid down in the regulation and shown in Figure 4.

More detailed information on the legal framework is provided in the Pan-European Offshore Network Transmission Needs report. Information on the methodology used to elaborate this plan can be found in the Methodology Report.

1 https://energy.ec.europa.eu/news/member-states-agree-new-ambition-expanding-offshore-renewable-energy-2023-01-19_en

Priority Offshore Grid Corridors

1. Northern Seas Offshore Grids (NSOG)
2. Baltic Energy Market Interconnection Plan (BEMIP offshore)
3. Atlantic Offshore Grids (AOG)
4. South and West Offshore Grids (SW offshore)
5. South and East Offshore Grids (SE offshore)

ENTSO-E Member
ENTSO-E Observer Member

TEN-E Priority Offshore Grid Corridors	Countries involved
1. NSOG	BE, DK, FR, DE, IE, LU, NL, SE
2. BEMIP offshore	DK, EE, FI, DE, LT, LV, PL, SE
3. AOG	FR, IE, PT, ES
4. SW offshore	FR, GR, IT, MT, PT, ES
5. SE offshore	BG, CY, HR, GR, IT, RO, SI

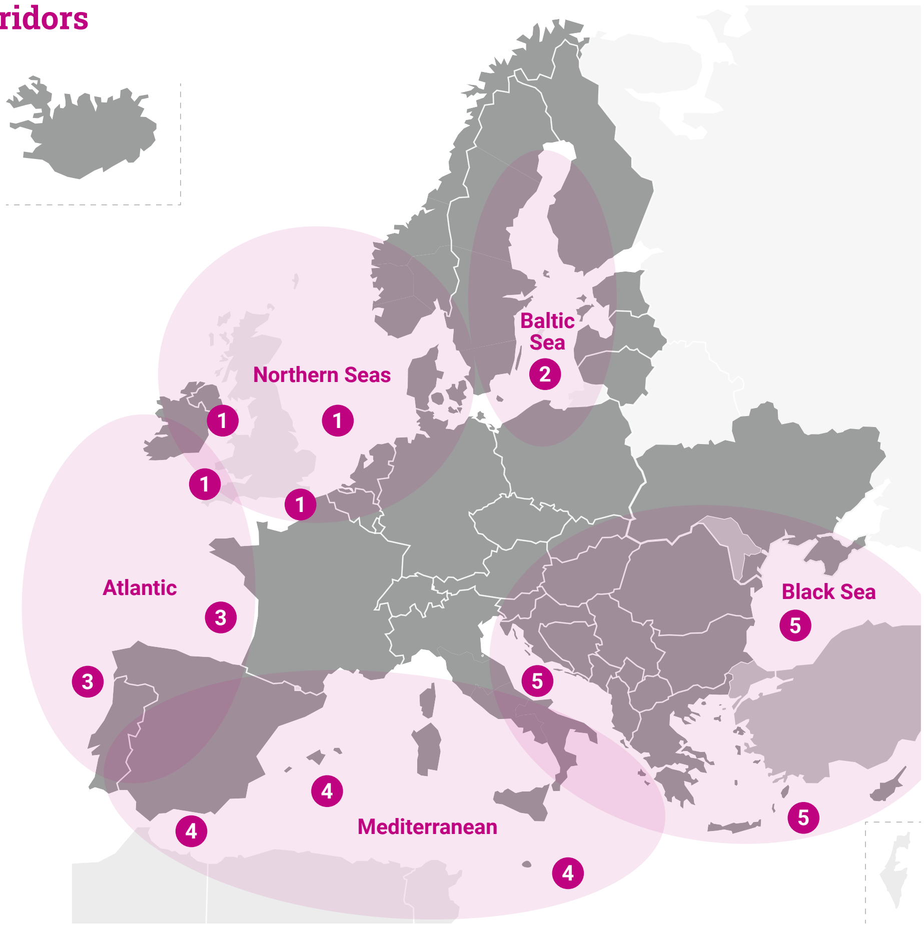


Figure 4 – TEN-E Priority Offshore Grid Corridors as laid down in Regulation (EU) 2022/869.

2 Member States' non-binding Goals

The non-binding offshore RES goals for capacity have been provided by the EU Member States to the European Commission (EC), who collected a list of non-binding goals per Member State and sea basin for each reference year[2]. Adjacent to the Northern Seas, TSOs from non-EU countries also joined the work to make this ONDP a complete plan[3].

Some Member States delivered a range; in these cases as a standard approach ENTSO-E uses the upper boundary, unless more detailed information is available. This has been done to provide the full picture of a potential offshore network infrastructure.

Applying upper limits				TSO data status 6.4.2023							
MS	2030	2040	2050	ONDP Data [GW]	2030	2040	2050	Delta [GW]	2030	2040	2050
BE	6	8	8	BE	5.8	8	8	BE	− 0.2	0	0
DE	26.4	60	66	DE	26.4	60	65.5	DE	0	0	-0.5
DK	5.3	19.3	35	DK	5.3	19.3	35.3	DK	0	0	0.3
FR	2.1	8	17	FR	2.1	10.5	14.5	FR	0	2.5	-2.5
GB				GB	55	95.2	96.9	GB	55	95.2	96.9
IE (RoI)	4.5	13	20	IE (RoI)	4.7	13	20	IE (RoI)	0.2	0	0
LU				LU				LU	0	0	0
NI				NI	0.5	1	1	NI	0.5	1	1
NL	16	50	72	NL	16.3	50.3	72.3	NL	0.3	0.3	0.3
NO				NO	3	15	15	NO	3	15	15
SE				SE	0	2	4	SE	0	2	4
Total	**60.3**	**158.3**	**218**	Total	**119.1**	**274.3**	**332.5**	Total	**58.8**	**116**	**114.5**
				EU	**60.6**	**163.1**	**219.6**	EU	**0.3**	**4.8**	**1.6**
				UK+NO	**58.5**	**111.2**	**112.9**	UK+NO	**58.5**	**111.2**	**112.9**

Table 1 – Offshore RES capacities – left: upper range delivered by the Member State; middle: data applied by ENTSO-E; right: difference between both.

Below is an explanation for countries where the differences are high. In the appendix, the input data is further described for all countries.

2 The MS agreements on the non-binding targets are published on the EC's website including explanatory comments for some countries.

3 More information on how TSOs translated and enriched the non-binding targets can be found in the appendix of this document

France

The non-binding goals communicated by France during the data collection phase were expressed as rather large ranges. To enable the identification of a high level strategic offshore grid, ENTSO-E selected a single "expert value", considered as likely and rather close to the upper range. The expert values were consistent with the national goal of 40 GW by 2050 re-affirmed by president Macron during the Northern Seas Summit of 24 April 2023 as representing the French contribution to the 300 GW goal of the EC[4].

At a later stage (June 2023), France updated its official goals[5]. The differences by time horizon may be summarised as follows for the Northern Seas basin:

Northern Seas corridor (in GW)	2030	2040	2050
Non-binding goal (Jan 23)	2.1	4.6 to 8	4.6 to 17
ONDP data collection (March 23)	2.1	10.5	14.5
Official updated goals (June 23)	2.1	7 to 11	12 to 15.5

Table 2 – Differences by time horizon [GW]

Sweden

Sweden has a technology-neutral national target and communicated the offshore RES ambition in terms of energy to the European Commission. This has been translated to capacity by the TSO. During the work on the ONDP in 2023, the Member State and TSO agreed that the value applied by ENTSO-E can be used as a working assumption.

Ireland (ROI) and Northern Ireland

The ONDP data that have been included for Ireland's offshore wind capacity development in the Northern Seass Basin closely matches the non-binding goals provided by Ireland's government. For Northern Ireland, no non-binding goals have been provided. However, there are ambitions to develop offshore wind in Northern Ireland's offshore waters and data have been included to represent two radially connected offshore windfarms. This estimate provides a good view of local offshore development but appears as a delta in the table above, comparing Member State goals with aggregated ONDP data.

Luxembourg

Although Luxembourg does not have direct access to the Sea; Luxembourg needs to cooperate in the exploitation of offshore renewable energy in the Northern Seass through major investments in wind energy and the promotion of interconnections for green hydrogen and electricity.

For example, Luxembourg is already working closely with Denmark on a project to build "energy islands", artificial islands off the coast of Denmark linked to wind farms and supplying energy from the sea. A strong commitment to developing the offshore network and interconnections is essential.

Strengthening Luxembourg's cooperation with the other Northern Seas countries will also support Luxembourg's security of energy supply and confirm that offshore energy production is also a solution for landlocked countries.

4 Ostend Declaration

5 Letter sent 6 June to the Sea Basin Coordination Prefects, signed by the Minister of Energy Transition, the Minister of Ecological Transition, the Secretary of State in charge of the Sea and secretary of State in charge of Ecology

Great Britain

As Great Britain is not part of the EU, the British Government was not part of the European data collection in January 2023. In December 2022, a Memorandum of Understanding (MoU) between NSEC[6] and the British government was signed which also facilitates collaboration on long-term infrastructure planning such as the ONDP. National Grid ESO delivered input on potential capacities based on material from the Crown Estate[7, 8]. Related information has been entered in the above table. As for Northern Ireland, it appears as delta when comparing the MS-data with ONDP data.

Norway

The Norwegian parliament decided in 2022 as a political goal to facilitate offshore wind-fields for offshore-wind-production of 30 GW by 2040. This Norwegian goal is different from other countries' goals as other countries have decided on a hard goal to realise offshore production, whereas Norway has a goal to open offshore fields, which does not necessary mean building 30 GW. This means that, among others, the national energy balance and the cost of Norwegian offshore wind will decide how much of the 30 GW will be realised.

In Statnett's Long-term Market Analyses 2023, the baseline scenario shows 15 GW commissioned by 2040 – 2050. This is also the input used in the scenario-process for the ONDP. However, a value of up to 30 GW could potentially be seen, e.g. based on a tighter national energy balance or based on a political decision to also connect Norwegian windfarms to other countries.

6 NSEC = North Sea Energy Collaboration
7 Future Offshore Wind Scenarios
8 Offshore Wind Report, 2022

3 Offshore RES Capacities and Infrastructure Today

Offshore wind energy has been used since 1991, when the first offshore wind farm (OWF) of approximately 5 MW was installed in Danish waters. Since then, the installed capacity has, according to WindEurope, ramped up to roughly 27 GW by mid-2023 in the Northern Seas Region alone, of which 14 GW are located in GB. This capacity is expected to increase >4-fold to ~119 GW in 2030. Further considerations related to this increase can be found in Chapters 6 and 7.

Reaching today's 27 GW required more than 30 years of development and innovations as well as brave and expensive decisions by some companies. While the first offshore wind farm was installed at a specific CAPEX of approx. 2 M€/MW, today's offshore RES installations have increased to 3.2 M€/MW together with size, the largest being a 300-fold (1.5 GW) size plant[9]. In addition, the CAPEX for infrastructure has seen price developments.

Up to now, almost all offshore wind capacity has been radially connected, with the only exception being Krieger's Flak Combined Grid Solution in the Baltic Sea[10]. However, more offshore hybrid projects are to come, with the dual purpose of connecting the offshore generation to shore and linking two or more countries/market zones. The TYNDP 2022 included already six of these projects[11]. These are depicted in chapter 2 of the ONDP24 Pan-European Summary Report.

The path from connecting the early 5 MW offshore wind farms to shore to connecting today's up to 1,500 MW-sized plants has seen a variety of technologies used. In the beginning, AC technology to connect near-shore farms was used, with voltages starting at 50 kV, passing the 150 kV, 220 kV and 380 kV level. Now, the next step is HVDC 320 and 525 kV, the voltage level increasing together with the wind farm size. In the 2000s, a standardisation to 900 MW 320 kV HVDC platforms took place, e.g. in Germany due to the long distance passing the Wadden Sea. A modular method of platform expansion was developed in Belgium in the 2010s.

Today's offshore wind farms have, according to information provided by WindEurope, an average size of almost 900 MW, thus cable capacities connecting these have increased, with ENTSO-E expecting this to further increase to up to 2 GW in the near future. For example, TenneT has a 2 GW programme for unlocking offshore wind farms in Dutch and German waters already by 2029[12]. For the ONDP, a size of 2 GW has been assumed for the 2040- and 2050-time horizons.

Country	MW	Country	MW
Belgium	2,261	Ireland	25.2
Denmark	821.2	Luxemburg	0
Germany	6,977	Netherlands	2460
Great Britain	13,667	Norway	98
France	/	Sweden	/

Table 3 – Offshore RES Capacities installed in the Northern Seas Sea basin today (Source: WindEurope, August 2023).[13]

9 1,500 OWF in NL since Sept 2023 being the largest European plant. Hornsea 2 in Great Britain, in operation since August 2022 was, with 1,386 MW, the largest until recently.

10 Connected via the "combined-grid solution", in operation since October 2020

11 European Projects | ENTSO-E TYNDP (entsoe.eu)

12 TenneT's 2 GW programme

13 Remark – Deviance from numbers in national statistics e.g. for Denmark, this might result in differences to the definition of "Sea basin" – see also appendix on maritime spatial planning. Sometimes the Kattegat is allocated to Northern Seas, sometimes to the Baltic Sea. This might also explain why Sweden is not listed in Wind Europe's North-Sea statistic.

4 Potential Environmental Impacts – specific to Sea Basin Northern Seas

The planned large-scale deployment of offshore wind farms and accompanying offshore energy infrastructure are one of the key production options to decarbonise the energy system. offshore wind farms and infrastructure, of course, also have an impact on marine ecology (marine flora and fauna, which is described in Chapter 4) and may also lead to spatial conflicts with other maritime uses, such as fishing and shipping, which is discussed in the following Chapter 5.

In November 2022, the North Seas Energy Cooperation (NSEC) published the **"Spatial study North Seas 2030 – offshore wind development"** to assess the potential spatial impact of offshore wind development towards 2030 on a regional sea scale[14]. NSEC will publish a follow-up study. This follow-up study will look beyond 2030 and focus on the potential ecological impacts, both negative and positive. Based on these follow up "Quick Scans", the NSEC aims to provide recommendations to policy makers.

Both Chapters 4 and 5 are largely based on the work of the NSEC's collaborating Support Group (SG) 2 "Maritime spatial planning" and Support Group 4 "Delivering 2050"[15]. For further and more detailed information, it is recommended to visit the NSEC's publications **directly**. Another important source, especially for Chapter 5, is the **European Maritime Spatial Planning platform**.

The NSEC's "Support Group 2" is led by two ministries and the European Commission (EC) and composed of the nine Member States' ministries responsible for offshore spatial planning. Together they elaborate joint maritime spatial plans, mapping the various usages of the marine space today and in the future. NSEC's "Support Group 4" is led by two countries' ministries and the EC and composed of the nine Member States' ministries working with offshore energy deployment. Most ministries have also invited their national TSOs as well to support the group's work. Due to this collaboration between ministries and TSOs, it is possible to include the NSEC's findings in this document. The Regional Group Northern Seas finds it important to highlight the potential environmental impact of offshore energy activities, although the ministries' studies mainly focus on the generation part. So far, the impact of infrastructure on the environment has not been deeply investigated.

The impact of energy infrastructure is not part of the NSEC SG2 studies. Nevertheless, it is clear that all energy from the offshore wind farms have to be brought to the main load centres onshore by energy infrastructure. Although the spatial need for the offshore energy infrastructure is limited, it will have an impact on the environment. However, it is unknown how much impact the infrastructure will have and what kind of mitigating measures can be taken. More study is needed to have a better view on this topic.

14 In this study the Northern Seas are divided into several regions, which extend beyond national EEZ boundaries of one country but refer to the entire NSEC offshore area.

15 SG2 and SG4 gave their permission to quote this study.

4.1 Sea basin specifics

The Northern Seas basin consist of the North Sea, the English Channel, the Celtic Sea, the Irish Sea Skagerrak and Kattegat. It connects with the Baltic Sea on the East side and with the Atlantic Ocean on the North-West and South-West side. The North Sea is the biggest sea in this sea basin and offers good opportunities for Offshore Wind. The different seas have different characteristics such as water depth, stratification, sweat water inflow and usage such as shipping, fishing and natural protection areas, and therefore also give different opportunities and challenges.

4.2 Key findings of the NSEC SG2 studies on ecological impact

4.2.1 Towards 2030

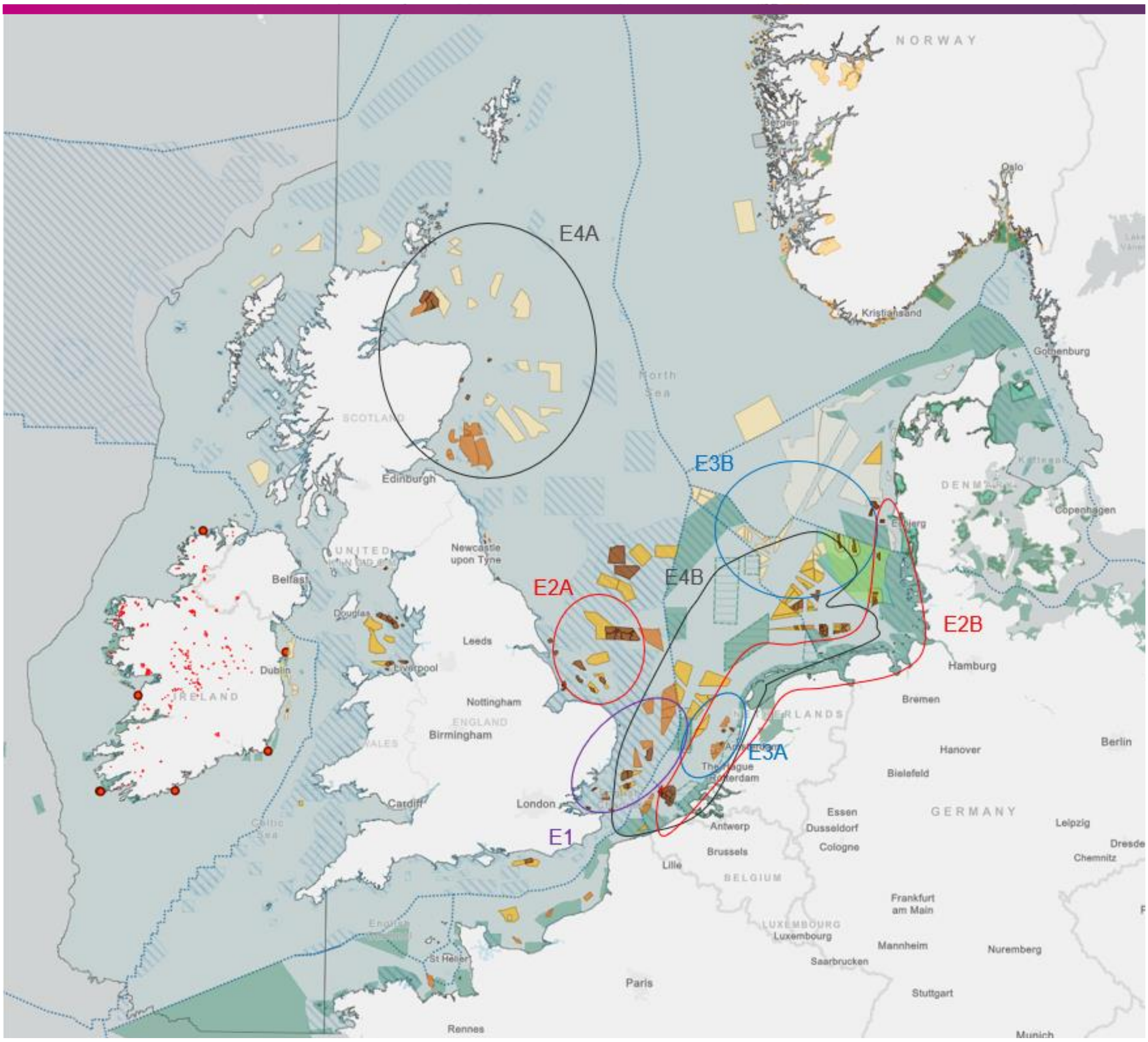
In 2030, 4.4-times the 2022 offshore wind capacity is planned for the entire sea basin. In their study looking until 2030, the NSEC SG2 notes that the combination of the offshore wind farm plans and the ecological function of certain parts of the sea creates hotspots, i.e. places where there are potential conflicts between the ecological function and the offshore wind production. For 2030, the **North Seas spatial study** identifies four types of such hotspots:

- E1: The area north-east of the English Channel: barrier for migrating birds and marine mammals;
- E2: Ecological valuable areas that might be affected by landfall cables (new grid);
- E3: Areas with potential stratification issues (large-scale wind energy development can influence the stratification of the water column and thus affect the whole ecosystem); and
- E4: Areas with potential conflicts for seabirds (concern for breeding colonies and key areas during other seasons).
- NSEC SG2 states that although these areas have the highest likelihood of negative impacts, the effects of OFWs on ecology are not limited to these hotspots. The impact on the ecology of the North Seas is widespread as species migrate far beyond protected areas and national borders and ecosystem effect are large scale effects.

The locations of these hotspots are illustrated in Figure 5.

Spatial conflicts between offshore wind farming and ecology can mainly be related to impact on stratification, sediment and primary production[16], direct collision risk as well as displacement and barrier effects on birds during the operational phase; and the impact of noise during construction works on marine habitats and species, ecological damage to the sea floor and during construction and potentially the deconstruction phase. In the North Sea, high and low tides in addition to the large nature reserves, e.g. in the Wadden Sea, are special features that have to be considered when locating wind farms and during construction and cable laying work.

16 Primary production is described as "primary productivity, in ecology, the rate at which energy is converted to organic substances by photosynthetic producers (photoautotrophs), which obtain energy and nutrients by harnessing sunlight, and chemosynthetic producers (chemoautotrophs), which obtain chemical energy through oxidation." – Britannica, The Editors of Encyclopaedia. "primary productivity". **Encyclopaedia Britannica, 24 Jan. 2022.**



Status OWF areas
SIMPLIFIED_STATUS
- Existing windfarm
- Licensed windfarm
- Designated windfarm area
- Other
- Other (partial OWF capacity)

World Exclusive Economic Zone Boundaries
Status
- Agreed
- Disputed

OSPAR Regions II & III

OSPAR MPA 2021 (ODIMS)

Natura 2000 – Habitas and Birds Dieective Sites

Ecology
Ireland (MarinePlan.ie)
- NMPF 5 1 2 Protected Marine Sites – Natural Heritage Area
- NMPF 5 1 2 Protected Marine Sites – Refugees for Local Faunal

Figure 5 – Location of the ecological hotspot in the Northern Seas. The maps shows some nature protected areas and potential wind farms. The lines show different hotspots areas. Source: **the Spatial Studies North Seas**

4.2.2 Beyond 2030

After 2030, the Member States' offshore wind ambitions will lead to a further increase in the number of offshore wind farms and thus may lead to an increase in conflicts with ecology.

In the study which looks beyond 2030, the NSEC SG2 focuses on offshore environmental questions and comes up with the preliminary findings that offshore renewable energy developments in the North Seas will increasingly influence other interests at sea and especially the biodiversity and ecosystem functioning. The main concerns include the Northern Seas' large-scale changes in primary production, which will affect the Northern Seas ecosystem as a whole and will have an impact on birds using the area. The study also points out that the ambitions to increase and speed up the scale of renewable energy development on the one hand, and ambitions to preserve ecosystems and restore biodiversity on the other hand, are in some ways conflicting due to the likely adverse impacts that large scale offshore renewable energy deployment will have on biodiversity and ecosystems. Another assessment of the study is that although nature enhancement in single windfarms can be promising on a local scale, it is unlikely to reduce or compensate for the loss of biodiversity on a regional sea basin scale.

The study focuses on three key elements to address the potential impacts of offshore wind development. The first is the potential impact on large-scale ecosystem processes; the second is the impact on species; and the third is the potential positive impact of wind farms. The impact of energy infrastructure is not part of this study. The results for each of the three key elements are discussed in more detail below.

Potential impact on large-scale ecosystems

The study states that offshore wind farms will affect the wind, the waves and the major streams, which in their turn can affect stratification (structure and mixing of vertical water layers), sediment and primary production. However, the impact varies from place to place. The stratification impacts the transport of heat, oxygen, carbon and nutrients.

Cumulative impact on species

The NSEC SG2 study points out that large-scale developments of offshore wind farms add a risk to populations of certain species. Although offshore wind farms do not pose the greatest risk compared to the total of human activities, for example compared with trawling, they certainly are expected to have an impact. As might be expected, the risk varies for different species. The main findings of the study are that future scenarios show a net increase in impact risk for some ecosystem components, e.g. birds and Littoral habitats. For birds, this increase can be ascribed to the impact of offshore wind farms. In the whole North Sea area, the bird species with the highest future increase with respect to the baseline (2022) in cumulative impact risk are the Northern Gannet and the Black legged Kittiwake. The study also points out that the contribution of offshore wind farms to the impact risk is relatively small compared to some other human activities, but relatively large compared to many other activities. Benthic trawling poses the highest risk for the studied ecosystem components of the North Sea.

Potential positive impacts on biodiversity

The NSEC SG2 finds that with offshore wind farms, there is the potential to have a positive impact on the biodiversity. For example, offshore wind farms can act as artificial reefs, and the exclusion of fishing in offshore wind farms increases the habitat complexity. Nature enhancement design might help limit the impact of bio biodiversity on local scale, whereas it is less likely that the impact on sea basin regional level can be reduced.

4.3 Measures to be taken to mitigate the effects and TSOs' reflections on NSEC SG2/SG4 reports

For many conflicts between offshore wind farming and ecology, mitigating or compensatory measures can be found. The influence of construction related noise in foundation work for wind turbines and platforms can be reduced, for example, by noise protection measures during construction or dismantling or by certain protection periods. Impacts on the soil as the result of laying submarine cable systems depend on the laying method used and can be kept as low as possible through a conscious choice. Other influences, such as the potential warming of the sea-bed through the operation of the submarine cable systems, can be mitigated by cable insulation and laying depth and breadth. Where influences on the environment cannot be avoided completely, compensatory measures can be taken.

While many possible measures to mitigate the negative impacts are already known, the NSEC SG2 studies show that, especially regarding the impacts on primary production, more research is needed and further measures need to be developed to reduce them. The TSOs of the North Sea region recognise that this issue needs full attention and that there is a need to focus on finding a solution here.

The Member States have this on their agenda to contribute to a healthy marine ecosystem, as stated in the **Ostend Deceleration**:

> *"…We will take all relevant and appropriate steps to accelerate regulatory and permitting processes for renewable energy and the related grid infrastructure, and aim to work with the European Commission to actively support these efforts. To this end, renewable energy should serve public interest and public safety while promoting **balanced co-existence** of renewable energy, **biodiversity** and environmental protection as well as to **contribute to a healthy marine ecosystem**. With regard to support schemes, we will continue to improve the design and cross-border coordination of tenders, including auctions. …"*

When considering the environmental impact of offshore wind energy, it must be considered that the extensive expansion of offshore wind energy and the interconnection of systems is a building block for achieving the EU climate targets. These targets were set, among other things, to protect the environment and (maritime) ecosystems from the negative impacts of climate change.

The impacts of the offshore wind expansion on the environment can be most effectively limited through joint action. With the optimisation of the offshore grid infrastructure towards a more integrated and coordinated system with both electrical and hydrogen connections, some of the potential spatial conflicts with ecological areas can potentially be avoided or at least reduced. The ONDP is a step in the direction of better coordination across multiple users of the offshore area the Northern Seas.

As the topics of this chapter and Chapter 5 "Spatial planning needs" are highly interlinked, the conclusion in Chapter 5 and the given recommendations refer to both chapters.

5 Spatial Planning Needs – specific to Sea Basin Northern Seas

The planned large-scale deployment of offshore wind farms and the offshore energy infrastructure will have an impact on the marine ecology (see Chapter 4) and beyond that may also lead to spatial conflicts with other uses, such as fishing and shipping, which is described in this chapter. In November 2022, the NSEC published the "Spatial study North Seas 2030 – offshore wind development" to assess the potential spatial impact of offshore wind development towards 2030 on a regional sea scale.

The previous chapter focused on the environmental impacts, mainly quoting the upcoming "quick-scan" referring to the horizon beyond 2030, whereas this chapter focuses on other uses such as fishing and shipping. Both Chapters 4 and 5 are largely based on the work of NSEC's collaborating Support Group 2 "Maritime spatial planning" and Support Group 4 "Delivering 2050"[17]. For further and more detailed information, it is recommended to visit the NSEC's publications directly. Another important source, especially for the current Chapter 5, is the **European Maritime Spatial Planning platform**.

The current MSP approach of the different Northern Seas Member States can be found in the appendix.

5.1 Introduction and general remarks

The NSEC's study points out that the high ambition to increase the number of wind farms leads to potentially more conflicts with other marine uses, especially with nature protection, fisheries, shipping, military, tourism and other offshore infrastructure (e.g. oil/gas extraction and pipelines). All countries in the North Sea allocate space for offshore generation and infrastructure, but the location decisions are made differently in all countries. For example, in the Netherlands, Germany and Belgium, the government determines exact locations and launches a tender for bids from OWF developers, while in the UK developers have more freedom to select a spot in a "search zone". In most countries, a substantial share of the Exclusive Economic Zone (EEZ) will be used for Offshore Wind already in 2030.[18]

In general, spatial conflicts between different sectors arise from direct competition over limited space, or when one sector is negatively impacting the other, even if it is not in the same location. The Northern Seas have been busy sea areas, with conflicts between different users even before the first OWFs were planned and built. As the first offshore wind farms have led to spatial conflicts, the first Maritime Spatial Planning (MSP) activities started in North Sea countries around 2009.

17 SG2 and SG4 gave their permission to quote **this study**, published in November 2023.

18 **https://energy.ec.europa.eu/system/files/2023-01/Final Report spatial studies North Seas2030.pdf**

5.2 Conflicting sector interests and resulting spatial planning needs

The main aim of this chapter is to show how spatial planning measures can help issues related to multiple sectors.

5.2.1 Nature protection

A brief overview of the NSEC SG2 findings related to the impact of offshore wind energy on the marine environment was given in Chapter 4.

5.2.3 Shipping

The NSEC SG2 study reports that in the North Sea, the shipping intensity is greatest in the north-south direction and in an east-west direction between the UK, Belgium and the Dutch coast. The increase of offshore wind farms potentially leads to increasing collision risks, to increasing risk for crew, environment (oil spill, cargo loss) and vessel damage-loss and to higher costs for search and rescue and cleaning.[19] SG2 recommends that MSP should be used to improve communication between sectors and find common solutions. For example, it could be required that cables cross shipping lanes – where possible – at right angles to decrease the time spent on the laying, operation, maintenance and dismantling of pipelines and submarine cables and thereby reduce negative effects on shipping traffic.[20] However, specifications regarding the cable crossing of shipping routes may hamper meshing of the offshore grid. To make more or suitable contiguous areas available for offshore wind energy, options include the use of marginal areas of shipping routes or reallocating shipping routes that are no longer needed. This has been implemented in the past in Germany, for example, with SN6 and coordination is currently taking place between the Netherlands, Germany and Denmark on the partial use of shipping route SN10 for offshore wind energy. This is necessary to achieve the expansion targets and to preserve other areas for nature conservation. However, as shipping routes run through several EEZs, coordinated planning must ensure that shipping traffic is as safe as possible across borders and that areas which become free can be made available quickly for other uses.

5.2.2 Fisheries

With the fisheries sector, spatial conflicts can arise for both offshore wind farms and subsea cables. Although fisheries and cables can mostly occupy the same space, they can come into conflict when fishing involves bottom trawling or, as is generally the case in connection with shipping, when vessels are stranding on a cable or when anchors are being dropped on the cable.[21] For fisheries and wind farms, conflicts are mainly related to collision risk. The situation is aggravated by the fact that in the North Sea there is often a triple conflict between fisheries, environmental protection and offshore wind, which leads to cumulative effects. Whether fishing is allowed within wind farms or what distances to wind farms and cables have to be kept is regulated very differently in all countries. For example, in Belgium, all non-maintenance vessels have to remain at least 500 meters away from wind farms while in the Netherlands, vessels up to a certain length are allowed to transverse but not fish and there are even pilot projects where fishing inside wind farms is allowed under certain conditions.[22] Here, too, SG2 finds that MSP can be a tool to improve the communication between the sectors and help finding solutions. These could be, for example, the development of corridors for cables and pipelines to bundle cables and pipelines as much as possible by means of parallel routing, or the development of multi-use-areas.[20] Even when no concrete planning solutions can be found, it may help to gain a greater mutual understanding and finding other kind of solutions.[22] Cooperation between the North Sea countries in the development of a more integrated offshore network infrastructure can contribute to a more efficient use of cables and platforms and thus to fewer conflicts with the fisheries sector.[20]

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19 European MSP Platform – Conflict fiche 7: Maritime transport and offshore wind

20 Spatial study North Seas 2030 – offshore wind development

21 European MSP Platform – Conflict fiche 2: Cables/pipelines and commercial fisheries/shipping

22 European MSP Platform – Conflict fiche 5: Offshore wind and commercial fisheries

5.2.4 Military

There are also spatial conflicts between offshore wind farms and military use, which include an increased collision risk of submarines and military vessels with wind turbines and a disturbance of the radar as it might register the rotating blades of the turbines as aircrafts.[23] As defence interests are a national priority in most countries, defence interests usually take precedence over all other sectoral interests.[24] Nevertheless, the possibility of laying cables in certain areas used by the military without restricting military use should be examined. In this manner, major detours in cable laying could be avoided and costs saved. The sharing of territories could possibly also facilitate the securing of critical infrastructure.

5.2.5 Tourism

The NSEC SG2 study states that, although the development of offshore wind energy is already taking place mostly in areas further away from the coast and will continue to shift in this direction in the future, conflicts can still arise if wind farms are visible from the coast or are located in areas that are, for example, used for water sports. Maritime and coastal tourism is an important economic sector for many countries in the North Sea region and on a regional and local level there is usually sufficient interest and capacity of this sector to engage in the planning processes.[25]

SG2 points out that nearshore conflicts differ from offshore conflicts in that they have an additional dimension by referring to local communities and involving more and very different stakeholders. They often also have an emotional dimension, which can make them difficult to deal with. To address these problems, SG2 recommends that local communities should be involved as early as possible and MSP can be used to minimise the visual impact and to communicate on the visibility and other influences.[24] Data on the coastal tourism and recreation sector should be collected so that local needs can be considered in planning efforts. Where possible, access to offshore wind farms for recreational vessels should be allowed and can even serve as a visitor attraction, and visitor centres may serve an additional educational purpose. There are some examples of offshore wind – tourism multi-use in Denmark and the UK.[25]

23 Spatial study North Seas 2030 – offshore wind development

24 Addressing conflicting spatial demands in MSP

25 European MSP Platform – Conlict fiche 1: Maritime tourism (incl. local communities) and offshore wind

5.3 TSOs’ Reflection on NSEC SG2/SG4 Reports and EC’s MSP Website

As the topics of Chapter 4 and Chapter 5 are highly interlinked, these conclusions and the given recommendations refer to both chapters, with their origin nonetheless being the joint work of the ministries under NSEC SG2.

Due to the large number of different sea users, there are numerous conflicts between the various uses – not only but also with OWFs and the associated infrastructure. There are no simple or universal solutions for addressing spatial conflicts in MSP but more intensive international cooperation in planning, monitoring and research will help in all affected areas. The various interests and impacts on the seas need to be balanced by policy makers, preferably at large regional sea level. Policies will affect the location and timing of OWFs, but also the way in which the energy will be unlocked, the routing of the infrastructure and the landing sites. The potential environmental impact of new infrastructure has not yet been investigated on a large scale but may be the subject of further studies in the future. New policies are likely to follow after studies such as the spatial study within the NSEC.

Proactively specifying the conflicting interests as precisely as possible and outlining the respective context (level of risk, knowledge gaps, needs of the parties involved) are crucial for developing a solution. In addition to conflict avoidance, where spatial planning activities ensure that incompatible activities do not take place in the same space or negatively affect each other, conflict mitigation and compensation measures can be taken[26]. This involves mitigating the effects of spatial competition or negotiating compensatory measures between the sectors concerned. For ecological impacts, for example, there are already legal obligations for the use of preventing and mitigating measures and compensation. Regarding offshore wind energy, a more integrated offshore network infrastructure and thus a potential more efficient use of offshore space can avoid some of the potential conflicts. Therefore, it is important to develop a joint vision for the offshore grid infrastructure and to incorporate it into spatial planning activities. The ONDP, as a biennial product, will iteratively present a high-level infrastructure that will evolve over time, as will the Member States’ non-binding goals.

However, prevention, mitigation or compensation might not always be possible within existing policy frameworks and choices need to be made. International collaboration and collaboration across multiple users of the offshore area will help in finding optimised solutions for these spatial tensions and choices to make.

26 Addressing conflicting spatial demands in MSP

6 High-Level Results on Offshore Network Infrastructure Needs

6.1 2030 Offshore Network Infrastructure Needs

As shown in Chapter 2, an amount of 119 GW offshore wind capacity is expected to be installed in the North Sea in 2030, of which 58 GW are expected in Great Britain and Norway. Comparing these high ambitions to today's installations of 27 GW[27], of which 14 GW in GB, this implies, for the next six years, a >4-fold increase of what is in operation now. Translating this further, annual installations of 15 GW are needed between 2024 and 2030. (If the installations were to follow the same distribution as up to today, this would be 8 GW annually for European Member States and 7 GW annually for Great Britain plus Norway.) According to WindEurope[28], during the last 10 years average annual installations reached 2.5 GW, and during the last 5 years, the annual installation rate was 2.9 GW.

Acceleration is needed not only for offshore RES installations, but for the related transmission infrastructure as well. Connecting the additional 92 GW offshore RES radially to the EEZ's home-countries with an assumed average 2 GW-sized cable installations, a route length of estimated 7,000 km would evolve in EU Member States + Norway. British radial connections are not part of the equation here, but they target the same supply chains as everyone else.

It should be noted that "Route length" does not mean cable length; this might be twice to three times as long depending on the technology and design used (DC monopole or bipole, with dedicated metallic return – or AC in one or three separated cables). In addition, significant reinforcements will be required to the onshore infrastructure to bring renewable electricity to the load centres and help land-locked countries to further decarbonise their energy mix. These implications to the onshore systems will be investigated as part of the TYNDP2024 needs-identification exercise.

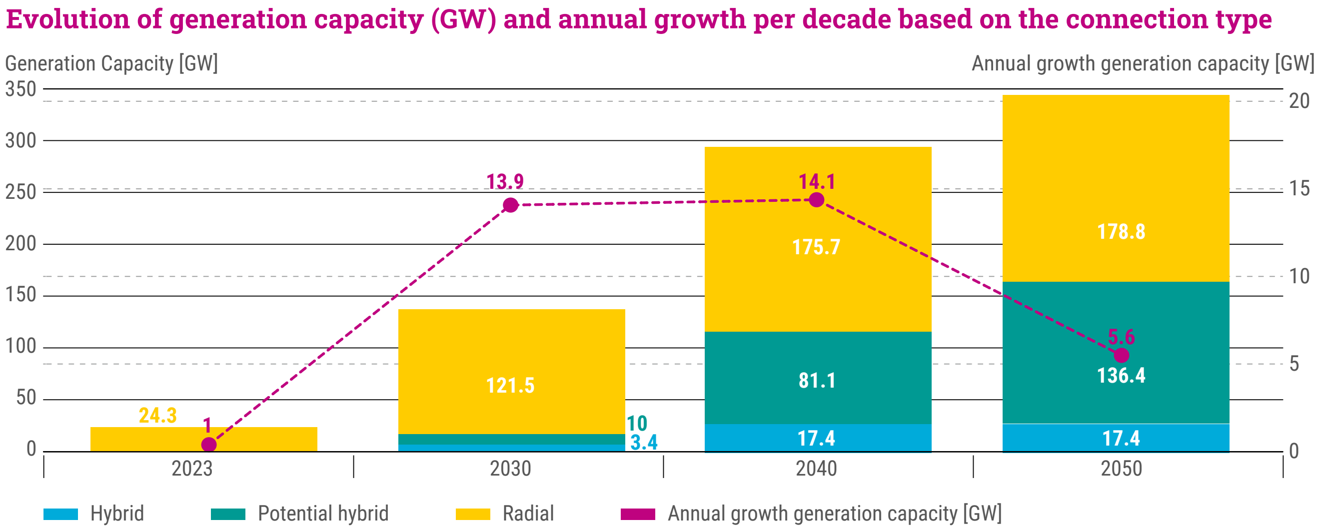


Figure 6 – Offshore targets in EU Member States + Norway and UK and annual growth rate for the Northern Seas basin (input data). Growth rate shows difference between time slices.

27 WindEurope statistics

28 Offshore Wind Energy 2022 statistics, WindEurope, August 2023.

As a reminder, there is no expansion loop performed for the 2030-time horizon. The maps hereunder provide an overview of the RES goals of the North Sea Member states as well as Norway. The bubbles provided for each country inform the way these goals are integrated. More precisely, the bubbles indicate in yellow the share of offshore RES radially connected without any possibility of further expansions (e.g. into a hybrid system), in blue the share of offshore RES connected to a hybrid system, and in green the share of offshore RES radially connected but with a possibility of further expansion. Unsurprisingly, offshore RES integrated by 2030 is mostly radially connected but some hybrid systems are already appearing on the map (e.g. the LionLink project between NL and UK or the Nautilus project between BE and UK with Princess Elisabeth Island planned in Belgium).

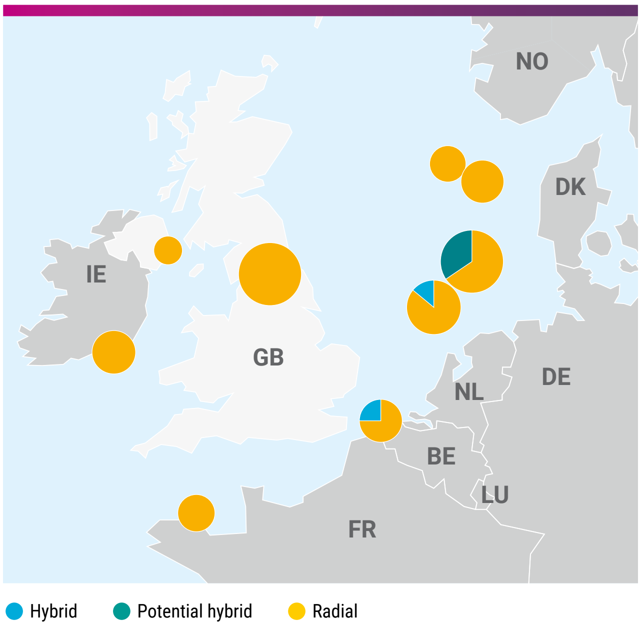


Figure 7 – Generation capacities [GW] per country and per connection type in 2030 (input data).

6.2 2040 Offshore Network Infrastructure Needs

By 2040, an amount of 274 GW offshore wind capacity is expected to be installed in the North Seas, of which 110 GW are expected in Great Britain plus Norway. Comparing these numbers to those for 2030 mentioned in the previous section, this implies more than a doubling of the offshore wind level in the North Sea in one decade. Translating this further, annual installations of ~10 GW for European Member States and of >5 GW for Great Britain and Norway are needed between 2030 and 2040, see Figure 7. Connecting the missing 155 GW offshore RES radially to the EEZ's home-countries with an assumed average 2 GW-sized cable installations, estimated 21,140 km route length would evolve for the EU Member States + Norway (GB not considered here), translating to an annual expansion of 2,100 km. Again, significant onshore reinforcements are also to be expected and will be investigated as part of the TYNDP 2024 needs investigations. In 2040, the EU-**starting grid** connects 79 GW offshore RES radially, 17 GW via hybrid connections and offers 68 GW offshore RES to be tested for hybrid connections ("potential hybrid connections"). This generation capacity totals a total capacity of 164 GW that is complemented by 110 GW in Norwegian and British waters. For the 2040-time horizon, in addition to the starting grid, an **expansion loop** has been performed. Anticipating the availability of DC circuit-breakers, out of the 84 expansion candidates, 15 links have been selected, adding an extra interconnection capacity of 21.5 GW to the entire region (incl. NO+GB). In configuration without the DC circuit breaker, a DC converter station would be needed at the ends of each expansion in addition to an AC offshore substation to clear faults on the AC side of the converter. This results in a selection of 6 links, adding a total interconnection capacity of 7.5 GW. The lower amount of expansions selected in the absence of DC circuit breakers is a logical result due to the higher cost of each expansion.

The North Sea TSOs are striving to develop offshore systems that can be interconnected with others in the future. With early consideration in the system design, a later interconnection is already possible today but to a limited extent. There are several efforts to extend the technical possibilities for interconnection. One example is TSOs' participation in the EU-funded development project "InterOPERA", which aims to better enable interoperability between HVDC assets from different manufacturers.

A general trend can be observed of developing or reinforcing the links between countries with excess RES and countries with RES deficit. This translates to 2 high-level transmission corridors in the North Sea:

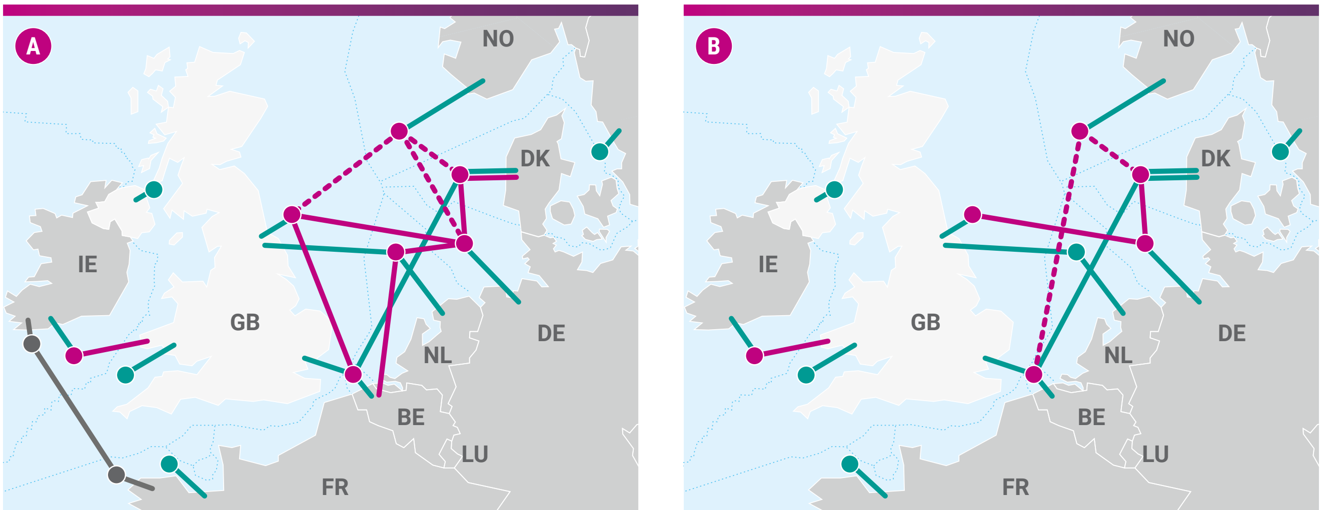
- One West-East transmission corridor, allowing the transmission of abundant offshore RES produced towards the continent via offshore hubs; and
- One North-South transmission corridor, allowing the transmission of abundant renewable energy produced in Northern Europe down to the Continental system. This transmission corridor appears for both configurations, i.e. with and without DC circuit breakers.

Table 3 summarises the key numbers related to these expansions, both for the configuration with and without DC circuit breaker.

Figure 8 provides the infrastructure to integrate the 2040 offshore wind goals of the North Sea Member states, Norway and Great Britain. The nodes symbolise aggregated offshore RES per country. This map reflects the selected expansions. The share of offshore RES connected to more than one country increases due to more offshore hybrid projects materialising on top of the initial radial connections. In this manner, the European power system facilitates better sharing of offshore RES between the countries adjacent to the Northern Seas sea basin and beyond.

Additional equipment 2031 … 2040	Scenario with DC breaker	Scenario without DC breaker
Number of expansions selected	15	6
Total transmission capacity	21.5 GW	7.5 GW
Offshore route length	19,890 km	17,790 km
Onshore route length	1,250 km	1,250 km
Number of offshore DC converter stations	53	59
Number of onshore DC converter stations	58	56
Offshore AC substations	5	11
Amount of DC circuit breakers	15	0
Cost	148 bn€	148 bn€

Table 4 – Summary of the key numbers related to the 2040 expansions (entire area, not counting radial equipment and cost for GB).



DC Circuit breaker available

- Corridors identified in ONDP
- Corridor identified in neighbour SB
- Existing, planned hybrid and radial links
- Potential corridors identified in ONDP

DC Circuit breaker not available

- Corridors identified in ONDP
- Corridor identified in neighbour SB
- Existing, planned hybrid and radial links
- Potential corridors identified in ONDP

Figure 8 – 2040 expansion results on top of the starting grid. Clusters of offshore RES are in this visualisation aggregated to one cluster per offshore climate zone per country.

6.3 2050 Offshore Network Infrastructure Needs

6.3.1 Electricity Transmission Infrastructure Needs

According to the Member States' non-binding goals for 2050, an amount of 218 GW offshore wind capacity is expected to be installed in the North Sea; in addition, 112 GW are planned to be installed in Norway and Great Britain. Compared to the goals for 2040, this means an additional installation of 60 GW. For the European Member States, this translates to an annual installation of 6 GW between 2040 and 2050, which is a significantly lower speed of expansion than between 2030 and 2040.

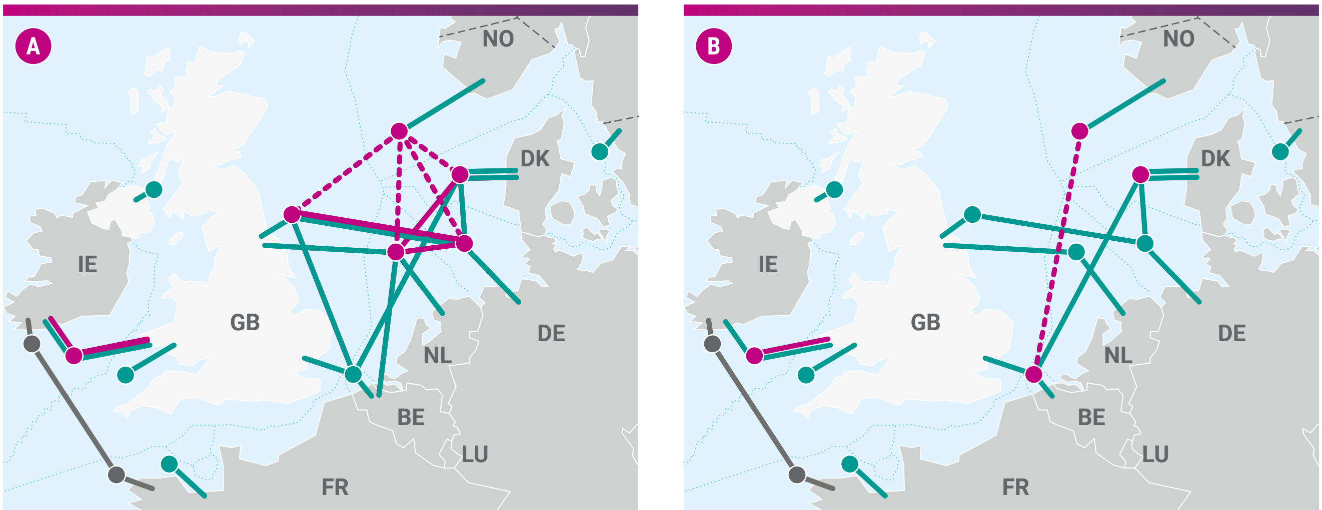
For the connection of the additional 60 GW radially to the EEZ's home-countries with an assumed average 2 GW-sized cable installations, an estimated 8,000 km route length would evolve for the EU Member States plus Norway (GB not considered here). As already mentioned above, onshore reinforcements are also expected.

In 2050, a number of **different starting grids** have been considered according to expectations related to technology development (with/without/with late availability of DC breakers – see the methodology document for a more detailed description).

For all 2050 configurations, the starting grid includes 5,100 km route length to connect the additional offshore RES, stemming from the Member States' goals. The distribution between hybrid and potential hybrid connections, however, varies between the configurations used for 2040 because different amounts of connections have been selected in the optimisation for the 2040- time horizon.

Similar as for the 2040-time horizon, on top of this starting grid, an **expansion loop** has been performed. In the scenario which anticipates the availability of DC circuit-breakers, out of the 180 expansion candidates, 6 links have been selected, adding a hybrid interconnection capacity of 8.5 GW via offshore clusters.

In the scenario without DC circuit breaker, i.e. requiring a DC converter station on each side of each expansion, 4 links have been selected, adding a hybrid interconnection capacity of 3 GW. These expansions are visualised on the following maps in an aggregated form.



DC Circuit breaker available

- Corridors identified in ONDP
- Starting grid (existing + planned + identified in 2040 [hybrid + radial links])
- Corridor identified in neighbour SB
- Potential corridors identified in ONDP

DC Circuit breaker not available

- Corridors identified in ONDP
- Starting grid (existing + planned + identified in 2040 [hybrid + radial links])
- Corridor identified in neighbour SB
- Potential corridors identified in ONDP

Figure 9 – 2050 expansion results on top of the starting grid. Clusters of offshore RES are in this visualisation aggregated to one cluster per offshore climate zone per country.

Compared to the results for 2040, fewer additional links have been selected. Nevertheless, the results still show the transmission corridors West-East and North-South.

Table 3 summarises the key numbers related to these expansions, for both scenarios with and without the anticipated availability of DC circuit breakers:

Figure 10 provides the 2050 offshore wind goals of the North Sea Member states as well as Norway. The circles indicate for each country the share of offshore wind that is radially connected (in yellow), connected to a hybrid system (in blue) and radially connected with possibilities for further expansions in the future (in green). This map reflects the selected expansions. The share of offshore RES connected to more than one country increases due to more offshore hybrid projects materialising on even top of the 2040 radial and hybrid connections. In this manner, the European power system facilitates the better sharing of offshore RES between the countries adjacent to the Northern Seas sea basin and beyond.

Additional equipment 2041 … 2050	Scenario with DC breaker	Scenario without DC breaker
Number of expansions selected	6	4
Transmission capacity	8.5 GW	3.0 GW
Offshore and onshore route length	8,020 km	7,950 km
Onshore route length	0 km	0 km
Number of offshore DC converter stations	22	22
Number of onshore DC converter stations	28	30
Offshore AC substations	0	4
Amount of DC Circuit breakers	6	0
Cost	59 bn€	57 bn€

Table 5 – Summary of the key numbers related to these expansions, both for the configuration with and without DC circuit breaker.

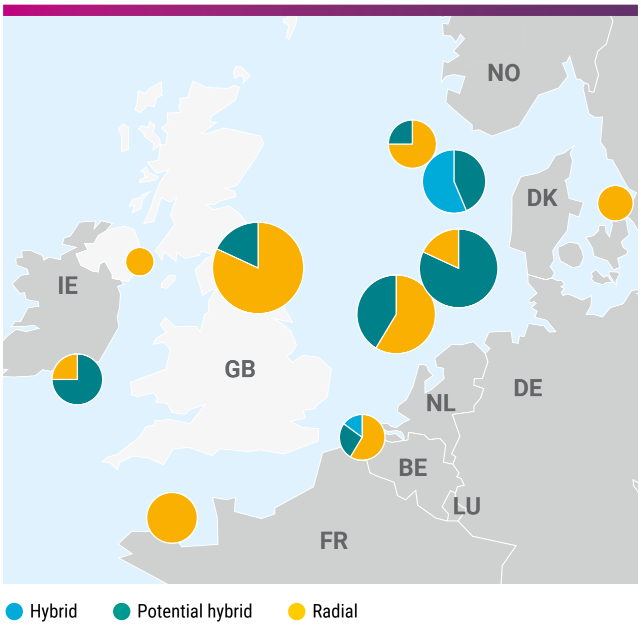


Figure 10 – Generation per country and connection type for 2050 (input data).

6.3.2 Hydrogen Infrastructure Needs

As input data, the Member States delivered their non-binding goals for generation capacity and the information for whether to connect them electrically or via Power-to-Gas (PtG). Three countries are already at the stage of identifying potential generation capacities in the North Sea that will be connected to PtG and thus the hydrogen sector. These countries are the Netherlands, Denmark and Ireland. Based on their input, offshore electrolysers with a total capacity of 34 GW are anticipated to be installed in the North Sea in 2050. As this load consumes electricity at the point of production, less electricity infrastructure has to be developed in the case of the direct use of hydrogen. In most other countries, the future role of offshore hydrogen production is yet to be defined and PtG capacities are therefore assumed to be located only onshore there. Onshore electrolyser allocation provides the benefit that both the offshore wind capacity and the electrolyser are fully integrated into the onshore electricity system, allowing for the direct use of the offshore wind power for electricity end-use in times of onshore RES shortage or to increase electrolyser operation (beyond offshore wind power generation) in times of onshore RES oversupply. The electrolyser capacity in the different countries represents, based on the TYNDP 22 DE scenario, a total amount of 265 GW.

For all other countries, conclusions for hydrogen potential could be drawn from the surplus of energy available at the offshore wind plants. However, these surpluses are a result of the market interaction and might change if new flexible loads (such as PtG) are added to the market as they have an impact on the prices and thus the operational hours of the flexible load/ an electrolyser. In conclusion, the surpluses can only be seen as a rough indication. In general, there is a surplus of electricity where the potential RES production is higher than the demand or when the transmission capacity of the existing electrical infrastructure is not high enough to transport the electricity from the generation to the demand location. Adding new flexible loads in the respective nodes would increase the integration of this already existing RES potential. Throughout the different scenarios, we see similar amounts of excess energy per country. The table below shows the amount of excess energy available for potential flexibility measures energy (TWh) per country in perspective to the installed offshore wind capacity exemplified for scenario 1a.

In addition to the total amount of excess energy, a higher resolution in time and location is useful for concluding the potential usage of these energy amounts. The duration curves of each offshore node reflects for most of these nodes a similar trend: There is good surplus potential during around 5–15 % of the year. That might be due to lack of demand or network codes requiring down-dispatch to ensure ancillary services.

To conclude: There are high amounts of surplus energy which could be used for hydrogen production or any other flexible load or storage. However, the operation of PtG unit is a function of the electricity price if connected to the electricity network infrastructure and depends on wind profiles if built-stand alone. An interlinked model with PtG capacities connected to the onshore and offshore network infrastructure with concrete locations will provide more insights.

In general, the objective is to arrive at an optimised integrated offshore network infrastructure where electrolysers do not lead to an additional (RES or) electricity network built-out, but instead lead to a higher usage of already planned offshore RES plants and DC links. This contributes to the European objective to decarbonise the Energy system. This optimum may vary from country to country depending on being an (electricity/hydrogen) importer or exporter and on the connection of PtG, either stand-alone (no connection to the electrical grid) or integrated. The integrated connection can be achieved via radial connection, hub connection and including overplanting or not. More thorough investigations on combined electricity-and-hydrogen will be executed in the fully integrated TYNDP26 process, when presumably the information database on national plans and on asset prices will also have evolved.

Country	2050 Offshore RES Capacity (GW)	2050 Excess energy (TWh), available for flexibility measures Configuration with offshore DC circuit breakers
Belgium	8	1
Germany	65	60
Denmark	35	34
France	15	10
Ireland	20	37
Netherlands	72	22
Norway	15 (30)	6
Sweden	4	9
United Kingdom	98	48
Total	**332**	**226**

Table 6 – Offshore RES capacity (GW) and excess energy (TWh available for flexibility measures).

6.4 Resulting assets for the offshore electrical infrastructure

For the results found, a first estimation can be made on how many and which assets are needed to build this potential network. Results for the entire sea basin are given in the Appendix. There are many uncertainties; therefore, some rough estimations had to be made. Figure 11 gives an impression of the required assets and the costs for EU Member States.

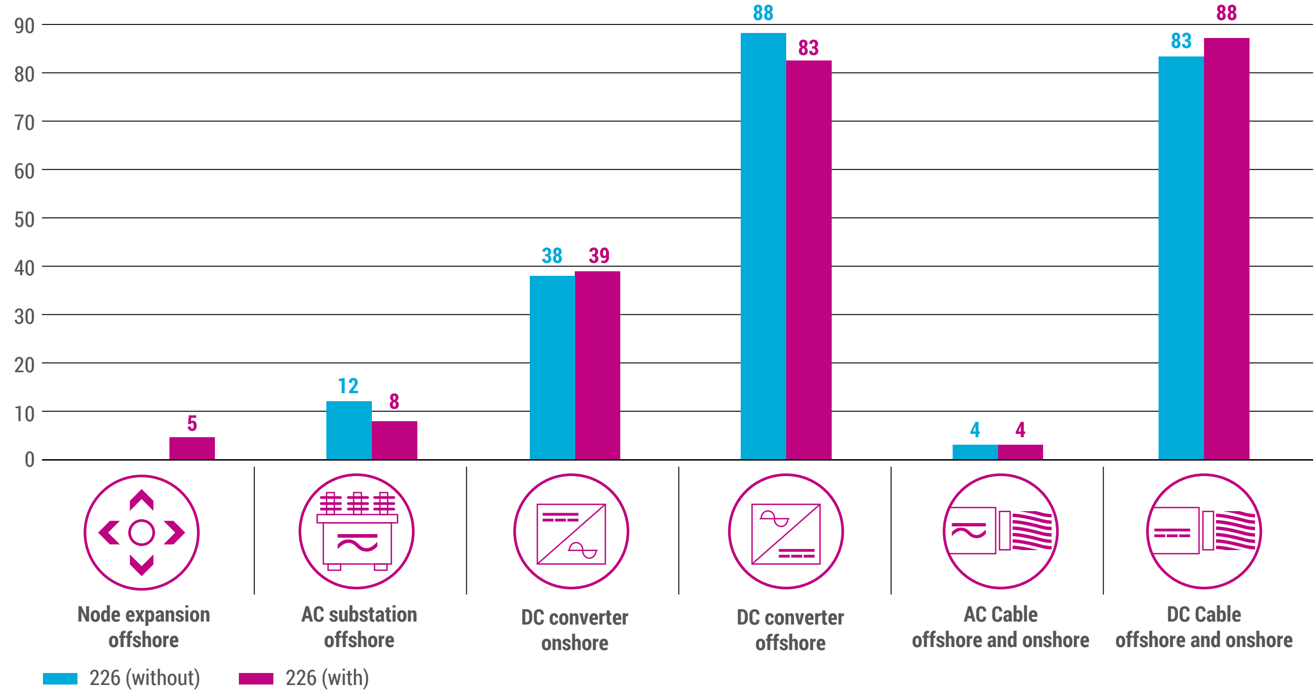


Figure 11 – Comparison of CAPEX needed per infrastructure equipment (2025 – 2050) – EU MS only.

7 Reflections for the Region

7.1 Reflection on the transmission corridors in the Northern seas

7.1.1 Results show robust transmission corridors in the Northern Seas

In this study, the development of potential offshore infrastructure is tested for two main configurations: one with DC circuit breakers available, and another where this is not the case. When DC circuit breakers become mature for offshore applications, less converters will be needed, creating higher levels of interconnectivity in the offshore network infrastructure at slightly lower costs. The offshore network infrastructure will be more integrated compared to a situation without DC circuit breakers.

Regardless of whether the DC circuit breakers become mature, the transmission corridors found in this study are robust in both configurations. The transmission capacities and exact network routing of these transmission corridors differs between both configurations.

In conclusion, the identified high-level North-South and West-East transmission corridors are robust and grow over time.

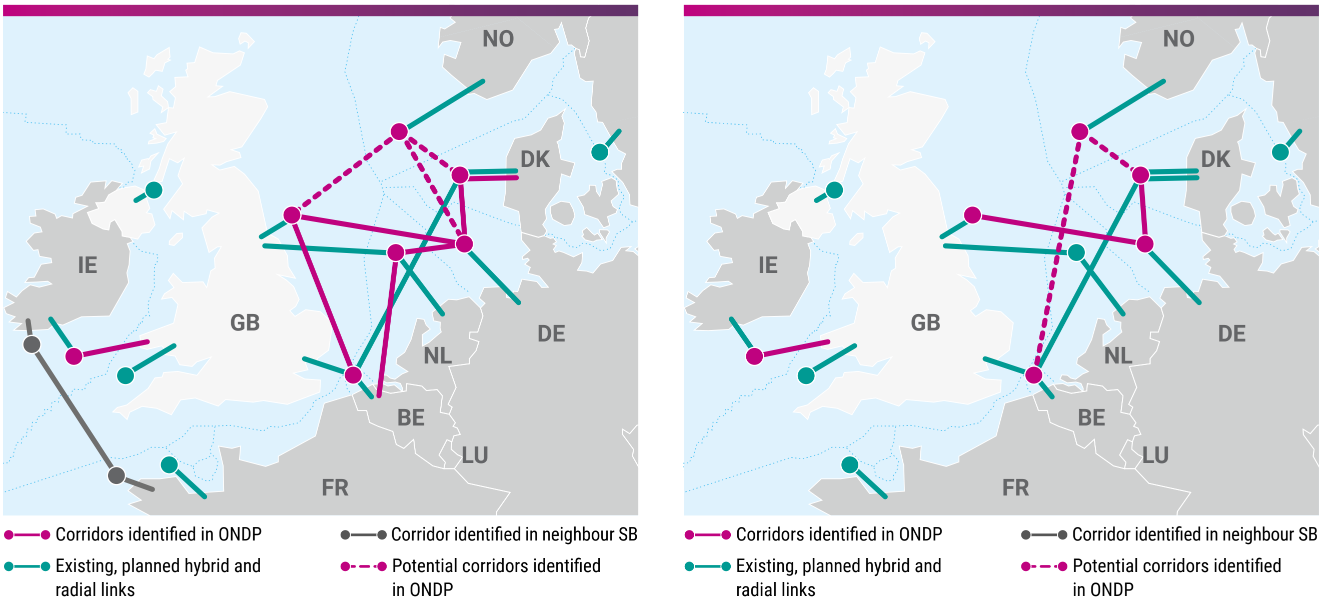


Figure 12 – The transmission corridors found in 2040: with (left) and without (right) the availability of offshore DC circuit breakers.

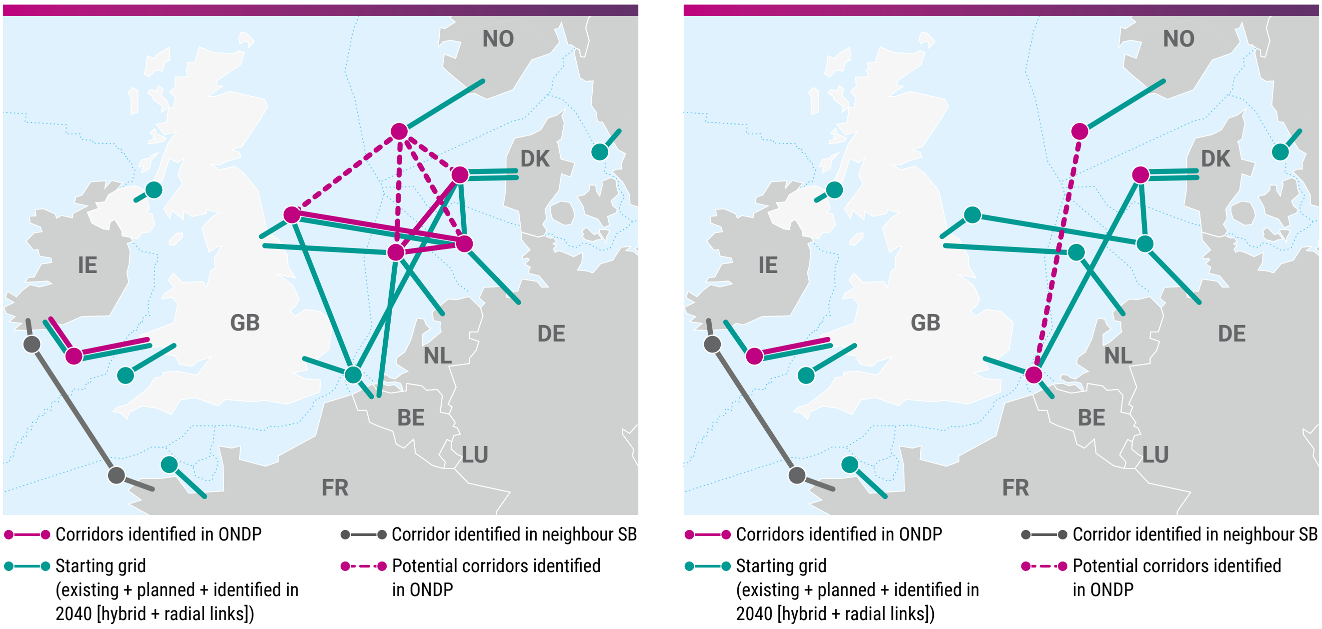


Figure 13 – The transmission corridors found in 2050: (left) and without (right) the availability of offshore DC circuit breakers.

7.1.2 Role of the transmission corridors

In 2040, the North-South and West-East transmission corridors appear the most prominent in the situation with DC circuit breakers. The North–South transmission corridor connects offshore nodes from Norway via Denmark, Germany, the Netherlands to onshore Belgium. This transmission corridor has both an interconnection function as well as the function to unlock generation. The West–East transmission corridor connects Irish offshore nodes via the UK by offshore and onshore nodes towards the Norwegian, Danish and German offshore nodes.

Examining the flows of the whole potential offshore network gives an impression of how the potential transmission corridors will be used and what their benefit is. For example, the North–South will not be used for only flows going to the south.

Examining the flows for 2040, see Figure 14, we can draw a number of conclusions:

In general, it can be seen that the infrastructure is used as a main function to evacuate the energy produced offshore to onshore systems, be it to the EEZ's country or to a foreign country. This is easy to understand as this is the main function of the infrastructure. During times of low offshore wind production, the infrastructure is not highly used with their interconnection function. The main exceptions are BE–UK, NL–UK, IE–UK and NO–DE as these connections are applied with their interconnection function as well during times of low offshore wind.

Countries with excess RES (Ireland, UK, Denmark, Norway, the Netherlands) export via the offshore infrastructure to countries with a deficit (Belgium) or balanced (Germany) in RES. See Figure 15 to see which countries have a surplus or deficit in RES.[29]

For the flows in the North–South transmission corridors are mainly from Norway and Denmark to Germany; and from the Netherlands to Belgium. Between Germany and the Netherlands is used but more or less balanced over the year.

29 Only offshore wind from the Northern Seas is taken into account in this report.

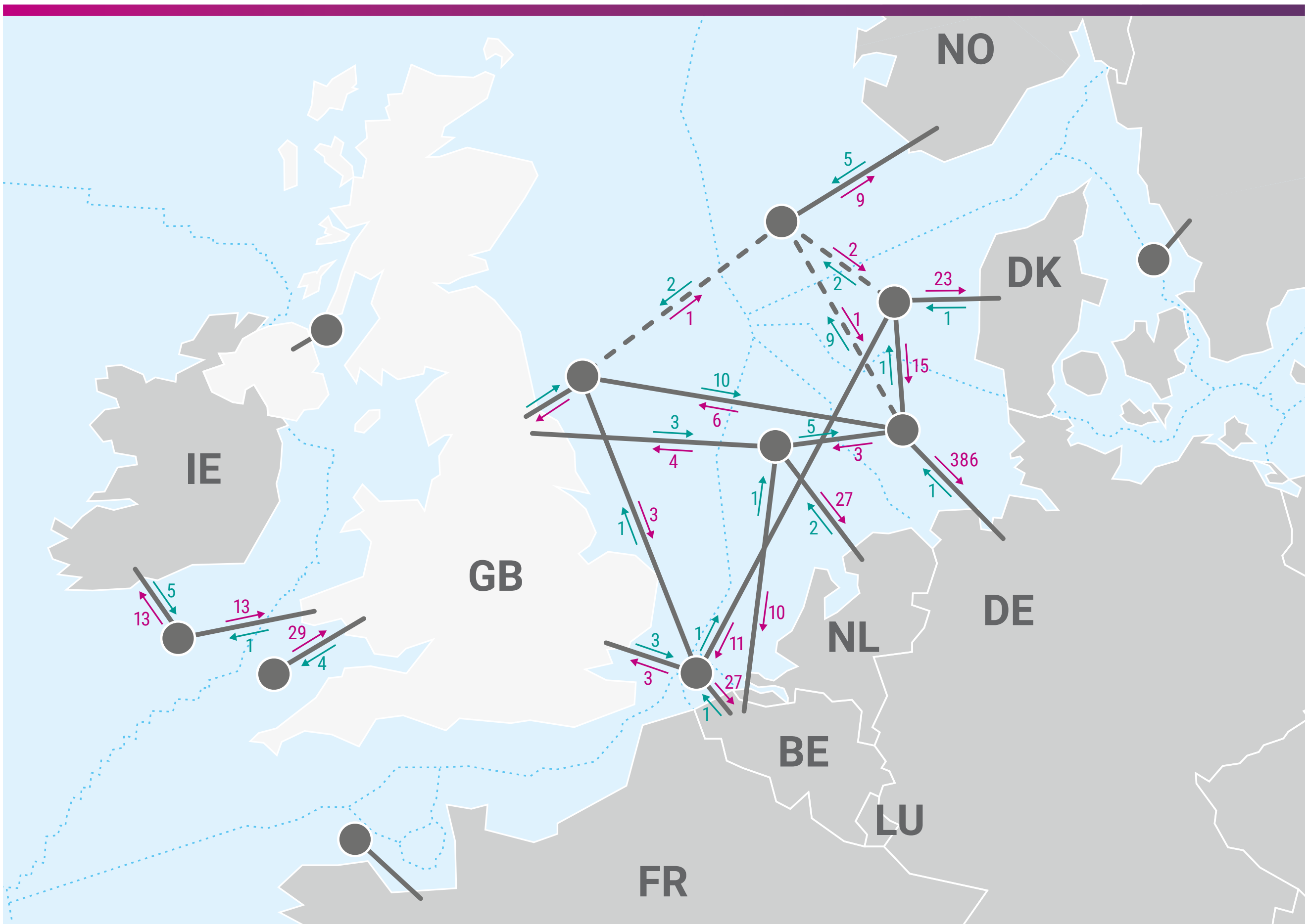


Figure 14 – Annual flows offshore, in the event the DC circuit breakers are available. The connection IE–FR is part of the Atlantic Sea basin.


Figure 15 – This map shows per country whether the annual onshore and offshore RES production exceeds or falls short to the annual demand. Green indicates it exceeds and blue it falls short. Note: offshore wind from the Northern Seas is taken into account only in this analysis.

7.1.3 Non-financial impact of an offshore interconnected system

There is a benefit in connecting some of the offshore nodes and creating transmission corridors. The high-level benefits of connecting systems is potential economic benefits, i. e. due to electricity price convergence in the region and better energy security by increased network redundancy, which also leads to better utilisation of the offshore RES. This leads to limiting the CO_2 emission and emission costs. However, a hybrid offshore infrastructure offers additional advantages and also disadvantages. Hybrid infrastructure connects different market areas. This will facilitate the better utilisation of offshore RES by up to 53 TWh in 2040, in the entire system and with this lowering the CO_2 emission and the non-CO_2 emissions. For 2040, the 8 Mega ton of CO_2 emission is avoided when having a hybrid grid with DC circuit breakers. Without DC circuit breakers, less offshore infrastructure would be built, thus only 4.6 Mton CO_2 would be saved.

A better interconnected system offers in general more reliability in the event of disturbances, building on fast protection systems and switches. There are always disturbances in any system. The onshore system builds on redundancy criteria, which ensure that major disturbances can be overcome. A better-connected offshore system provides increased network redundancy to offshore generators that can export their energy even during a network fault, as several paths are offered. However, the challenges related to dimensioning faults for smaller systems and frequency stability for the entire continental system still needs to be solved. The simultaneous loss of 3000 MW production would endanger the entire continental system and must be avoided. In other parts of the interconnected system, smaller losses of production or transmission would cause major disruptions locally.

A hybrid system composed of AC and DC elements also comes with operational challenges. A more interconnected DC system is more difficult to operate than radial DC links connected to an AC system. Offshore disturbances will directly impact the onshore systems.

Therefore, there is a need for adaptive and international coordinated procedures. Keeping the system secure is a complex task which influences the technical requirements and possibilities, market rules and regulations.

7.1.4 Financing challenges

The offshore infrastructure cost total 255 bn€ (of which 27 bn€ in GB+NO. For GB, only the links to the EU are considered, not the radial links). This could financially overburden the countries hosting the infrastructure and thus the network users who pay the tariffs. When not building the infrastructure, the offshore RES realisation might be at risk. To ensure that the calculated needs for additional network infrastructure corridors is translated into concrete projects, funding and voluntary cost-sharing agreements should be supported. The European Commission is mandated under the new TEN-E Regulation to develop guidelines for a cost-benefit cost sharing system (CBCS) at sea basin level. The CBCS is not binding but is intended to facilitate negotiations between Member States.

7.1.5 Supply chain and port challenges

As mentioned in Chapter 6, the growth rate for offshore RES for the Northern Seas EU Members States increased from 8 GW each year until 2030 to 10 GW annually until 2040. This leads to stress on the entire supply chain. The International Energy Agency (IEA) foresees a faster growing demand for wind turbines than the foreseen growth of production capacity by 2030 – see Figure 16. In addition, other parts of the supply chain, such as the ports infrastructure, need to expand to facilitate these offshore wind grow rates. The ports study from Royal Haskoning for NSEC[30] shows that the current and the new build port capacity is not sufficient to accommodate the foreseen demand peak around 2030. The study illustrates that, based on the current practice, a 2 GW offshore wind farm needs ca. 20–30 hectares of storage area for two years. This results in the peak demand of roughly 850–1300 hectares for the North Sea, where there is currently approx. 600 ha. and 200 ha. planned. The report also suggests short-, medium- and long-term measures to cope with these challenges. The study shows challenges for the ports, but for all elements of the supply chain – from building the farms and the energy infrastructure – stress on the supply chains can be expected.

Stress on the whole supply chain and (port) infrastructure needs to be relieved to reach the expected rollout of the system.

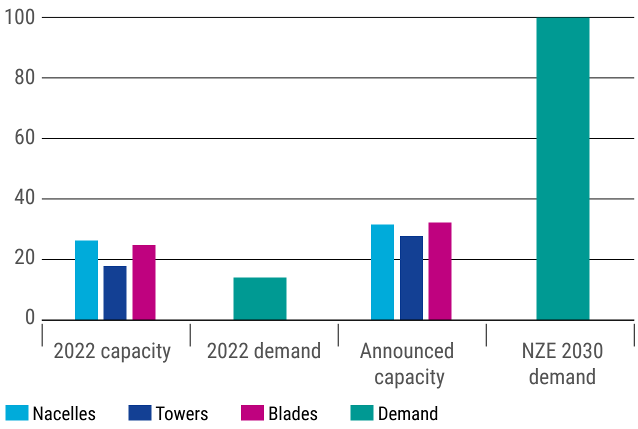


Figure 16 – **IEA, Offshore wind power manufacturing capacity in GW according to announced projects and in the Net Zero Scenario, 2022–2030, IEA, Paris** (This is a work derived by ENTSO-E from IEA material and ENTSO-E is solely liable and responsible for this derived work. The derived work is not endorsed by the IEA in any manner.)

30 Port study for NSEC and RVO by Royal HaskoningDHV – North Seas offshore wind port study 2030 2050 – which will be published on the NSEC website before the release of this study.

8 Sea Basin Specificities

The chapter provides a brief overview of activities and projects related to the Northern Seas Offshore Grid infrastructure, in which Northern Seas TSOs are involved. They range from Member States' activities to (research) projects or joint investigations on a new concept for a hybrid approach.

8.1 Northern Seas Offshore Grid Infrastructure collaborations

8.1.1 Northern Seas Energy Collaboration (NSEC)

The North Seas Energy cooperation (NSEC) is a joint activity of nine member states around the Northern Seas (Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway and Sweden) and the EC, being established in 2016. With the UK, there is an MoU to work together on voluntary basis. The NSEC can be considered as the follow-up to the North Seas Countries' offshore grid initiative (NSCOGI) collaboration, which was established in 2009. While NSCOGI was owned and organised by the Member States, NSEC is jointly chaired by the European Commission and Member States. The NSEC has nine objectives, listed in a political declaration, to set the scene for offshore development.

The collaboration is divided into four support groups focusing on different fields:

- SG1 Hybrid and joint projects
- SG2 Maritime spatial planning
- SG3 Support framework and finance
- SG4 Delivering 2050

More information on the activities and publications can be found on their website.

Revisiting a similar study from 12 years ago

In the context of this report it might be interesting to revisit the NSCOGI Grid study from 2011, which was a very similar exercise compared to this ONDP. The same countries were involved. The North Sea Countries' offshore Grid Initiative (NSCOGI), i.e. the NSEC's predecessor initiated that study in 2009. Member States shared their individual expectations on offshore RES capacities for the 2020- and 2030-time horizons. Now, more than a decade later, the actually installed capacities for 2020, and the development of the goal for the 2030-time horizon can be compared.

For the 2020-time-horizon, Member States' projections suggested offshore RES installations of 42 GW (including Great Britain and Norway). The 2030 offshore RES capacities summed up to about 55 GW for the same countries. Then TSOs from ENTSO-E's Regional Group Northern Seas elaborated the related possible infrastructure. A sensitivity analysis on a high-level offshore RES scenario had been investigated as well, with capacities of 117 GW in 2030.

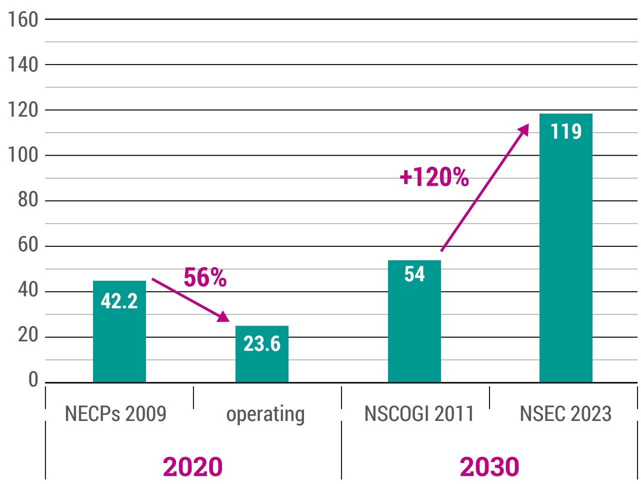


Figure 17 – Comparison 2020: Ambitions 2011 vs. realisation and 2030 goals 2011 vs. 2023.

The reality check of the 12-year-old non-binding targets with installations of the first target year reveals that in 2020, only roughly 56 % of envisaged offshore RES capacity was in operation. Comparing both 2030-goals, these have more than doubled. Thus, the task for the period 2020 to 2030 has become bigger over time.

Since then, it has generally been acknowledged that substantial acceleration is necessary. Several reasons for too slow developments have been identified, such as slow permits, supply chain challenges, a lack of workforce and recently as well shortages in ports capacities.

Latest European legislation addresses many of these challenges, among others legislation (EU) 2022/869, which is the basis for this report; the RePowerEU plan and the Fitfor55 package, the Wind package from October 2023 and the Infrastructure Action Plan published in November 2023.

8.1.2 Esbjerg/Ostend Declaration

Nine countries signed the "Ostend declaration" on 24 April 2023. These were the initial four "Esbjerg-declaration" member countries (Belgium, Netherlands, Germany & Denmark) and five new member countries (UK, France, Norway, Ireland & Luxembourg). The heads of states of the nine countries jointly issued a declaration covering the further development of offshore wind, offshore hydrogen and offshore hybrid projects in the North Sea, the Irish Sea, the Celtic Sea & the Atlantic. The Energy ministers for these nine countries also issued a joint declaration highlighting projects and areas of development on which member countries would co-operate. The overarching framework for work carried out to meet the Ostend declaration will be NSEC together with a MoU to include the UK.

Following the declarations, the TSOs of the nine member countries have met and agreed areas of work with which to take forward the Ostend objectives.

This work includes further developing the map that was included in the expert paper published by the "Esbjerg-TSOs". The map would be extended toward 2040 and would include further projects where these are justified.

In addition, the "Ostend-TSOs" will focus on areas of policy to support the development of offshore grid infrastructure. These areas might include the following:

1. Cost sharing & financing support;
2. Multi-terminal & multi-vendor interoperability;
3. System Integration/hydrogen;
4. Securing the supply chain; and
5. Market conditions for hybrid interconnectors and energy hubs.

Initial offshore grid | Cross border projects in mid 2030s time horizon

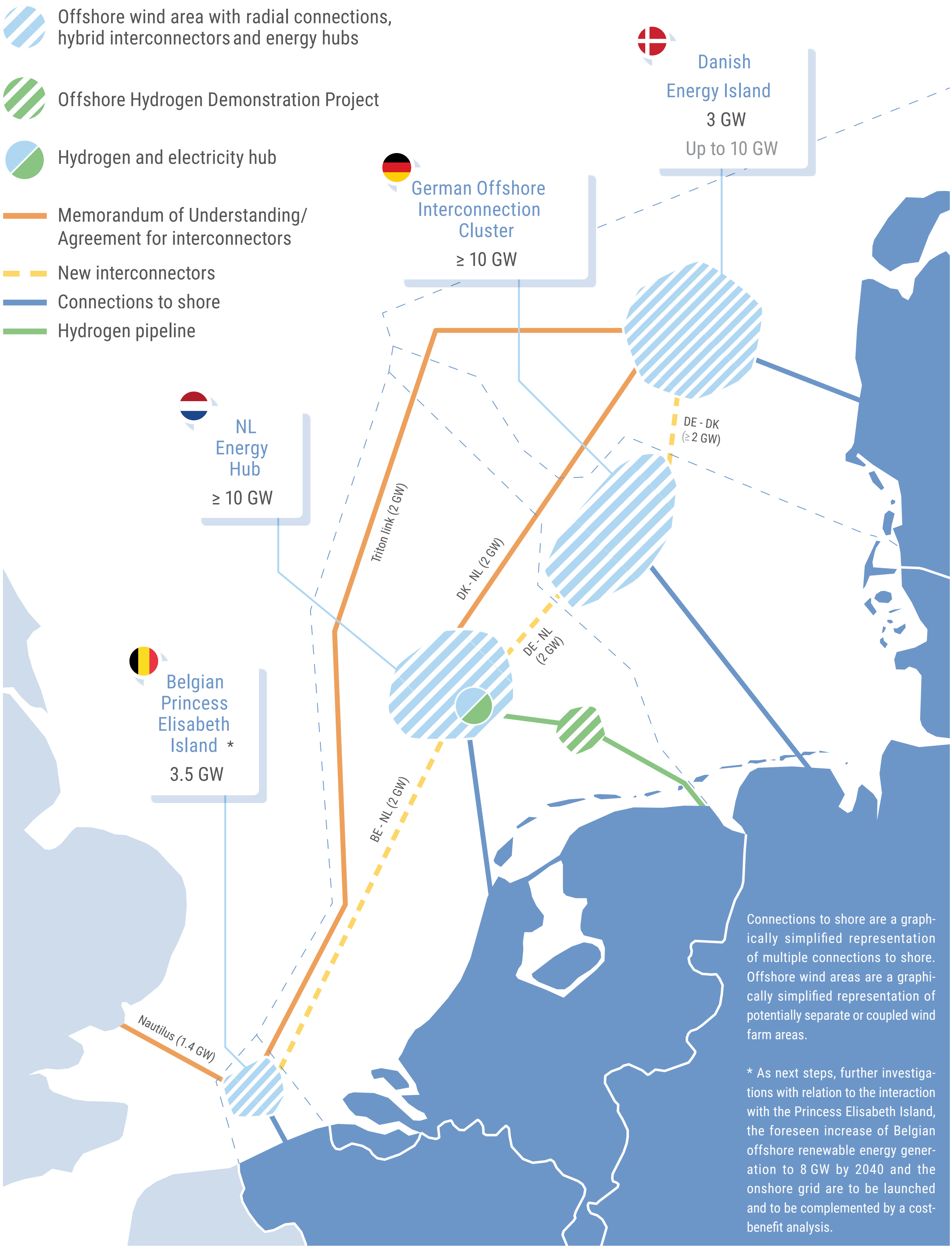


Figure 18 – Maps of the expert paper published by the "Esbjerg-TSOs".

8.2 Current studies and projects for an integrated offshore infrastructure

8.2.1 TritonLink

The **TritonLink** project covers the construction of a hybrid interconnector between the Danish North Sea Energy Island and the Belgian Energy Island. This would be one of the first long-distance offshore hybrid projects linking two energy islands, thus also an important step in creating a more interconnected offshore network infrastructure in the Northern Seas.

The project covers a total distance of almost 1.000 kilometres, starting from the Danish onshore HVDC converter, passing via two energy islands and ending at the onshore HVDC converter in Belgium. This project enables Elia Group (BE), Energinet (DK) and all the companies involved to gain experience. Expertise gained from the construction of the TritonLink will help accomplish further future sustainable offshore energy projects.

Elia and Energinet submitted the project as PCI candidate for the 6th Union list in 2022. TritonLink was submitted for the first time to ENTSO-E's TYNDP in October 2021.

The TritonLink project is currently in the study phase. According to the current schedule, the first exchange of electricity via this hybrid interconnector is planned for 2031/2032.

8.2.2 LionLink

TenneT in the Netherlands and its United Kingdom project partner National Grid Ventures (NGV) will develop an offshore hybrid – or Multi-Purpose Interconnector – with the name "LionLink". This project will create a new electricity link between the Netherlands and the UK. LionLink would support decarbonisation, energy independence and strengthen British, Dutch and European security of supply. The development would be the first of its kind for the UK and the Netherlands, and the first step towards an integrated North Sea grid.

LionLink combines a 2 GW grid connection system with connected wind farms in the Dutch EEZ and an 1.4 – 1.8 GW interconnector via a 525 kV DC cable (bipole with DMR system arrangement). By combining these two functions, LionLink will also be the first hub and the first foreseen offshore bidding zone in the Dutch EEZ. Construction is scheduled to start in 2026 and the commissioning is planned for around 2030.

More information can be found on the LionLink website.

8.2.3 Nautilus

Elia (BE) and National Grid Ventures (NGV) will develop an offshore hybrid system (or Multi-Purpose Interconnector) between the Princess Elisabeth Island located in Belgium and the UK. The increasing commercial market exchange capacity between Belgian and Great Britain will increase overall social welfare. An important security of supply contribution is also achieved through the implementation of this project, both from avoided alternative investments as from a reduction in loss of load expectancy. Such adequacy contribution can be linked to the decreasing figures of installed conventional generation and increasing RES. In addition, integrating offshore wind capacity to the interconnector could lead to increased benefits and/or investment savings. Finally, benefits related to the integration of cross-border redispatching, balancing markets, and exchange or sharing of ancillary services across the HVDC interconnection between synchronous areas can be obtained.

Since 2018, Nautilus has been part of the TYNDP. Nautilus was selected as PCI on the 3rd and 4th PCI list and is now candidate PMI candidate for the 6th Union. Nautilus has also been selected as a Multi-Purpose Interconnector pilot project by Ofgem in the UK.

8.2.4 The North Sea Wind Power Hub Concept (NSWPH)

TenneT Netherlands, TenneT Germany, Energinet and Gasunie joined forces in 2016 to investigate how to efficiently integrate large amounts of offshore wind into an integrated European energy system to meet the climate goals of the Paris Agreement. The North Sea Wind Power Hub (NSWPH) consortium conducted analyses of the broader energy system impact, the costs and benefits, the regulatory changes required and a fitting market system to support decision-making. By performing pre-feasibility and feasibility studies, the NSWPH created a good basis for building concrete Hubs in the North Sea and how to connect them internationally and cross-sectoral.

Central to the vision is the construction of hubs at suitable locations in the North Sea with interconnectors to bordering North Sea countries and between the hubs. This higher interconnectivity leads to more flexibility and thus a higher security of supply with lower costs.

This project is a first building block in the hub-and-spoke concept (NSWPH) connecting up to 14 GW future offshore wind farms to the systems of Denmark, the Netherlands and Germany.

8.2.5 Hybrid interconnector Norway-Sørvest F Windfarm-Continent (DK, DE, BE or UK)

Statnett has been given the task by the Norwegian Ministry to plan for one or more hybrid interconnectors connecting the Sørvest F windfarm area to Norway as well as to other countries around the North Sea. MoUs between Statnett and the TSOs of Denmark, Germany, Belgium and UK have been signed, aiming to develop one or more hybrid interconnectors. In the first phase, we are planning a 1,400 MW hybrid interconnector, but a 2,000 MW interconnector might as well be evaluated. At this stage, all the alternatives are considered equal.

Step 1 (1,500 MW) of the Sørvest F windfarm is planned awarded in Q1/2024 and radial connected. Step 2 is planned awarded in 2025 and will potentially be hybrid connected. Further steps might be expected as the potential of Sørvest F windfarms are in the range of 6 – 12 GW. The motivation of the project is both to develop Norwegian offshore wind as well as to increase flexibility and energy-exchange between hydro- and wind-dominated areas.

9 Conclusions

For the Northern Seas countries, this ONDP is the second investigation of its kind in a very similar setup. Also twelve years ago, Member States shared non-binding targets and TSOs investigated the implications for the necessary infrastructure. Since then, the goals have more than doubled, and the task to reach these goals has become more challenging.

Northern Seas TSOs have worked on solving questions that have been on the table since then. Consequently, the first offshore hybrid project ideas have already been started in this sea-basin, building on agreements between Member States and TSOs. New European legislation entered into force, addressing some of the known challenges. Recent Wind and Infrastructure action plans also aim to improve conditions for acceleration of implementation. New challenges have come along. A substantial higher pace in offshore developments is required by all parties, which can only be achieved by collaboration.

The results of this Offshore Network Development Plan study show that the work already started in the past is helping to integrate the offshore RES towards the future. In the sea basin Northern Seas, there is some economic potential to connect countries to each other and to form some corridors. Already in 2040, these corridors appear and further increase in size by 2050.

As shown in this report, there are some challenges for the offshore build out. Vast amounts of maritime space are already being used as a habitat for marine life, fishing and shipping; however, the renewable energy production has to get a place as well, ensuring coexistence with other usages. The supply chain needs to scale-up to get all the wind farms offshore and quite a large amount of electric transmission infrastructure is needed to connect the new offshore renewable energy production to onshore. The work does not end here. In the next editions, the insights will be improved, with new integrated analysis on unlocking the offshore energy production, showing the need to connect it to the main load centres.

Appendix

ONDP Results per Sea basin – not considering GB Radial capacities

Equipment overview

Equipment Needs Route Length, Number	Radial (route length)			Expansion		Radial – considered in the expansion loop			Total			Total Sum [km] or nr.
Configuration with DC circuit breaker [km], [Nr]	2025 – 2030	2031 – 2040	2041 – 2050	2031 – 2040	2041 – 2050	2025 – 2030	2031 – 2040	2041 – 2050	2020 – 2030	2031 – 2040	2041 – 2050	2025 till 2050
Onshore DC Cables (updated)	3,120	4,304	1,057	332	0	2,314	11,248	5,089	5,435	19,889	8,020	33,344
Offshore DC Cables (updated)				4,005	1,874							
Onshore AC Cables (updated)	1,583	1,247	0						1,583	1,247	0	2,830
Offshore AC Cables (updated)												
Offshore DC converters	12	20	7			6	33	15	18	53	22	93
Onshore DC converters	12	20	7	5	6	6	33	15	18	58	28	104
Offshore AC substation	25	5	0						25	5	0	30
Offshore node expansion (incl. DC breaker)				15	6				0	15	6	21
											Total Route Length	**36,174**

Equipment Needs Route Length, Number	Radial (route length)			Expansion		Radial – considered in the expansion loop			Total			Total Sum [km] or nr.
Configuration without DC circuit breaker [km], [Nr]	2025 – 2030	2031 – 2040	2041 – 2050	2031 – 2040	2041 – 2050	2025 – 2030	2031 – 2040	2041 – 2050	2020 – 2030	2031 – 2040	2041 – 2050	2025 till 2050
Onshore DC Cables (updated)	3,120	4,304	1,057	208	104	2,314	11,248	5,089	5,435			31,169
Offshore DC Cables (updated)				2,026	1,696					17,787	7,947	
Onshore AC Cables (updated)	1,583	1,247	0						1,583	1,247	0	2,830
Offshore AC Cables (updated)												
Offshore DC converters	12	20	7			6	33	15	18	53	22	93
Onshore DC converters	12	20	7	3	4	6	33	15	18	56	26	100
Offshore AC substation	25	5	0	6	4				25	11	4	40
Offshore node expansion (with converter), E18	0	0	0	6	4				0	6	4	10
											Total Route Length	**33,998**

Investment Cost Overview

Costs	Radials			Expansion		Radial – considered in the expansion loop			Total			Total Sum [M€]
Configuration with DC circuit breaker [M€]	2025 – 2030	2031 – 2040	2041 – 2050	2031 – 2040	2041 – 2050	2025 – 2030	2031 – 2040	2041 – 2050	2020 – 2030	2031 – 2040	2041 – 2050	2025 till 2050
Onshore DC Cables (updated)	8,142	13,531	3,551	775	0	–	–	–	15,788	59,339	23,852	
Offshore DC Cables (updated)				9,198	4,672	7,646	35,834	15,629				98,979
Onshore AC Cables (updated)	1,893	1,620	0						1,893	1,620	0	
Offshore AC Cables (updated)												3,513
Offshore DC converters	10,274	19,800	7,700			6,270	33,330	14,300	16,544	53,130	22,000	91,674
Onshore DC converters	4,670	9,000	3,500	1,625	500	2,850	15,150	6,500	7,520	25,775	10,500	43,795
Offshore node expansion (incl. DC Breaker) E20				6,023	2,475				0	6,023	2,475	8,498
Offshore AC substation	6,416	1,852	0						6,416	1,852	0	8,268
												254,727

Costs	Radials			Expansion		Radial – considered in the expansion loop			Total			Total Sum [M€]
Configuration without DC circuit breaker [M€]	2025 – 2030	2031 – 2040	2041 – 2050	2031 – 2040	2041 – 2050	2025 – 2030	2031 – 2040	2041 – 2050	2020 – 2030	2031 – 2040	2041 – 2050	2025 till 2050
Onshore DC Cables (updated)	8,142	13,531	3,551	305,76	174,72	-	-	-	15,788			
Offshore DC Cables (updated)				4,126	2,299	7,646	35,834	15,629		53796,78	21653,27	91,238
Onshore AC Cables (updated)	1,893	1,620	0						1,893	1,620	0	
Offshore AC Cables (updated)												3,513
Offshore DC converters E18	10,274	19,800	7,700			6,270	33,330	14,300	16,544	53,130	22,000	91,674
Onshore DC converters	4,670	9,000	3,500	625	750	2,850	15,150	6,500	7,520	24,775	10,750	43,045
Offshore node expansion (with converter), E18	/	/	/	6,875	1,650				0	6,875	1,650	8,525
Offshore AC substation	6,416	1,852	0	5512,5	1323				6,416	7,365	1323	15,104
Sum per decade	**31,395**	**45,804**	**14,751**	**17,444**	**6,196**	**16,766**	**84,314**	**36,429**	**48,161**	**147,562**	**57,376**	**253,099**
												253,099

Input per country

The information provided by the Member States has been enriched by different sources and expert knowledge and where possible aligned with the related ministries. In the following sub-chapters, the input is further explained per country.

Belgium

Belgium currently has 2.3 GW offshore wind in operation, with initial OWFs dating back to early 2000s, for which a retrofitting strategy is being analysed to contribute to the 2040 goal.

Belgian offshore wind capacity targets set by the government are the integration of up to 5.8 GW in total by 2030 and up to 8 GW[31] in total by 2040 and 2050.

The MSP of Belgium (2020 – 2026) provides space within the Princess Elisabeth Zone for three new offshore wind zones (± 285 km²) until 2030 as well as space for the required offshore infrastructure.

Elia will develop a world's first artificial energy island, "Princess Elisabeth Island", about 45 km off the Belgian coast by 2026, which will function as an offshore energy hub:

- The island will facilitate the connection of 3.5 GW domestic offshore wind using both AC and DC technology (2026 – 2030), thereby providing efficient access for consumers via connections to the mainland. This 3.5 GW will complement the existing 2.3 GW of offshore wind in Belgium, thereby together enabling 5.8 GW by 2030.
- The island will also enable the efficient sharing of those and other renewables in and around the North Sea through the integration with neighbouring North Sea countries via additional interconnections to the United Kingdom (Nautilus – 2030) and to Denmark (TritonLink – 2031 – 2032).
- Towards 2035, Elia aims to complete the offshore energy hub on the island through the realisation of a HVDC substation (incl. DC-circuit breaker) that will enable a larger common electrical node offshore, further improving European welfare and overall RES integration.

To enable the 8 GW target by 2040, a new conceptual project for a 3rd modular offshore grid is being investigated as part of the TYNDP24. Whether this setup should become a pure radial connection or rather a second energy hub in addition to the Princess Elisabeth Island is subject to further investigation, for which this first ONDP will provide valuable insights.

To enable the full decarbonisation of the Belgian energy system by 2050, additional RES imports via standalone (radial) or shared offshore links (interconnectors) will be required in addition to the further build out & integration of domestic onshore & offshore RES, considering the limited local Belgian RES potential. The planned offshore energy hub(s) in Belgium and abroad in the future can play the role of collecting & further distributing offshore RES to the Belgian onshore load centres as well as to the offshore neighbouring nodes.

As a next step, this first ONDP will help contribute to further investigations for additional radial and (hybrid) interconnectors from the EU system perspective complementary to recurrent national development plans & TSO initiatives. Both the Princess Elisabeth Island and 3rd modular offshore grid concept (MOG3) are, in this sense, assumed to be expendable (subject to further technical analysis) in this first ONDP for both further European and Belgian system integration.

The Belgian hydrogen strategy aims to use hydrogen and renewable molecules to make certain applications climate neutral where electrification is not economically viable or technically feasible. Electrolysis capacity will remain limited in Belgium because of limited local renewable energy potential, which should in priority be used for the decarbonisation of the electricity supply and to further electrify energy needs, thereby abiding by the "Energy efficiency first" principle. About 20 TWh in 2030 and 200 – 350 TWh in 2050 of renewable hydrogen molecules and derivatives will be imported, to cover domestic demand and transit activities to neighbouring countries.

31 The 8 GW target is officially for offshore RES and could come from both the repowering of existing OWFs, as well as a new designated area for offshore wind and/or floating solar offshore

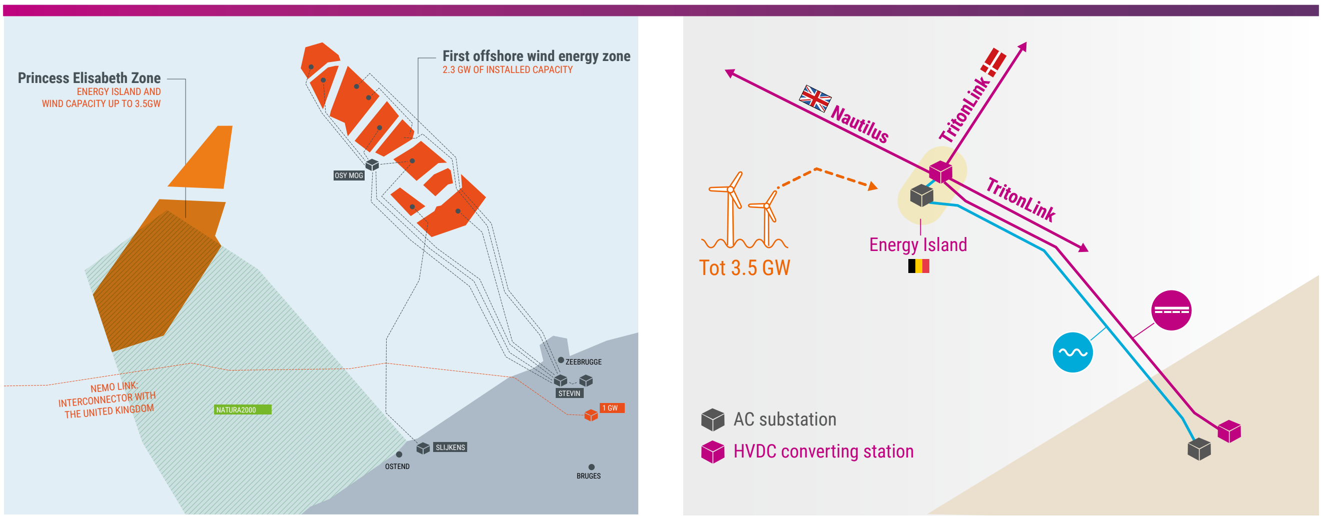


Figure 19 – Belgium offshore planning – 2030 horizon.

.Domestic hydrogen demand (incl. bunkering fuels) will be limited to 125 – 200 TWh in 2050 for Belgium.

- Pilot electrolysis projects will be developed (minimally 150 MW towards 2026)
- Hydrogen infrastructure for import will be developed (by 2026) with a key role for Zeebrugge as a terminal for both pipelines and ships. Other import routes (e.g. shipping) outside of the North Sea area are equally considered.
- Hydrogen infrastructure for transit will be developed (by 2028 towards Germany, Netherlands, France) through the build-out of new and repurposed pipelines (100 – 160 km), with open access and mainly around industrial clusters in Antwerp, Ghent, and the Industrial valley in Wallonia.
- The synchronised development of offshore electricity and hydrogen networks in the North Sea, coordinated with other countries, will allow this energy to be rapidly harnessed. Any synchronisation or coordination should, however, not negatively impact the development speed of no regret projects.

Denmark

Denmark has a long history of developing offshore windfarms (OWFs), starting with a 5 MW project called Vindeby in 1991 and continuing with Horns Rev 1, the first large scale wind farm, installed in 2002. Today, Denmark has 15 existing OFWs, with a combined capacity of 2,308 MW in the Northern Seas and in the Baltic Sea area together. These are all radially connected projects, except the Krieger's Flak wind plant, that is connected via offshore hybrid infrastructure.

The Danish government has ambitious goals for the green transition, and the development of green technologies at sea is a key tool for achieving these goals. New large offshore wind farms and energy islands will help Denmark to comply with the Paris Agreement on the reduction of greenhouse gases and achieve the target of a 70 % reduction in CO_2 in 2030 and climate neutrality in 2050.

The Government has decided that two energy islands or hubs on platforms shall be constructed in Danish waters: one in the North Sea and another in the Baltic Sea (see Baltic Sea ONDP). The energy island on Bornholm will have a capacity of 4 GW, while the North Sea Hub will have a capacity of 3 GW in 2033, and 10 GW in the longer term. This is enough to meet the average electricity consumption of 6 million households.

An energy island or hub allows for several connections: They can pool the power from multiple offshore wind plants and feed this directly to several countries. This represents a change from the previous philosophy of building isolated offshore wind plants with a power connection to one country only. Both islands represent various construction alternatives.

In addition to the planned development of energy islands or hubs, the Danish government has planned areas for new radial projects in the Northern Seas region. Additional new offshore wind farms in Denmark are established after a tendering procedure to realise new offshore wind farms at the lowest possible cost. All tenders are decided in political energy agreements. For nearshore wind projects (closer to 15 km to shore), an open-door procedure has been established, where the project developer takes the initiative to establish an offshore wind farm subject to approval by the Danish Energy Authority (DEA). This open-door process is currently under review by the DEA[32].

Energinet's roles are the following:

- Preliminary studies: Energinet is responsible for carrying out the preparatory environmental studies and seabed surveys.
- Energinet, being TSO for electricity, gas and hydrogen is responsible to investigate potential synergies across energy carriers. Currently, Energinet investigates options of how and where best to interlink electricity from offshore RES and potential national and international hydrogen demand.
- International connections: Energinet is responsible for developing and operating international connections, including any possible future links via the two energy islands/ hubs.
- System operation: Energinet is responsible for ensuring that renewable energy from the energy islands is connected to and integrated with the onshore energy system.

France

1.5 GW offshore wind is already connected to the grid in France. Another 1.5 GW is expected before 2025, and a total of ~4.5 GW is expected to be commissioned by 2030. All these projects are radial 225 kV HVAC projects. Around 2030, a mix of HVAC and HVDC projects are expected; after 2032, given the growing distance and size of offshore windfarms, only HVDC projects are planned.

To reach its **carbon neutrality goals** by 2050, the French government has set the target to generate 18 GW offshore wind by 2035 and 40 GW by 2050. These targets were re-affirmed by President Macron during the North Sea Summit of 24 April 2023, and represent the contribution of France to the **300 GW target of the** EU by 2050.

The French energy plan will be updated before the end of 2024, based on a new Energy and Climate Law to be finalised before the end of 2023. A large public debate covering both the electricity planning and the marine spatial planning perspectives will take place between October 2023 and April 2024, allowing the Sea Basin Marine Spatial Planning Strategic Documents to be updated with a similar timeframe.

To prepare this public debate, the per Sea Basin 2040 and 2050 figures for offshore wind communicated for the purpose of the ONDP have been updated by the French government. The table below compares, at the national level, the initial non-binding Member State values, the expert values established by ENTSO-E and the official updated values communicated by the French government in June 2023. The "expert figures" are consistent with both the initial and updated values.

In GW	2030	2040	2050
Initial ranges (jan 23)	4.4	10.4 to 22	10.4 to 47.5
Expert values (March 23)		22	40
Updated values (June 23)		18.5 to 30.5	10.4 to 47.5

Table 7 – Initial MS targets, Expert values and Updated MS targets

Reaching these goals implies a great acceleration of the development in the offshore wind sector in France: to meet the 40 GW target by 2050, the volume currently in operation or construction phase (3 GW), will be need to multiplied by 13. Hence, between 2024 and 2050, it is expected that 1 to 2 GW will be commissioned each year, with nearly half of the 40 GW target to be realised within the last decade.

32 **In December 2023, the government decided to close the open door process** (in Danish)

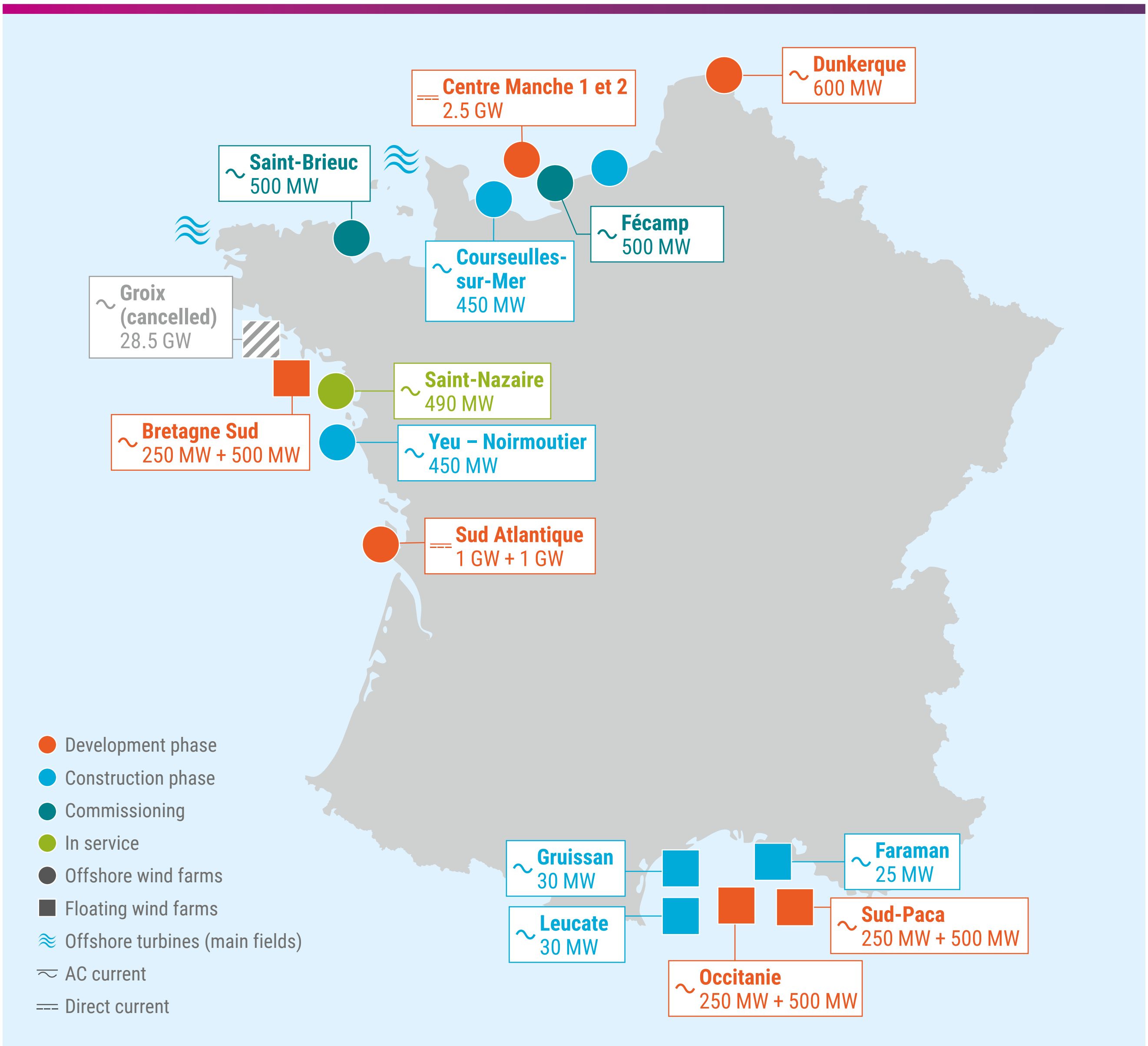


Figure 20 – Offshore plans of France

This led the French State to issue two laws supporting this increase:

- 2020's law for the acceleration and simplification of public action (ASAP) provides for the possibility that public debates focus on the development of several offshore wind projects within in the same sea basin.
- 2023's law for the acceleration of the production of renewable energies (APER) makes it possible to pool public debates regarding development of offshore wind power and the sea basin strategic marine spatial planning documents (DSF). This provision will improve the consistency of maritime spatial planning and provide visibility of the development of offshore wind power for several years ahead.

Pursuant to France's decree no. 2002-1434 of December 4, 2002, the French Energy Regulatory Commission (CRE) is responsible for implementing the tendering procedure. As of today and since 2012, 8 calls for tenders (AO) have been issued or are under preparation, each regarding one specific offshore area and expected generation capacity. A given call for tenders may cover several wind farms.

Besides working on implementing new technologies for the future grid and its offshore/onshore assets, RTE is also engaged in marine environmental R&D to improve the knowledge of the ocean and how to manage its resources in order to preserve sea biodiversity.

Offshore Network Infrastructure

3 generations of offshore network infrastructure are being developed by RTE:

The **first generation**, with 4 radial 225 kV HVAC connections, totals **2 GW** offshore wind capacity connected or to be connected before 2030. The wind farm areas cover a surface of 237 km² and represent 300 km of offshore and onshore cable routes. 11 years was needed between the award of the Fécamp offshore wind farm and the final commissioning.

The **second generation**, composed by radial 320 kV HVDC connections partly pooled together by an HVAC interlink, offers **2.5 GW** offshore wind capacity to be connected by 2031/2032. These standardised 320 kV HVDC links, due to be replicated in other Sea basins, represent a first change of scale, doubling the capacity per offshore wind farm connection. The wind farm areas cover a surface of 400 km² and the cable routes total 200 km of offshore and onshore. 9 years are expected between the award of the Centre Manche 1 OWF (2022) and the final commissioning.

The additional capacity needed to reach the governmental targets, i. e. between 7 and 11 GW in 2040 and between 12 and 15.5 in 2050, will form the **3rd generation** of offshore grids. For the purpose of the ONDP study, RTE considered standardised 525 kV "offshore grid ready" conceptual projects, all located in the **"least impact area" of the development area n° 5 defined by the State in 2021**, enabling the development of an additional 4 GW in 2040 and 6 GW in 2050.

Figure 21 – Offshore Network Infrastructure

No international expandable hubs were considered for this area, pending a positive CRE opinion on future interconnectors between France and the UK. The last relevant CRE deliberation, published in January 2022, concluded that there was "a lack of reasonable certainty about the costs and benefits attached to this project, in a particular context where the uncertainties linked to the United Kingdom's exit from the European Union remain strong despite the Trade and Cooperation Agreement […]". An update of the CRE study is expected in September 2023, but will be published too late to be incorporated into the study.

	Project	Connection capacity (MW)	Technology	Commissioned
A01	Fécamp	500	HVAC 225 kV	2023
A01	Calvados	450	HVAC 225 kV	2024
A02	Dieppe-Le Tréport	500	HVAC 225 kV	2026
A03	Dunkerque	600	HVAC 225 kV	2028
A04	Centre Manche 1	1,250	HVDC 320 kV	> 2030
A08	Centre Manche 2	1,250	HVDC 320 kV	> 2030

Table 8 – Connection capacity, technology and commissioning year of project

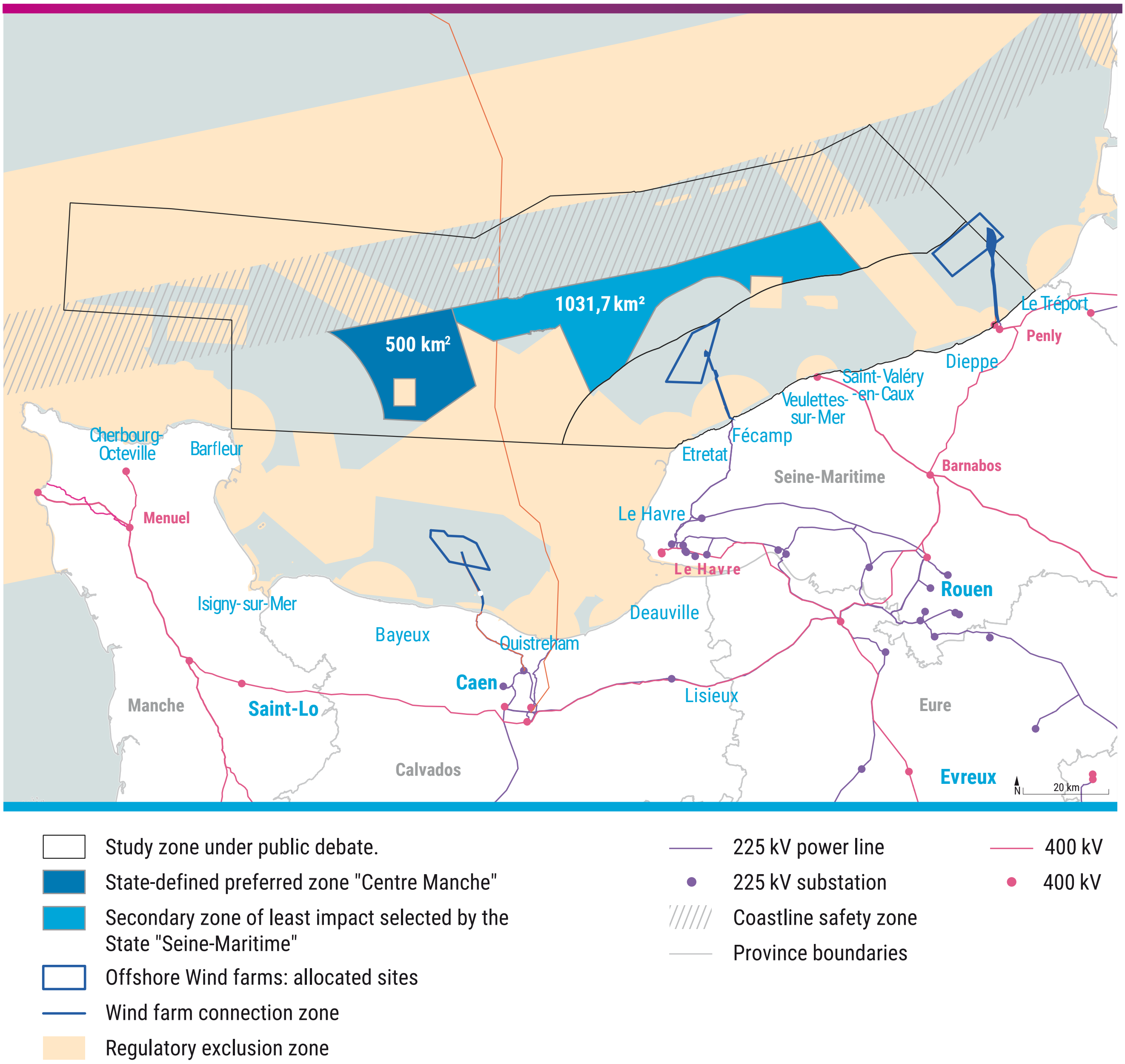

1031,7 km²
500 km²
Cherbourg-Octeville
Barfleur
Menuel
Isigny-sur-Mer
Bayeux
Ouistreham
Caen
Saint-Lo
Manche
Calvados
Le Havre
Le Havre
Deauville
Lisieux
Etretat
Fécamp
Veulettes-sur-Mer
Saint-Valéry-en-Caux
Dieppe
Le Tréport
Penly
Barnabos
Seine-Maritime
Rouen
Eure
Evreux
20 km
N
Study zone under public debate.
State-defined preferred zone "Centre Manche"
Secondary zone of least impact selected by the State "Seine-Maritime"
Offshore Wind farms: allocated sites
Wind farm connection zone
Regulatory exclusion zone
225 kV power line
225 kV substation
Coastline safety zone
Province boundaries
400 kV
400 kV

Figure 22

Germany

In the German North Sea, 14 wind farms with a total generation capacity of 7.8 GW are currently connected. The grid connections have a transmission capacity of between 62 and 916 MW and use partly AC and partly DC technology. The turbines already in operation are located relatively close to the coast. The Wind Energy at Sea Act sets expansion targets for offshore wind energy in the North Sea and Baltic Sea of at least 40 GW by 2035 and 70 GW by 2045. The Network Development Plan (NDP) 2023 is also based on these targets. In accordance with the revised TEN-E Regulation, non-binding targets for the years 2030, 2040 and 2050 were set specifically for the ONDP by the responsible ministry. The slight deviations of the ONDP input values from these can be explained by the smaller wind farms already in operation.

The German Federal Ministry of the Interior, Building and Community (BMI) is responsible for setting MSPs for the EEZ of the German North Sea and Baltic Sea. For more information, see "Approach to MSP" later in the annex.

The current Site Development Plan (German: "Flächenentwicklungsplan", FEP), which was published in 2023, only makes specifications for offshore wind areas up to 2032 as there is currently still a need for coordination with the neighbouring countries of Denmark and the Netherlands regarding the designation of further areas in the SN10 shipping route. The Network Development Plan 2023 is therefore based on an older version of the Site Development Plan (see figure 23), which includes further areas north of the shipping route SN10, in order to be able to make spatial and temporal specifications up to 2045. In addition to specifications for areas, tendering and commissioning years, the FEP also specifies technical principles for grid connection. For all future grid connection systems from 2026 onwards, a DC concept with a transmission capacity of 2 GW is defined as the standard.

Due to the goal of climate neutrality by 2045, Germany is, on the one hand, strongly pushing the expansion of offshore wind energy itself and, on the other hand, is dependent on networking with other countries due to the relatively small German offshore area and therefore limited generation capacities in the German North Sea and Baltic Sea. For this reason, Germany is already working on hybrid projects together with Denmark and the Netherlands and is in close exchange with other partners to identify potential for hybrid cooperation projects.

There is currently one area (SEN-1) dedicated for energy production other than electricity generation from offshore wind. The area has a production capacity of about 1 GW and is not intended to be connected to the electricity grid. The hydrogen is to be transported onshore via a pipeline, but it is not yet clear whether a pipeline should be built for this area only or whether it should be sized to transport hydrogen from further areas or other countries.

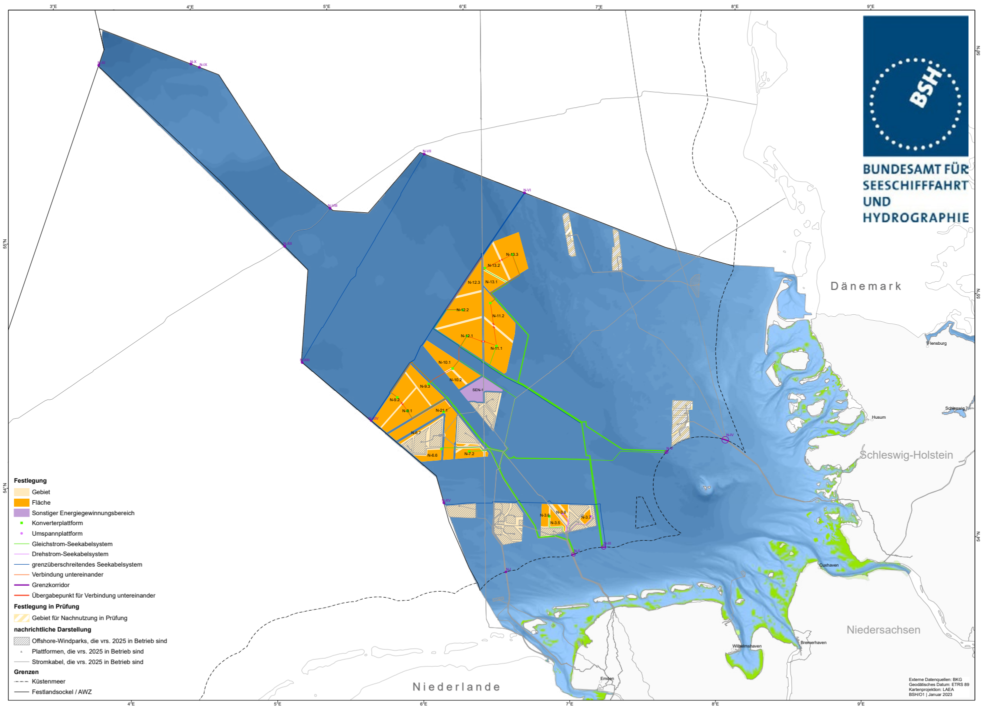


Figure 23 – Source: BSH, First Draft FEP 2023

Netherlands

For the purpose of the Offshore Network Development Plans (ONDPs), the Dutch government has submitted non-binding targets (ranges) for offshore wind in the Dutch North Sea EEZ for 2030, 2040 and 2050. ENTSO-E needs high resolution spatial information for the ONDPs. For the short term (i.e. up to 2030) considerable information is available, but for the longer term (up to 2050) this is not always the case.

The Dutch TSO TenneT, in dialogue with the Dutch government, enriched the data to the required level of detail. The government provided as much knowledge, known uncertainties and insights as possible, and TenneT translated this into the required spatial detail, enriching the available data with expert view assumptions.

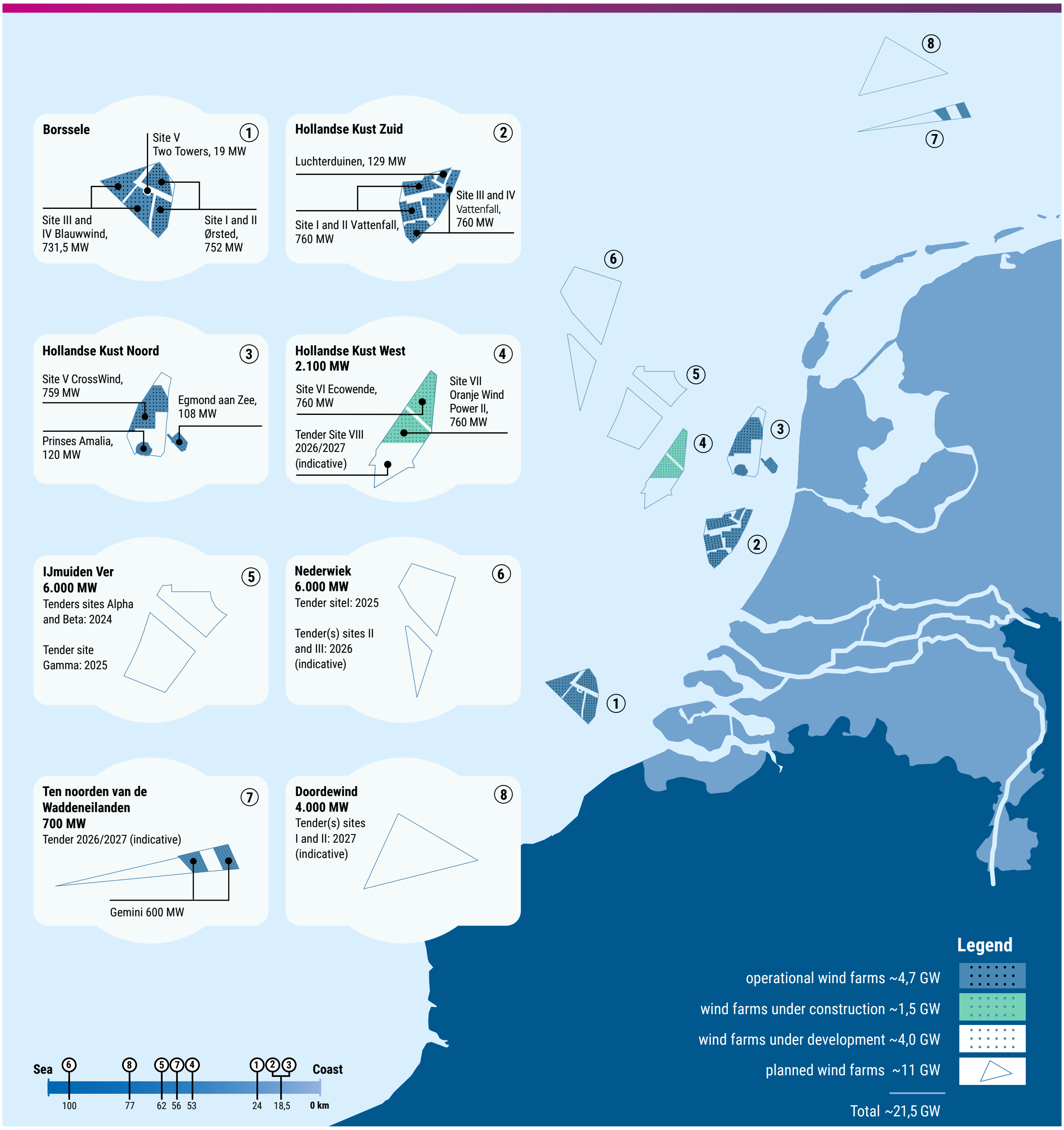


Figure 24 – **Dutch offshore wind plans up to 2030, status by the end of 2023**

Offshore wind and hydrogen up to 2030

It is assumed that all offshore wind farms will be electrically connected up to 2030. By 2030, the capacity of new to be built wind farms and existing wind farms is projected to be 16.3 GW. This is 0.3 GW more than the non-binding high-level target. In alignment with the Dutch government, it has been noted that this is correct – in the high-level target, the figure has been rounded down.

Hydrogen will play an important role in the planned energy transition in the Netherlands. In the draft national plan for the energy system, Nationaal Plan Energiesysteem (NPE)[33], the goal is to have 4 GW of electrolyser capacity installed onshore by 2030. In addition, there are two offshore hydrogen demos are planned, Demo 1 of up to 100 MW and Demo 2 of around 500 MW. However, these will be complementary and, given the current uncertainties, are not included in this ONDP.

Offshore wind and hydrogen from 2031 up to 2040

The offshore wind ambition grows towards 30 – 50 GW by 2040. Part of this ambition is already taking shape in the form of plans sq. appointed development areas, while the other part is currently in the exploration phase.

There are four wind farms that are planned to be installed by 2031 at the latest. These wind farms (*Doordewind, Ten Noorden van de Wadden* and *Nederwiek III*) have a total capacity of 6.7 GW and are sometimes mentioned as part of the 2030 target. However, they are officially planned to be installed after 2030 and are therefore included in the non-binding targets for 2040. All these are assumed to be electrically connected.

For some of the areas included in the scope in the official area exploration, there are indications that further exploration is required to understand their suitability for offshore wind. Therefore, these are considered to be in the upper limit for this timeframe, to indicate the uncertainty of these areas. First, after consultation with the Dutch government, it has been decided not to include *zoekgebied 5mb* and *zoekgebied 8* in the planning. Second, the *Lagelander* area lies within a valuable mining area, of which the eastern part is more intensively used than the western part. Therefore, the eastern part of *Lagelander* is considered to be in the upper boundary for this timeframe. Third, *zoekgebied 3* is a relatively small area and is also still under exploration, which also gives a reason to include this in the upper boundary.

The remaining will be developed in *zoekgebied 6/7*. For this area, it is assumed that the first 8 GW will be developed electrically as this is a proven technology. Thereafter, a combination of hydrogen and electricity is assumed to be developed, of which 7.3 GW is a combination of hydrogen and electricity and 8 GW of dedicated hydrogen.

This is in line with the current hydrogen plans. The Dutch government has stated in its draft NPE that it is aiming for an electrolysis capacity of between 15 and 20 GW by 2040. It is expected that more of this will be developed offshore in the future.

Offshore wind farms installed from 2041 up to 2050

The eastern side of the exploration area *Lagelander* is intensively used for other offshore activities. Maritime spatial planning needs to be revised to exploit the full capacity of this area. The area itself can accommodate up to 6 GW, which is more than the 4 GW currently in the official exploration. Therefore, an additional 4 GW of offshore wind capacity could be realised in this area by 2050, giving a total of 6 GW.

As for the area *zoekgebied 4*, it is currently used as a military zone. Therefore, the Dutch government has indicated that the development of the 4 GW within this area is quite uncertain. The remaining capacity to reach the upper band width is distributed over *Potentieel zoekgebied A* (PZA) and *Potentieel zoekgebied B* (PZB). These are two areas which are not in the official exploration, but show a great potential for hosting offshore wind farms. In PZA it is assumed that the offshore wind is connected with a combination of electricity and hydrogen, PZB is assumed to be fully dedicated to hydrogen.

33 Rijksoverheid 3 July 2023 – Concept National Plan Energiesysteem

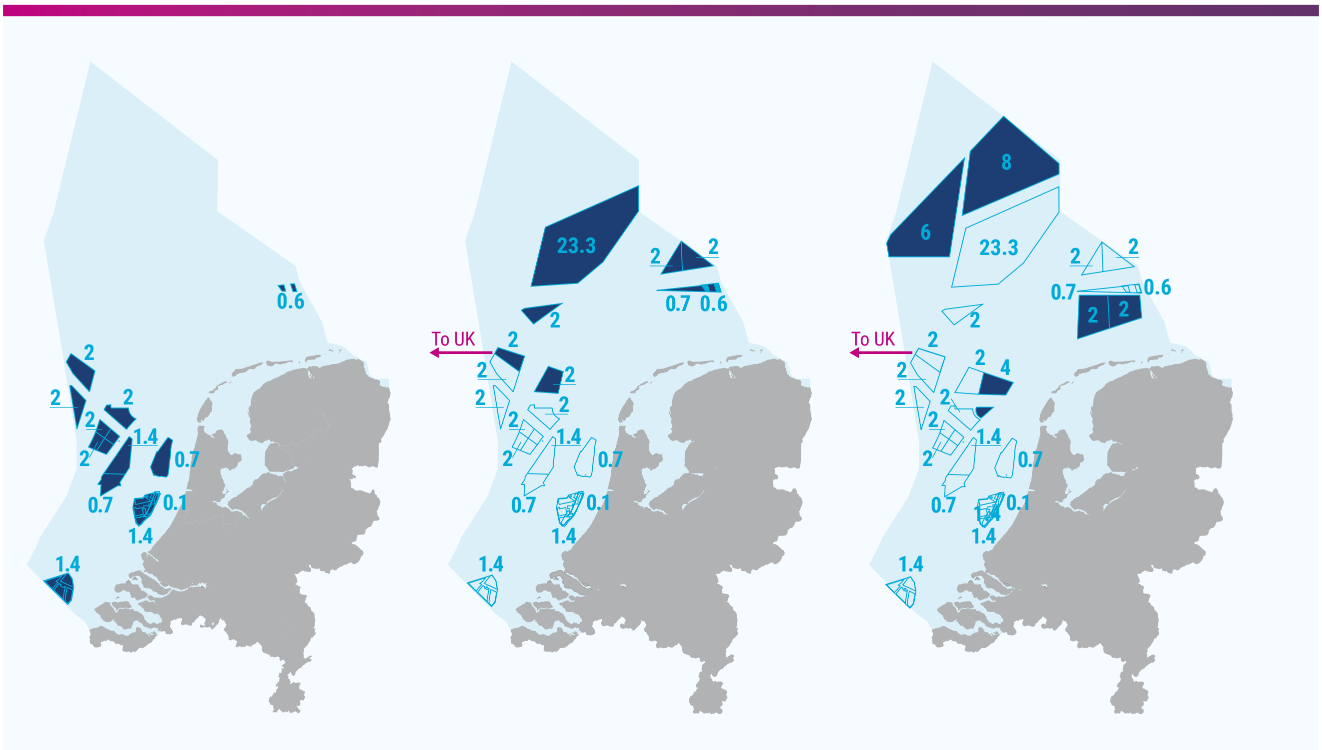


Figure 25 – Offshore wind data input for 2030 (left), 2040 (middle) and 2050 (right).

Northern Ireland

Northern Ireland currently has no offshore wind capacity, though this is expected to change significantly in the coming years. In early 2023, the Department for the Economy (DfE) in Northern Ireland and The Crown Estate who manage the seabed around Northern Ireland agreed a Statement of Intent towards establishing offshore wind leasing for Northern Ireland. Under its Energy Strategy, Northern Ireland aims to install 1 GW of offshore wind from 2030.

Norway

The Norwegian parliament decided in 2022 on a political goal to facilitate offshore wind-fields for offshore-wind-production of 30 GW by 2040. This Norwegian goal is different from other countries' goals as other countries have decided a hard goal to realise offshore production, while Norway has a goal to open offshore fields, which does not necessary mean building 30 GW. This means that, among others, the national energy balance and the cost of Norwegian offshore wind will decide how much of the 30 GW will be realised.

In Statnett's Long-term Market Analyses 2023, the baseline scenario shows 15 GW commissioned by 2040 – 2050. This is also the input used in the scenario-process for the Offshore Network Development Plan. However, a value of up to 30 GW could potentially be seen, e. g. based on a tighter national energy balance or based on a political decision to connect Norwegian windfarms to other countries as well.

Development before 2030 – Low offshore-wind generation (98 MW)

The first Norwegian offshore wind farm is Hywind Tampen. The installed capacity is 94 MW (original 88 MW) and was by 2023 the world's biggest floating wind farm. The 11 turbines were put into operation in 2022 and 2023. The wind-production is electrifying Norwegian petroleum-fields, which is part of the climate-strategy to decrease CO_2-emissions.

Expected development 2030–2035 – Utsira, Sørlige Nordsjø II (4.5 GW)

In 2022, the Norwegian government decided on a political goal to open wind-fields for 30 GW by 2040. As a first step, it was decided to open the tendering process for the two wind-farms Utsira Nord and Sørlige Nordsjø II. Seventeen different industrial consortiums entered the pre-qualification-phase.

Utsira Nord (first step): 1,500 MW floating wind turbines. The cost of floating wind is high; hence the windfarm will be realised with large financial support schemes. The expected commissioning year is at the earliest 2030. The windfarm will be radial connected and the connection point will be the Utsira/Haugesund-area.

Sørlige Nordsjø II/Sørvest F (first step): 1,500 MW bottom-fixed windfarm approximately 250 km out of the Norwegian coast. The average depth of the wind-field is about 60 m, which means that this windfarm is also expected to be rather expensive compared to bottom-fixed windfarms in the southern North Sea. The expected commissioning-year is at the earliest 2030. Sørlige Nordsjø II (first step) is planned to be radial connected, and the planned connection point is the very southern part of Norway.

Sørlige Nordsjø II/Sørvest F (second step): 1,500 MW bottom-fixed wind-turbines. The tendering process is planned to be started in 2025. The size of this step might be increased. Although the potential windfarm developers are very much in favour of connecting Sørlige Nordsjø II (second step) by hybrid connection, also connecting other countries, the issue is still being discussed politically. The decision is expected in due time before the 2025 tendering process. The Norwegian TSO Statnett is, by the Norwegian Ministry, given the task to investigate potential hybrid solutions. Based on this, MoUs towards other North Sea TSOs have been signed.

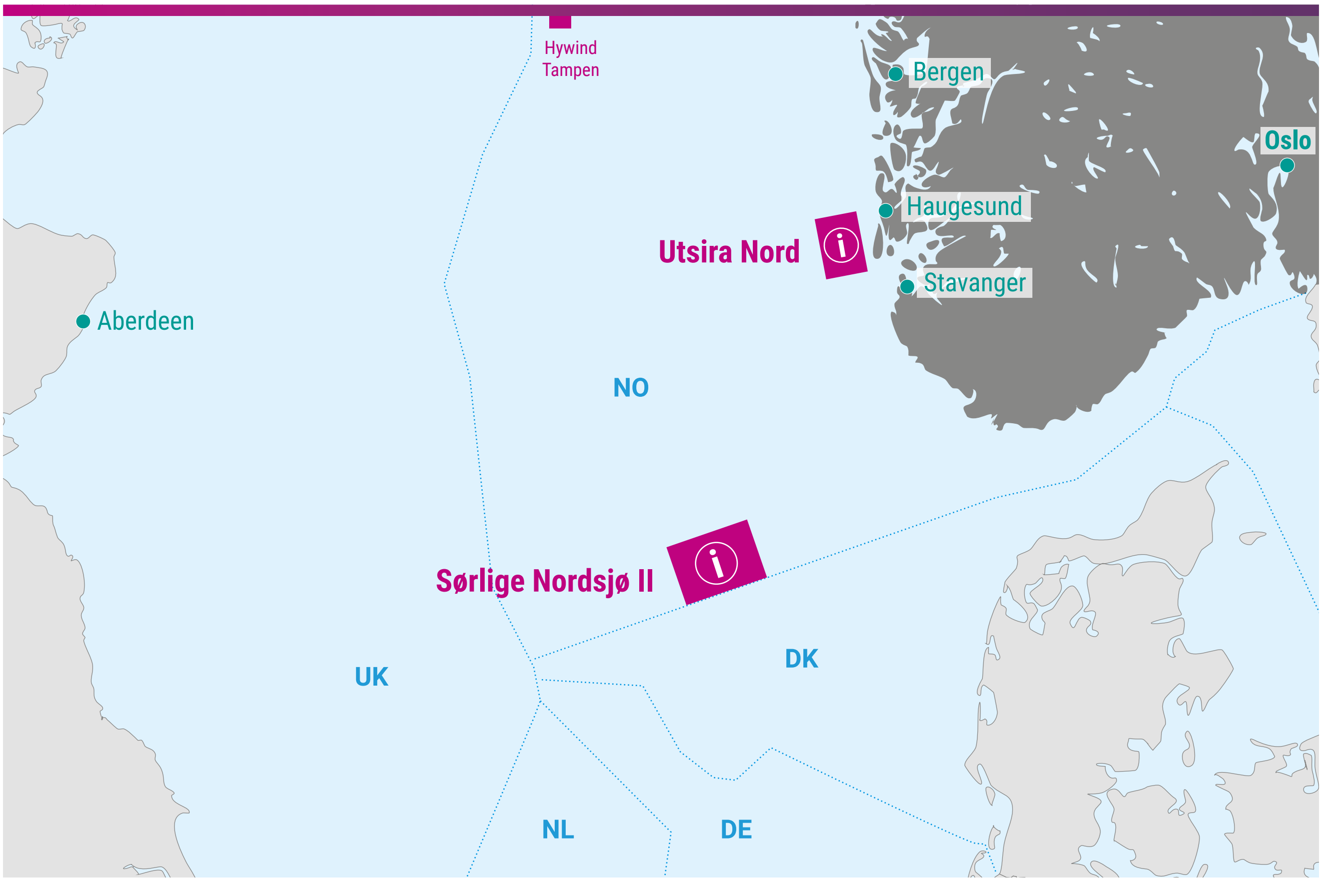


Figure 26 – Potential wind farms Norway 2030.

Potential development 2035–2050 (Up to 30 GW)

To evaluate potential offshore areas for building the 30 GW offshore wind, a public taskforce was nominated, with the Norwegian Regulator (NVE) in charge. The first delivery of this public taskforce was to evaluate the most promising offshore areas. In April 2023, a public report was given, pointing out potential offshore areas to be further evaluated. These evaluations were, among others, based on geography, depth of the sea, regional energy-need, onshore electrical infrastructure, export-potential and expected cost for wind developer.

The public task force has identified 20 different offshore areas, with the total size of 54,000 km². This means a total area about 10 times the needed area to realise 30 GW. The next step of the task force will analyse which areas have the best properties and also give a possible time-schedule and process for developing the 30 GW.

In the report published April 2023, the area of Sørlige Nordsjø II is proposed renamed and rescaled to area Sørvest F, while Utsira Nord is renamed/rescaled to Vestavind F. A part of the work for the public taskforce is to propose the further development of these areas (step 2 of Sørlige Nordsjø II and Utsira Nord). A rescaling of these areas to a higher volume will be considered, this to make the areas more economically viable. The goal is to conclude the size and the process before the 2025-tendering-process. The industrial consortiums entering the pre-qualification-phase are, in general, in favour of developing the areas in the southern part of the Norwegian territories and also in Favor of having connection to the other countries as well. This is in order to make the offshore wind development economically viable. A political decision of the issue is also expected before the 2025 tendering process.

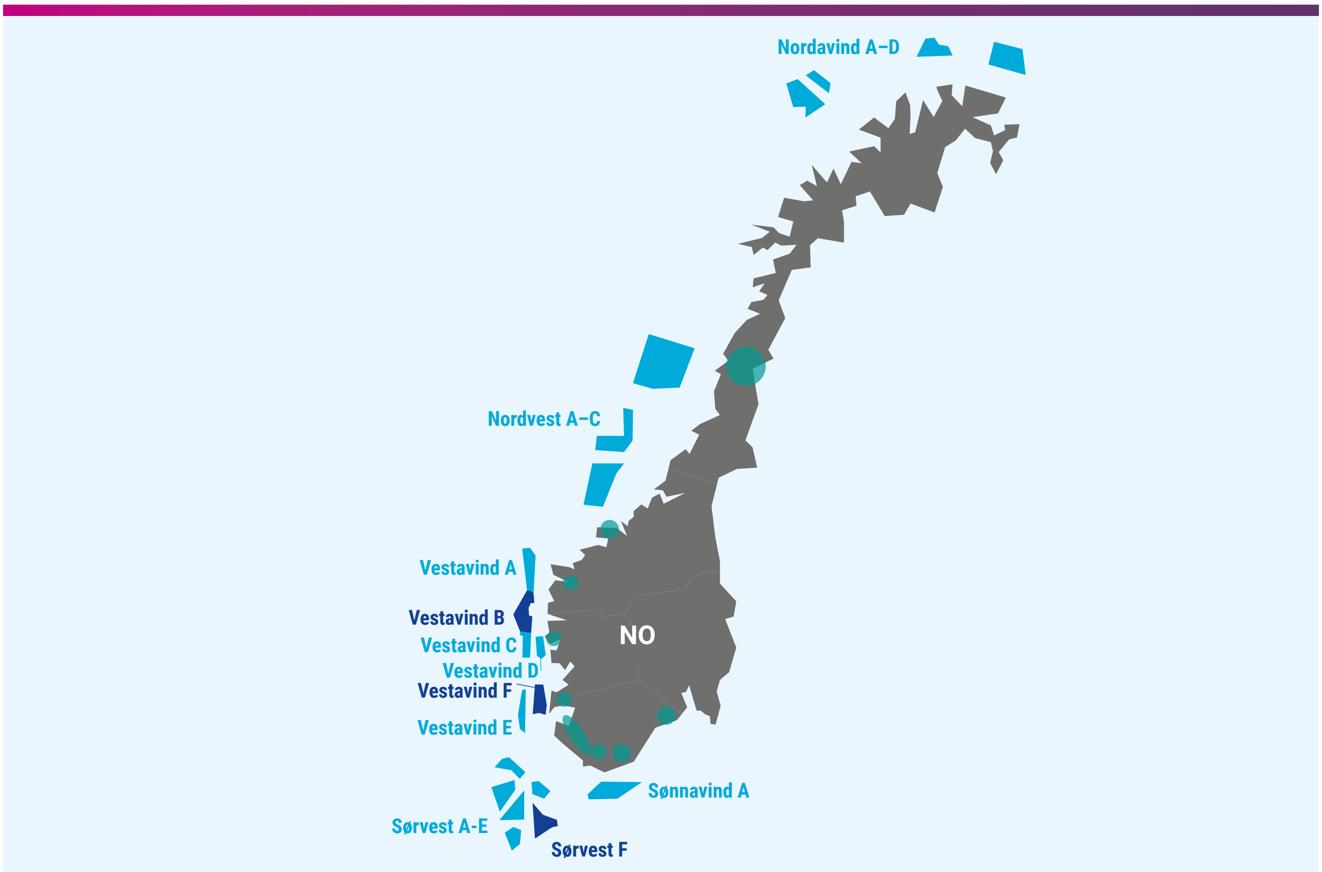


Figure 27 – Potential wind farm areas Norway 2030–2050.

Ireland

The generation and offshore network data provided for Ireland is guided by the non-binding goals provided by the Irish government, the ongoing projects that are being developed and by the processes being established to support longer term offshore development.

Table 6 shows the non-binding goals provided by the Irish government for offshore renewables in the Irish EEZ for the North Sea and Atlantic sea basins. The North Seas basin for Ireland includes the Irish Sea and the Celtic Sea. The Atlantic basin includes the Atlantic Ocean area to the west, north-west and south-west of Ireland.

Sea Basin	2030 Goal (GW)	2040 Goal (GW)	2050 Goal (GW)
North Seas	4.5	13	20
Atlantic	0.5 – 1	7	15
Total	5 – 5.5	20	35

Table 9 – Non-Binding Goals for Ireland

The approach in Ireland envisages several phases for offshore RES development:

- Phase 1 should be complete by 2030 and would include an initial group of windfarms intended to deliver much of the 2030 goal. Projects are already identified for Phase 1 and some have been successful in the recent auction for the first Offshore Renewable Electricity Support Scheme (ORESS 1). The Phase 1 projects are largely sited off the East Coast of Ireland in the Irish Sea and would be AC radially connected to the on-shore Irish transmission system. One project is located off the West Coast of Ireland. This would also be AC radially connected to the on-shore system.
- Phase 2 would include 2 further windfarms with a total capacity of around 700 – 900 MW. These would be located off the South Coast of Ireland in the Celtic Sea. The 2 projects are intended to be operational by 2030 and would be radially connected to the on-shore Irish transmission system.
- Phase 3 would include a further 2 GW of windfarm resources to be in development by 2030. These resources would be located in the Celtic Sea or Atlantic Ocean and would be designated for the production of green hydrogen.
- Following Phase 3, an enduring offshore regime would be established with EirGrid as offshore transmission operator. The RES projects developed after 2030 would be located in zones identified through Ireland's Offshore Renewable Energy (ORE) Designated Areas, which will be designated according to the legislative provisions for Designated Maritime Area Plans (DMAPs) in the Maritime Area Planning (MAP) Act. These projects are likely to be a mixture of fixed base and floating wind turbine technologies. They might be radially connected to the onshore transmission system or they might be connected via hybrid arrangements.

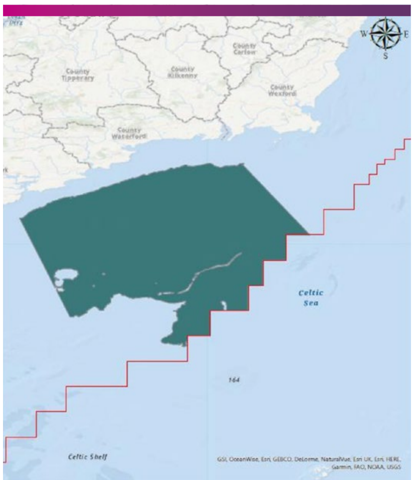
Windfarms included up to 2030

The windfarms included up to 2030 for the North Seas include a number of projects that are in development to help meet the 2030 goals (3,949 MW total capacity). A relatively small existing windfarm was also included in (Arklow 1.25 MW). These projects up to 2030 are well understood in terms of proposed location, capacities and electrical connections. The Phase 2 projects were also included as 2 x 350 MW wind farms, making a total of 4,674 MW. All these projects are assumed to be radially connected to the on-shore Irish transmission network.

Windfarms included up to 2040 and 2050

For the position beyond 2030, notional windfarms are connected up to a level that delivers the non-binding goals for 2040 and 2050. These windfarms were largely assumed to be windfarms of 2 GW capacity with a hybrid configuration and HVDC-connected. The commissioning dates for these projects were phased so that a new project would commission every second year.

- From 2030 up to 2040, a further 5 projects were included to meet the overall non-binding goal of 13 GW for the North Seas. Three of these additional projects were assumed to be windfarms of 2 GW capacity. The other 2 projects were assumed to have lower capacities that would deliver the overall non-binding goals of 13 GW by 2040. All but one of these projects were assumed to have a hybrid configuration and to be HVDC-connected.



Celtic Sea East Broad Area Floating Wind

Legend — Irish Exclusive Economic Zone Limit
Celtic Sea Broad Area (60 –100 m)
0 15 30 60 90 120 Kilometers

Mid-West Broad Area Floating Wind

Legend Mid-West Broad Area (60 –100 m)
0 10 20 40 60 80 Kilometers

Nort-West Broad Area Floating Wind

Legend — Irish Exclusive Economic Zone Limit
Nort-West Broad Area (60 –100 m)
0 17.5 35 70 105 140 Kilometers

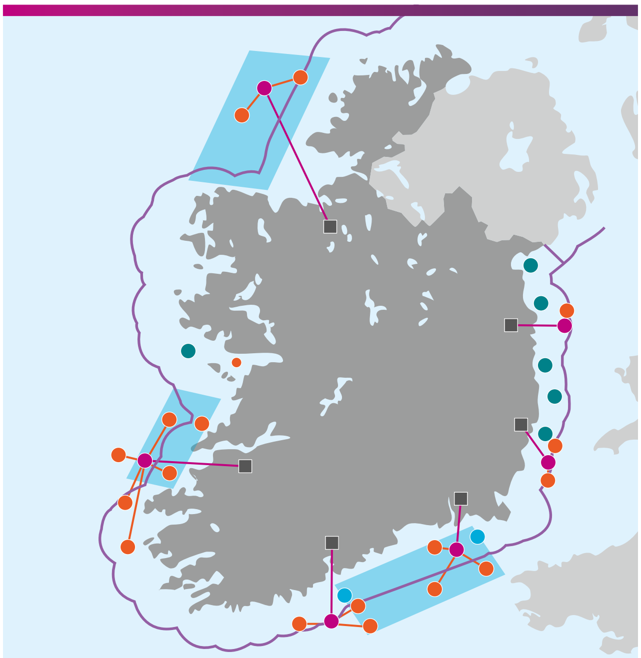
Figure 28 – Potential Broad Areas of Interest (OREDP II)

- From 2040 up to 2050, a further 4 projects were included. Three of these additional projects were assumed to be windfarms of 2 GW capacity. The other project was assumed to be 1 GW capacity so that the overall non-binding goal of 20 GW is met. All but one of the additional projects from 2040 to 2050 were assumed to have a hybrid configuration and to be HVDC connected.

The additional projects connected through to 2040 and 2050 were each connected to an offshore transmission node. These transmission nodes are intended to be the hub points for a transmission network in the North Seas. Two hub points were located in the Irish Sea (IE_01 and IE_02), and 2 hub points were located in the Celtic Sea (IE_03 and IE_04). Each hub point was assumed to have a 2 GW rated HVDC connection to an onshore location, close to a relatively strong connection point on the existing Irish onshore grid.

The location of the windfarms after 2030 and for the offshore transmission nodes was guided by three potential broad areas of interest for floating windfarms, which are illustrated in the Offshore Renewable Energy Development Plan II that is being developed by the Irish government. These are illustrated in Figure 28.

The overall data representation was shared with the Irish ministry (DECC). This representation of windfarms and nodes for both the North Seas and Atlantic sea basin areas is illustrated in Figure 29.



Legend
- Onshore 400 kV or 220 kV
- Phase 1 OS Windfarm
- Phase 2 OS Windfarm
- Further OS Windfarm
- Offshore Node
- HVDV to Onshore
- OREDP2 Broad Area of Interest

Figure 29 – ONDP Generation and Node Data for Ireland

Sweden

Political targets and development model

The Swedish government has not provided any non-binding offshore targets, a decision that stems from the country's long tradition of advocating a technology-neutral energy policy. Despite having a non-subsidised and open offshore wind development scheme that does not rely on traditional centralised site auctions, the commercial interest is articulated with 70+ ongoing projects, whose combined capacity amounts to 120+ GW.

Projects overview

Sweden today has some 200 MW of offshore wind in operation, most of which was installed between 2000 and 2013. In addition, there is one fully consented 640 MW wind farm, Kriegers Flak, in the Swedish EEZ in the southwestern part of the Baltic proper. The site is located next to the Danish wind farm sharing the same name. If a final investment decision is made by the project developer, Swedish Kriegers Flak is expected to be commissioned in 2029.

In May 2023, the Swedish government granted permits to two additional wind farms – Galene and Kattegatt Syd – located in the Swedish EEZ of the Kattegat between Jutland and the Swedish west coast. These two sites have a combined capacity of approximately 1,600 MW. Natura 2000 permits for the abovementioned projects are still pending approval. Final investment decisions by the project developers are expected between 2025–26. These two wind farms are expected to come online in 2031 at the earliest. Both projects will be connected to the Swedish transmission grid through radial AC grid connection systems.

An additional eight offshore wind projects located in the Swedish EEZ and having a combined capacity of some 14 GW have applied for permits between the years 2021–23. Final decisions from the national government on these permits are expected in 2024–25. Significant onshore reinforcements are required to connect the majority of these projects, hence, if permitted, most of these projects can come online in 2033 at the earliest.

Marine spatial plans

Sweden adopted its first marine spatial plans (MSPs) in February 2022. The current plans holds designated areas that can produce between 20–30 TWh of electricity per year. Directly after the first version of the Swedish MSPs were published, the government commissioned the Swedish Energy Agency and the Swedish Agency for Marine and Water Management with the task of reviewing the new plan and identify supplementary offshore areas that allow for an additional 90 TWh per year. The new national ambition is thus that the revised Swedish national MSP will allow for up to 120 TWh of offshore electrical generation per year, corresponding to a combined capacity of some 29–33 GW. In this context, it is important to note that the national MSPs are non-binding guiding documents and that final permitting is decided on a project-by-project basis.

There are three distinct marine spatial plans in Sweden – the Western Sea (Skagerrak and Kattegat), the Baltic proper and the Gulf of Bothnia. There are significantly less conflicts of interest for offshore wind development in the Gulf of Bothnia compared with the Western Sea and the Baltic proper. Permitting in the Baltic proper is in general a complex matter as the likelihood that projects developed along Sweden's east coast conflicts with defence interests is high.

The public consultation for the proposed new Swedish marine spatial plans started in September 2023 and will continue until December 2023. The proposed revised MSPs, with more and larger areas allocated to offshore energy conversion, can be downloaded from the **website of the Swedish Agency for Marine and Water Management**.

Swedish numbers provided to the ONDP

The Swedish TSO Affärsverket svenska kraftnät (Svenska kraftnät) has provided both the generation capacities and the position of offshore nodes used in the Offshore Network Development Plan due to the national governments' policy of not providing non-binding targets. With the 120 TWh figure from the marine spatial plans serving as a guiding reference, a total capacity of 25 GW for 2050 has been included in the ONDP. Choosing 25 GW instead of 30 GW provides for a margin of a handful of projects eventually ending up not being fully consented. Of the 25 GW, 4 GW are allocated to the Western Sea and are thus included in the North Sea ONDP. All these projects are expected to be connected radially to the Swedish transmission grid.

Windfarms in the North Sea included up to 2030

No Swedish windfarms in the Swedish part of the North Sea are expected to come online before 2030.

Windfarms in the North Sea included up to 2040 and 2050

Up until 2040, a generation capacity of 2 GW is added. This corresponds to the two projects Kattegatt Syd and Galene and an additional smaller project predicted to be realised within the territorial sea in the northern part of the Western Sea. In 2050, another 2 GW of generation capacity is added, giving a total of 4 GW. The additional 2 GW is modelled as though it is realised in the northern part of the Western Sea, due west of the industrial town of Stenungsund. In this part of the Western sea, four different GW-sized offshore wind farms – Mareld, Poseidon, Västvind and Vidar – are currently being developed.

Great Britain

As Great Britain is not part of the EU, the British Government was not part of the European data collection in January 2023. In December 2023, an MoU between the NSEC countries[34] and the British government **was signed**, which, as a consequence, also facilitates collaboration on the ONDP topic between NSEC-countries' TSOs and National Grid ESO. The National Grid ESO did deliver input on potential capacities based on a **report from the Crown Estate**. Related information has been entered into the ENTSO-E database.

This includes about 16 GW expandable nodes for 2040 spread over the different offshore zones defined in ENTSO-E's Pan European Climate Database (PECD).

34 NSEC = North Sea Energy Collaboration

Approach to MSP in each Member State

Each country has a different approach towards (new) Marine Spatial Planning (MSP). In this section, for each country the links to current processes are given and for some countries these processes are elaborated on.

Belgium

With its first marine spatial plan issued in 2014 and covering the period 2014–2020, Belgium was a pioneer in Europe and even in the world. The current version of the MSP was issued in 2019 and covers the period 2020 – 2026 (see Figure 30 and **Marine spatial plan | FPS Public Health (belgium.be)**). This version of the MSP anticipated the creation of a new zone (now known as the "Princess Elisabeth Zone") to achieve the ambitious offshore RES target set for Belgium for 2030.

In line with the new Marine Protection Act, the next MSP will cover a period of 8 years (i. e. 2026 – 2034). Its entry into force is planned in March 2026, after a public consultation and based on the advices of relevant bodies and neighbouring countries. The MSP is elaborated by the Marine Environment Service of the Federal Public Service "Health".

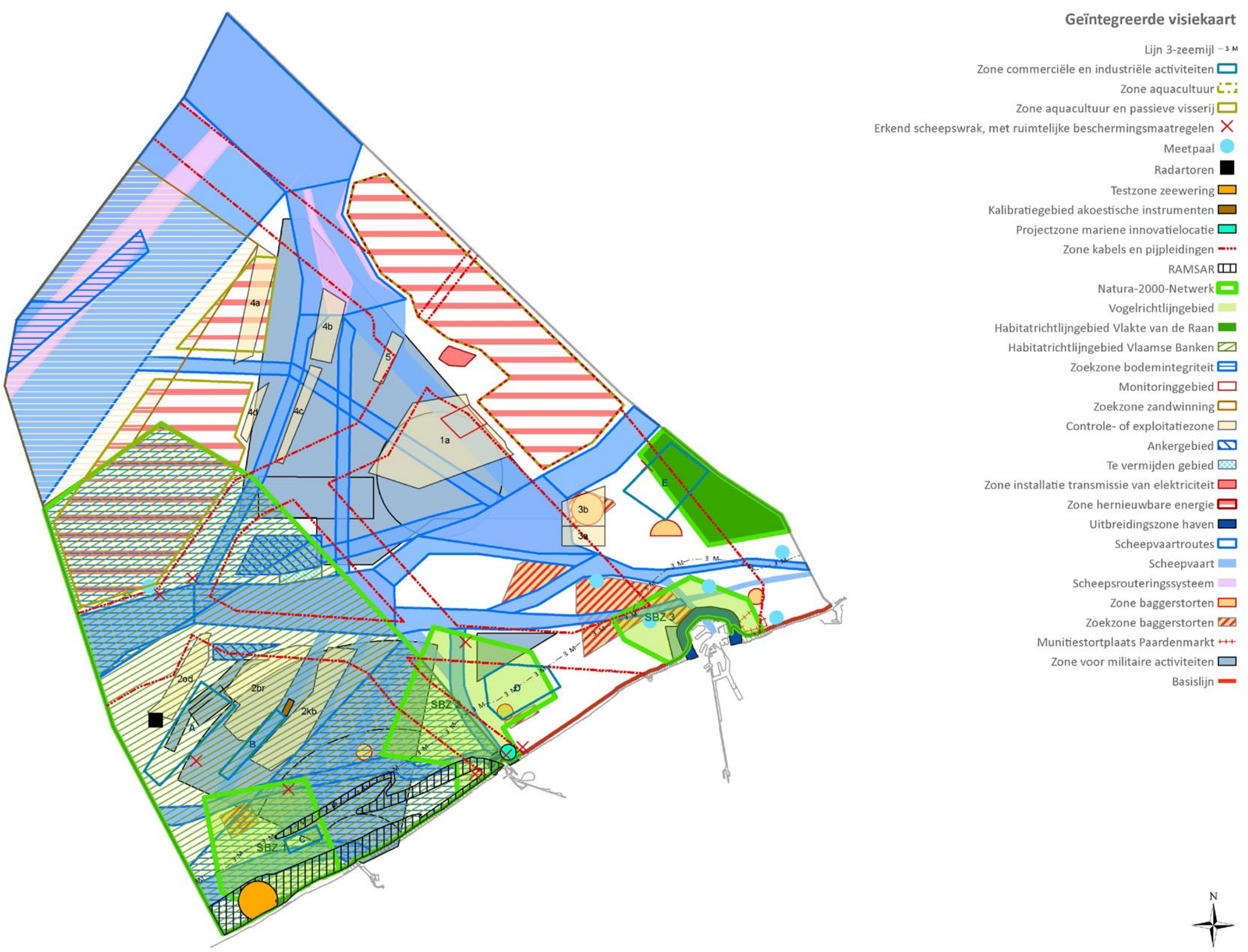


Figure 30 – Belgium's Maritime Spatial Plan 2020 – 2026 (zones for offshore RES marked in red/white hatched)

Denmark

The starting point for the ONDP is the **Danish Marine plan**. This interactive site provides an overview of the multiple usages of the Danish offshore area and is constantly updated. Denmark's marine plan is issued as a "digital notice", i.e. all relevant information about both the marine plan's content, hearings and historical versions of the marine plan are included. Additional service information that is not part of the notice is shown in extra service layers. These are not part of the marine plan decree and are not legally binding; however, they include information relevant for the ONDPs. More information on sea-uses is available at **msdi.dk**.

It is important to note that the allocation of production nodes between eastern and western Denmark does not follow the rules usually applied for ENTSO-E submissions. Usually, generation nodes are allocated to DKW (DK1) or DKE (DK2) according to their connection points. In contrast, for the ONDP, the DEA made the split between NSEC/ NSOC (North Sea Energy collaboration / North Seas offshore Corridor) and BEMIP (Baltic Sea Energy Market Integration Programme – offshore), following their **"Wind Energy Background Report – Area Interest"**, p. 22. This split runs through the middle of the Kattegat (see map at left page).

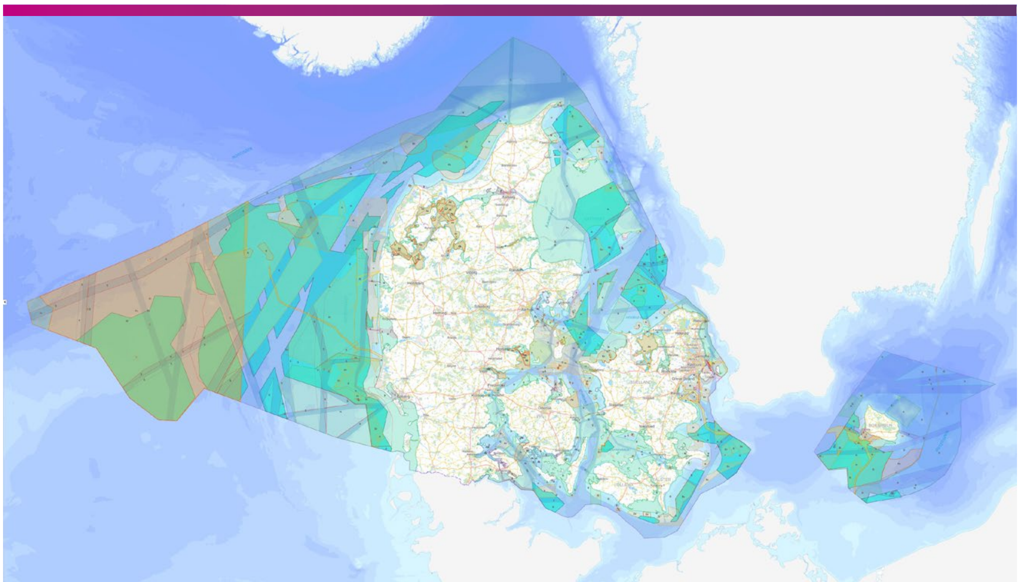


Figure 31 – Danish windfarm areas (source: **Danish Marine Plan**

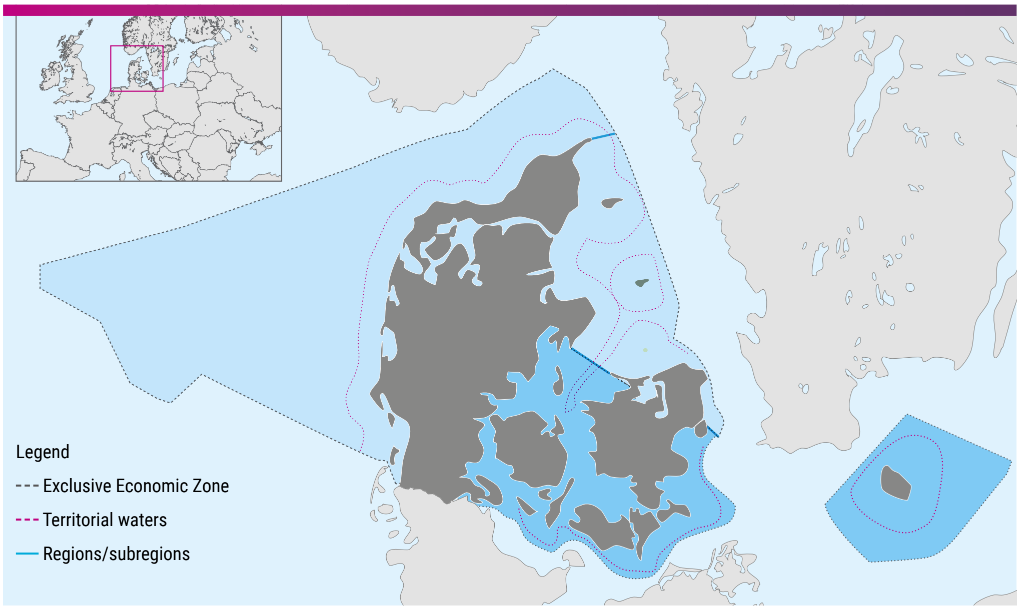


Figure 32 – Danish windfarm areas (source: **Background Report Area interests**

France

The French part of the Northern Seas Sea Basin ("East Channel North Sea") has a coastline of 1,022 km, from the Belgian border to the Norman–Breton Gulf in the south-western part of the Channel. Industrial activities such as nuclear generation (15 nuclear reactors in 4 different sites) and large ports are essential for both for the Regional, National and European blue economy. Several World Heritage sites designated by UNESCO (Mont Saint Michel, Tours de Vauban, Baie de Somme…) are located by the coast. Cultural and other kinds of tourism hence represent a major economic activity in the area. At sea, the sea basin is characterised by a large presence of fishing activities and shellfish breeding, as well as by intensive shipping lanes and 7 aggregate extraction sites.

The **Sea Basin Strategy Document** was approved in October 2019, following a large consultation process. It will be updated in 2024. The current document addresses the requirements of two European framework directives (MSFD and MSPD), and includes a "vocation map" of maritime areas. 8 different "vocation areas" (see below) have thus been defined, two of them being identified as "development areas" for offshore wind (areas 5 and 8), and three others as "co-existence" areas (areas 1, 3 and 4).

30 % of the East Channel North Sea waters are environmental protected areas, including a Marine Natural Park (area 2) and several Natura 2000 and RAMSAR areas.

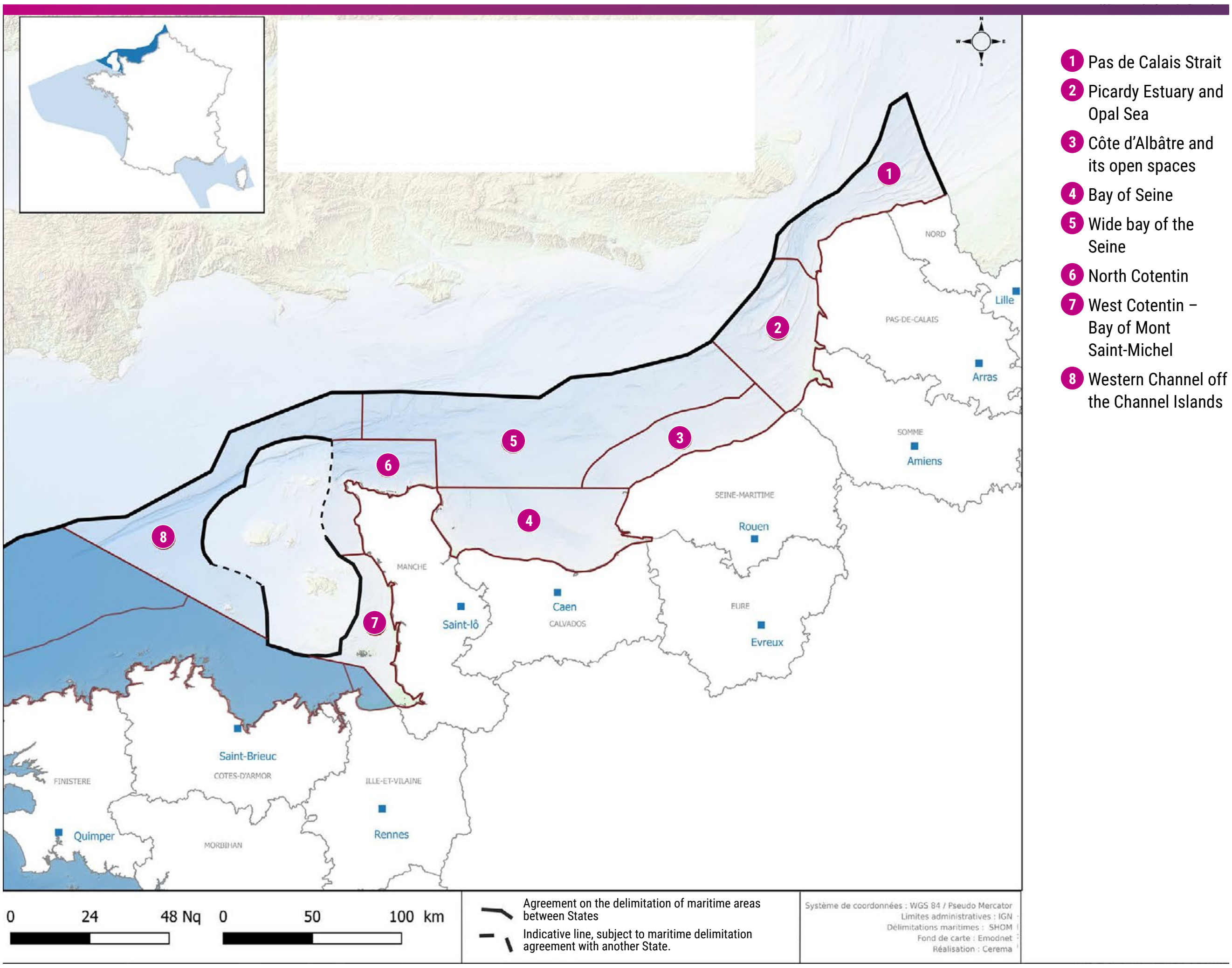


Figure 33

The main environmental impacts generated by offshore wind identified by the Sea basin Strategy Document are noise and vibration during construction and operation, as well as the introduction of chemical substances used to protect the substructures of wind turbines and offshore substation.

Four electrical interconnectors between France and the UK are located in Channel, reaching a total capacity of 4 GW.

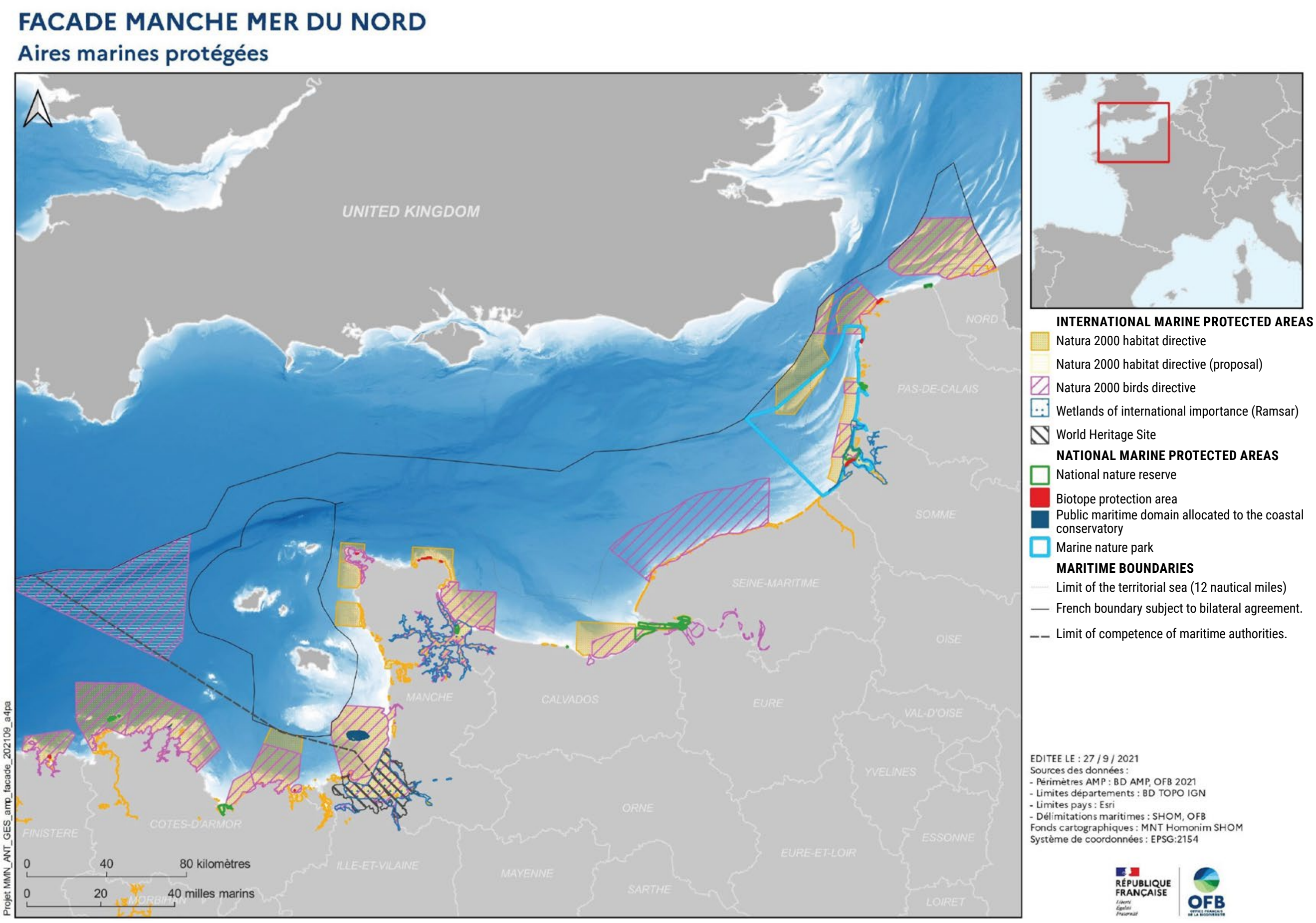


Figure 34

Germany

The German Federal Ministry of Interior, Building and Community (German: "Bundesministerium des Innern und für Heimat", BMI) is responsible for setting marine spatial plans for the EEZ of the German North Sea and Baltic Sea. The German Federal Maritime and Hydrographic Agency (German: "Bundesamt für Seeschifffahrt und Hydrographie", BSH) under the BMI is responsible for the preparation of these plans. Federal Coastal States are responsible for setting up spatial development objectives and principles for their respective share of internal waters and territorial sea in the North Sea and the Baltic Sea. Therefore, for the German North Sea there is a MSP (German: "Raumordnungsplan") for the EEZ (see figure 35), which was last revised in 2021, and for the territorial sea areas under the jurisdiction of the two coastal federal states Lower Saxony and Schleswig-Holstein.

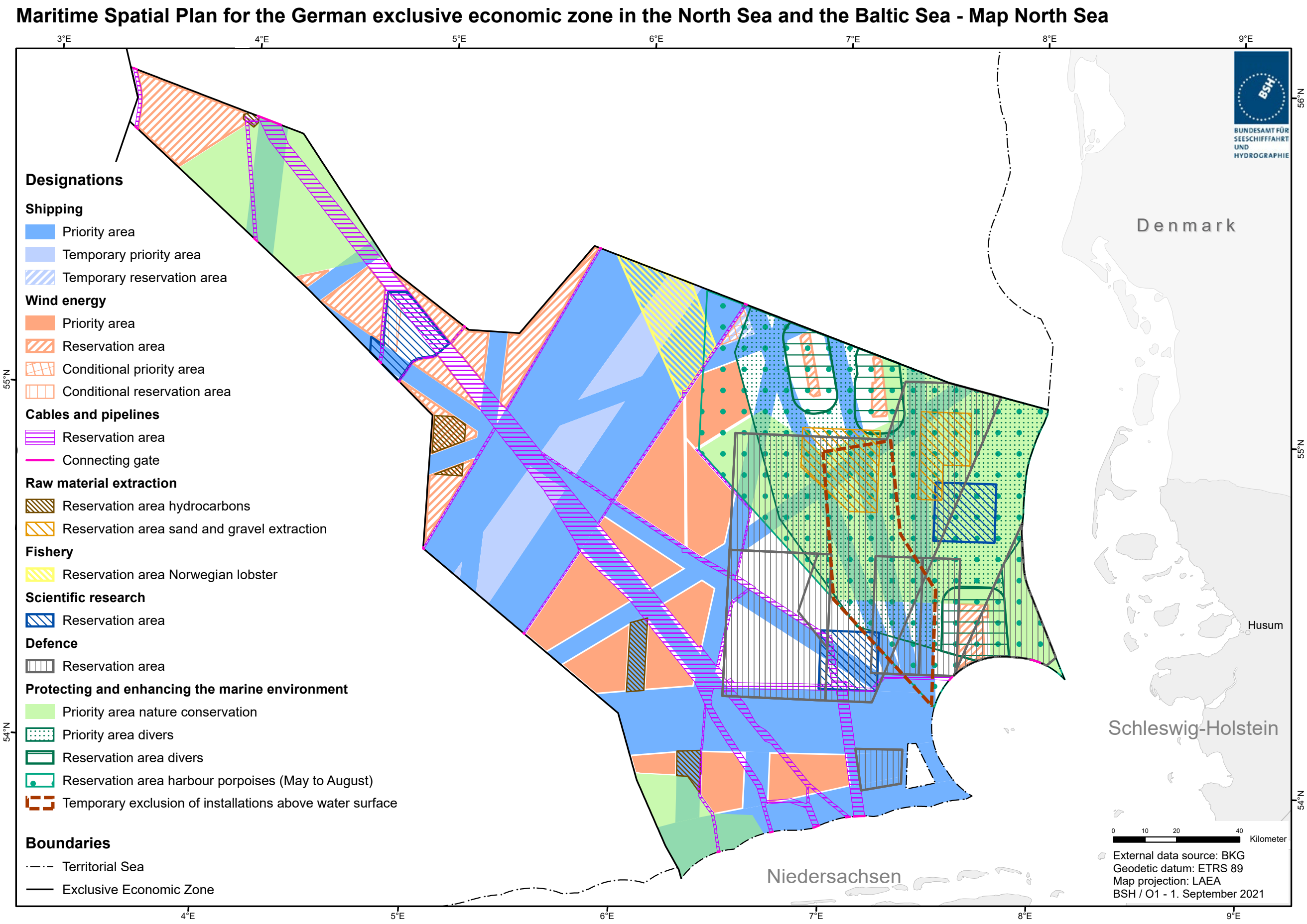


Figure 35 – Source: BSH, Maritime Spatial Plan, 2021.

Netherlands

In line with the Maritime Spatial Planning Directive (Directive 2014/89/EU), a framework for MSP has been established in The Netherlands. The Dutch government approved a National Marine Planning Framework in 2016 to bring together the planning policies for different marine activities in the North Sea. A subsequent plan for the period 2022–2027 has been drafted in 2021; *Programma Noordzee 2022–2027*[35].

Programma Noordzee 2022–2027 identifies areas for offshore wind energy generation to achieve the government's renewable energy goals. For the period until 2030, the government aims to generate a total of 21 GW offshore wind energy. For the period until 2040, this number should be increased by an additional 17 GW offshore wind energy.

35 RVO – Programma Noordzee 2022–2027

Ontwikkelkader windenergie op zee[36] (2022) sets guidelines – in broad terms – for the design, construction, availability, and lifespan of the offshore grid. This provides clarity in advance to developers of offshore wind farms in the Netherlands regarding the planning and conditions for the development of offshore wind energy at sea.

Norway

As of today, Norway does not have explicit maritime spatial plans, but operates with management plans for the marine areas. These are intended to function as management tools to ensure sustainable use, while at the same time maintaining the environmental values of the sea. As part of this work, the different areas/regions are mapped in different classes (e.g. Particularly Valuable and Vulnerable Areas). These classes mandate that planned activity must be sustainable, and plans may not be carried out if the impact is too large. See: **Marine management plans Norway**

Ireland

In line with the Maritime Spatial Planning Directive (Directive 2014/89/EU), a framework for MSP has been established in Ireland. The Irish government approved a National Marine Planning Framework in 2021 to bring together the planning policies for different marine activities. The Offshore Renewable Energy Development Plan II (OREDP II) was consulted on to facilitate the identification of areas most suited for the development of fixed wind, floating wind, wave and tidal resources. The intention is to provide the means to identify potential areas for ORE development and streamline exploratory works and data collection. Designated Marine Area Maps (DMAPs) are being produced to provide in-depth assessments of candidate areas. This establishes a holistic "plan-led"approach to offshore development. For developments underway that are to be commissioned by 2030 (Phase 1 & 2 offshore wind & associated grid infrastructure), detailed planning is being carried out. These early wind farms are being located where fixed wind turbines are feasible and where onshore connections are more straightforward. For subsequent developments (Phase 3 offshore wind & associated infrastructure), the more comprehensive "plan-led" framework will be in place. The designated areas for offshore development will take account of other marine activities and demand development (e.g. industry, hydrogen) as well as the scope for transmission development (onshore connections & interconnection). In respect of further electricity interconnection and possible hybrid arrangements, the Irish government has published a policy statement on Interconnection. An Offshore Transmission Strategy is also being prepared for publication in early 2024. This strategy will identify where interconnection routes, or hybrid interconnection routes, should be located to align with windfarm development, industrial demand development and onshore electricity network capability.

Sweden

Sweden adopted its first MSPs in February 2022. There are three distinct MSPs in Sweden – the Western Sea (Skagerrak and Kattegat), the Baltic proper and the Gulf of Bothnia. In general, there are significantly less conflicts of interest for offshore wind development in the Gulf of Bothnia compared with the Western Sea and the Baltic proper. In the Western Sea, shipping and fishery are the most important conflicting interests. In the Baltic proper, major challenges from a permitting perspective include defence interests and sensitive marine environments. The current Swedish MSPs hold designated areas for offshore electricity generation that can produce between 20 – 30 TWh of electricity per year. The Swedish government has also commissioned the Swedish Energy Agency and the Swedish Agency for Marine and Water Management with the task of reviewing the new plan and identifying supplementary offshore areas that allow for an additional 90 TWh per year. The updated national ambition is thus that the revised MSPs will allow for up to 120 TWh of offshore electrical generation per year, which can roughly be translated into a combined capacity of between 29 and 33 GW. The Swedish MSPs are non-binding guiding documents and final permitting is decided on a project-by-project basis. Revised MSPs, with more areas allocated to offshore energy conversion, are as of December 2023 subject to public consultation. The proposal can be downloaded from the **website of the Swedish Agency for Marine and Water Management**.

36 **RVO – Ontwikkelkader windenergie op zee**

Glossary

Term	Definition
ACER	The European Union Agency for the Cooperation of Energy Regulators
AOG	Atlantic Offshore Grid (priority offshore grid corridor – EU 2022/869)
BEMIP	Baltic Energy Market Interconnection Plan
BEMIP offshore	Baltic Energy Market Interconnection Plan offshore grids (priority offshore grid corridor – EU 2022/869)
EC	European Commission
EEZ	Exclusive Economic Zone: area of the sea in which a sovereign state has special rights regarding the exploration and use of marine resources, including energy production from water and wind. It stretches from the outer limit of the territorial sea (12 nautical miles from the baseline) out to 200 nautical miles (nmi) from the coast of the state in question. The EEZ does not include either the territorial sea or the continental shelf beyond the 200 nautical mile limit.
EU	European Union
ENTSO-E	European Network of Transmission System Operators for electricity: the European association for the cooperation of TSOs for electricity
IEA	International Energy Agency
IRENA	The International Renewable Energy Agency
MS	Member State of the European Union
MSP	Maritime Spatial Planning
NECP	National Energy and Climate Plan
NSCOGI	North Seas Countries' Offshore Grid Initiative (High level group; 2009 – 2015)
NSEC	The North Seas Energy Cooperation (NSEC) (High level group since 2016, follow-up to NSCOGI)

Term	Definition
NSOG	Northern Seas Offshore Grids (priority offshore grid corridor – EU 2022/869)
NT	National Trends – ENTSO-E scenario in the TYNDP22, building on countries' NECPs.
ONDP	Offshore Network Development Plan (new plan according to Art. 14.2 of EU 2022/869), part of ENTSO-E's TYNDP)
P2X	Power-to-X or conversion of renewable electricity into other forms of energy substances (such as gas, plastic, heat, chemicals etc)
PV	Photovoltaics
RES	Renewable Energy Sources
SB	sea-basin
SB-CB	Sea-basin cost benefit
SB-CS	Sea-basin cost sharing
SB-ONDP	Sea-basin Offshore Network Development Plan
SE offshore	South and East Offshore Grids (priority offshore grid corridor – EU 2022/869)
SW offshore	South and West Offshore Grids (priority offshore grid corridor – EU 2022/869)
TEN-E	Trans-European Networks – Energy, refers to Regulation (EU) 2022/869 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2022 on guidelines for trans-European energy infrastructure, amending Regulations (EC) No 715/2009, (EU) 2019/942 and (EU) 2019/943 and Directives 2009/73/EC and (EU) 2019/944, and repealing Regulation (EU) No 347/2013
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan; generated and published by ENTSO-E every two years for electricity infrastructure and by ENTSOG for gas infrastructure

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