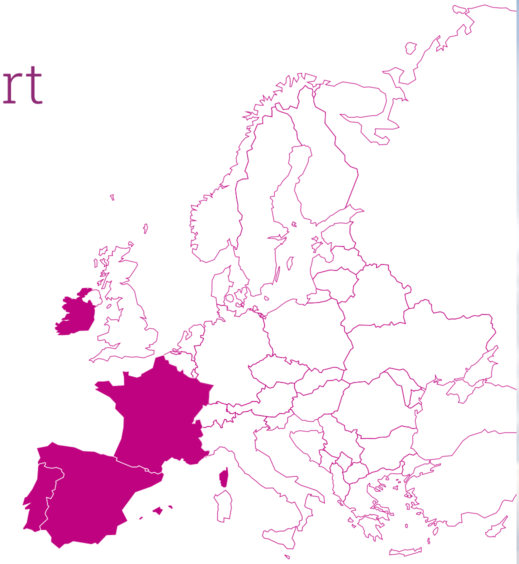
TYNDP 2024

Sea-Basin ONDP Report

TEN-E Offshore Priority Corridor: Atlantic Offshore Grids



January 2024

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.

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Offshore Network Development Plans 2024

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

Arrows
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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?

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Executive Summary

Key Messages for the Atlantic Offshore Grid corridor

Offshore wind energy is a promising and sustainable source of electricity generation that has gained significant attention and investment in recent years. Furthermore, it is one of the main pivotal elements in the global transition towards cleaner and more sustainable energy systems. The revised TEN-E regulation (Regulation (EU) 2022/869) within the European Union (EU) plays a significant role in promoting offshore wind development, aligning with climate goals and enhancing energy security.

Under the revised TEN-E regulation (Regulation (EU) 2022/869), ENTSO-E is tasked with developing offshore network development plans (ONDPs) which are essential for ensuring the efficient integration of offshore renewable energy sources (RES) into the European electricity grid. They serve as a roadmap for the expansion and enhancement of the offshore grid infrastructure, enabling the efficient transmission of electricity from offshore generation sites to onshore areas and across borders. This document focuses on the first ONDP for the Atlantic Offshore Grid corridor. This plan includes the Member States' (MSs) vision regarding the expected offshore RES generation in 2030, 2040 and 2050 horizons. The related necessary onshore infrastructure needs will be investigated under the framework of the Ten-Year Network Development Plan 2024 (TYNDP 2024) in the System Needs Study.

The main findings and key messages for the Atlantic Ocean Basin can be summarised as:

Evolution of offshore wind capacity: from radial connections in 2030 to first hybrid projects by 2040 and 2050 in north Atlantic

Within the Atlantic Offshore Grid corridor 5.66 GW offshore wind capacity is expected to be radially connected in 2030. It is anticipated that by the 2040 and 2050 time frames, this capacity will have grown to 26.26 GW and 44.26 GW respectively. The offshore wind capacity to be installed by 2050 in the north Atlantic represents 9 % of the total capacity expected to be installed in Europe by 2050.

For the 2040 and 2050 time horizons, two hybrid transmission corridors were assessed, one between Ireland and France, connecting wind farms on both sides and another one between Spain and Portugal. Finally, only the hybrid interconnection corridor linking an offshore French transmission node in the North Atlantic to an offshore transmission node off the South of Ireland returned reasonable capacities for the so-called "DC grid" configuration (namely, anticipating the availability of DC circuit-breakers): this project would cover a distance of approximately 500 km and would allow a power transfer of the order of 700 MW.

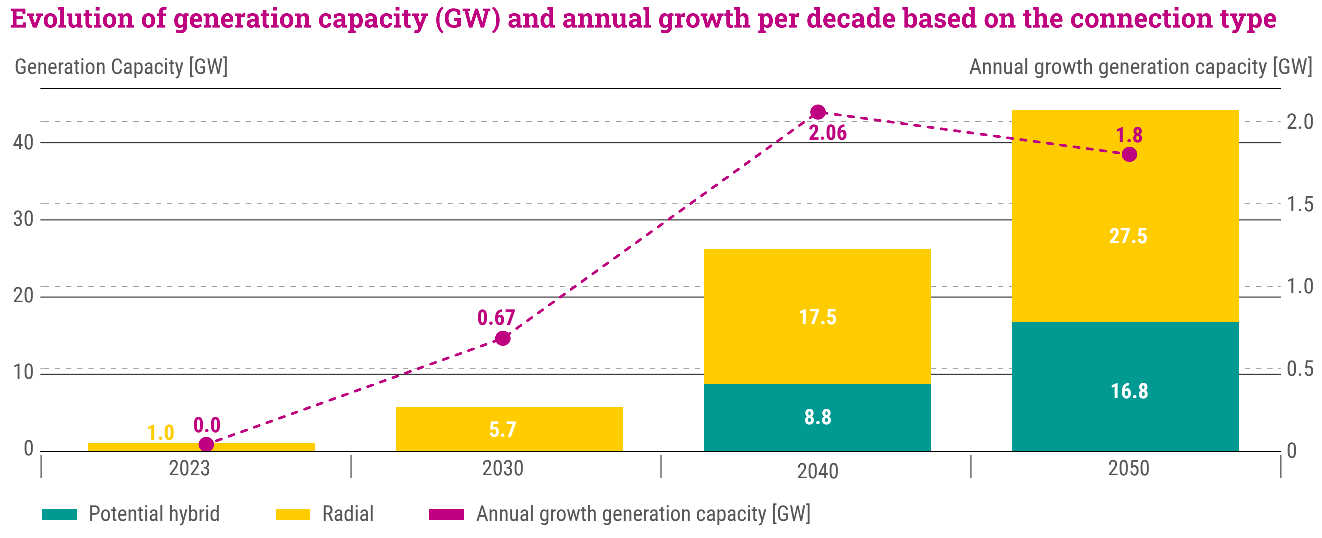

Evolution of generation capacity (GW) and annual growth per decade based on the connection type

Figure 1 – Evolution of offshore wind capacity in the Atlantic Ocean Basin in 2030, 2040 and 2050 and annual growth per decade.

The offshore wind capacity in the Atlantic Offshore Grid corridor will have a significant impact on the electrical system and on society

This ONDP includes an initial investigation of the cost and benefits related to an offshore infrastructure. The total cost of the interconnected offshore infrastructure for the Atlantic Offshore Grid corridor is about 30 bn€. The cost of the offshore infrastructure by 2030 is expected to be around 9 bn€. Between 2030 and 2040, the expected cost of the offshore infrastructure is foreseen in the range of 10.6 – 11.5 bn€. This cost by 2050 will increase to a potential range of 9.4 – 10.6 bn€. These costs do not include the cost of potential reinforcements needs in the internal grids.

The benefits result from having a more efficient onshore and offshore market, increasing the overall security of supply of the European power system, reducing curtailment of generation and lowering emissions:

Changes in power flows generation patterns due to future offshore wind development in 2030, 2040 and 2050 horizons

The high installation of wind offshore capacity and its use will create future higher flows and new flow patterns for which current grid is not designed. Therefore, these new flows incorporating higher volumes and variable directions, which may be opposite to those currently known, may result in cross-border and internal congestions in the long term. Those potential investment needs will be investigated in the Identification of System Needs (IoSN) exercise within the TYNDP 2024 framework.

Floating technology: the solution for the offshore development in the Atlantic Offshore Grid corridor

Solutions with fixed foundation structures become less attractive in locations deeper than 50 – 60 metres due to higher economic costs and practical difficulties of installation and operation. Floating technology in offshore wind energy represents an alternative that is transforming the renewable energy sector. The Atlantic Offshore Grid corridor often features deep water sites, where fixed bottom foundations are impractical. At the European level, the following Figure illustrates the potential for offshore wind deployment of floating solutions compared to fixed foundation solutions based on the water depth. However, floating technology seems to have a technological progress slower than the fixed foundation technologies, which can impact the offshore development of the region according to the MS goals.

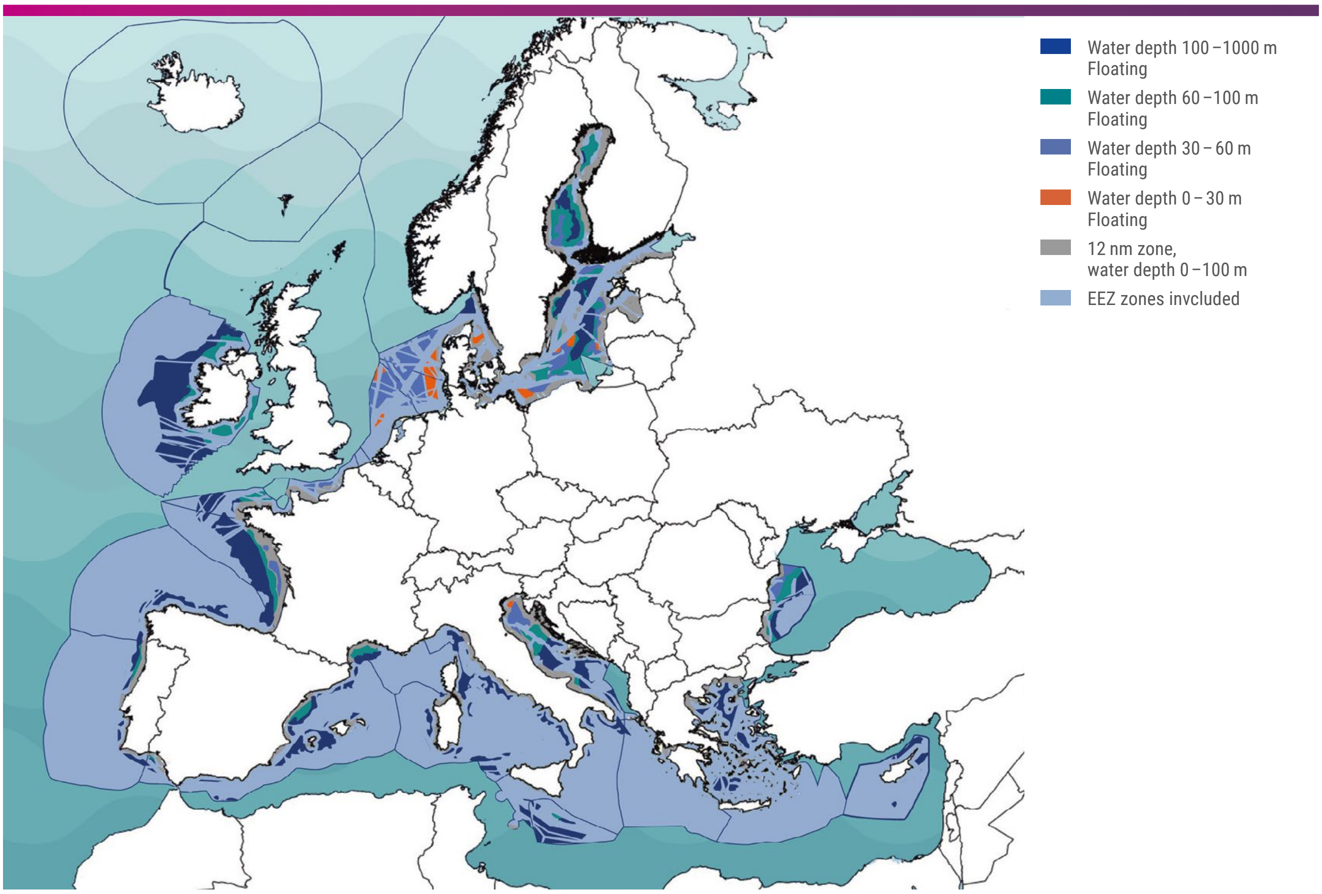


Figure 2 – Offshore wind energy potential. Source JRC.

Flexibility solutions are needed to increase offshore energy integration

Offshore wind energy has the potential to contribute significantly to the European climate goals. However, to harness this potential fully, additional flexibility solutions are required to adapt to the variable nature of wind, ensuring the grid remains stable and balanced. These solutions will also be essential for a successful transition to a low-carbon energy system that benefits both the environment and society as a whole.

Some of the current technologies offering flexibility solutions to balance supply and demand include:

- interconnections (offshore, hybrid and onshore), which play a dominant role in addressing flexibility needs particularly on the longer-term timescales;
- energy storage, such as batteries and pumped hydro, which play a crucial role in storing excess energy during high-wind periods and realising it when wind generation is low;
- electrolysers; and
- demand response.

1 Introduction to the Sea Basin Report Atlantic Offshore Grid corridor

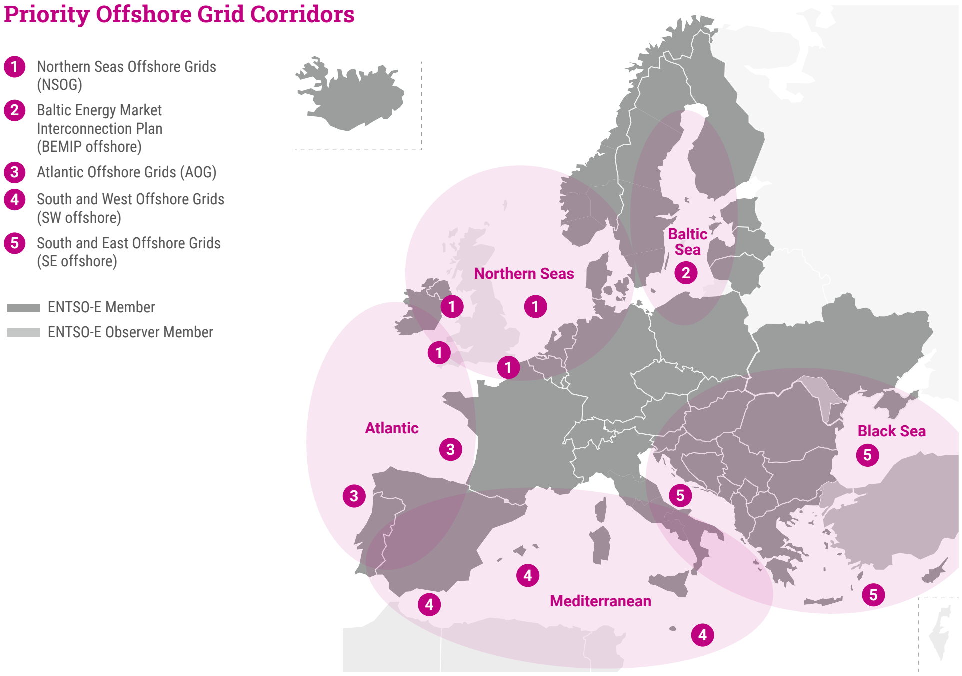
On 3 June 2022, the revised TEN-E regulation (EU) 2022/869 entered into force, mandating ENTSO-E with the new task of developing ONDPs for each sea basin by 24 January 2024. Formally, the ONDPs are a separate part of ENTSO-E's TYNDP. The offshore plans must build on the joint MSs' non-binding agreements on joint offshore RES goals for each sea basin.

On 19 January, EU countries, with the support of the European Commission (EC), 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](#).

- The ONDPs deliver a high-level outlook on offshore generation capacities potential and 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 3.

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](#).



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 3 – 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 ambition for the amount of capacity offshore was established by each EU MS. As prescribed by the new TEN-E Regulation, EU MSs concluded non-binding agreement on goals for offshore renewable generation per sea basin for each reference year.

Some MSs delivered a range; in these cases, as a standard approach, ENTSO-E used the upper boundary, unless more detailed information was available. This was done to provide the full picture of a potential offshore network infrastructure.

Applying upper limits				TSO data status 6.4.2023							
MS 20.1.2023 (GW)	**2030**	**2040**	**2050**	**ONDP Data [GW]**	**2030**	**2040**	**2050**	**Delta [GW]**	**2030**	**2040**	**2050**
ES	1.56	1.56	1.56	**ES**	1.40	1.40	1.40	**ES**	−0.16	−0.16	−0.16
FR	1.70	7.50	16.50	**FR**	1.76	7.86	17.86	**FR**	0.06	0.36	1.36
IE	0.5–1	7.00	15.00	**IE**	0.50	7.00	15.00	**IE**	0.00	0.00	0.00
PT	10.00	10.00	10.00	**PT**	2.00	10.00	10.00	**PT**	−8.00	0.00	0.00
Total	14.26	26.06	43.06	**Total**	5.66	26.26	44.26	**Total**	−8.16	0.2	1.2

Table 1 – Offshore RES capacities: left: upper range delivered by the MSs on 20.01.2023; middle: data applied by ENTSO-E; right: difference between both.

The reasons for differences > 1 GW are explained below.

France

France is adjacent to three sea-basins and the MS delivered ranges to all of them. However, summing the maxima up would exceed the intended national policies. At the point of data collection in January 2023, the allocation to the sea basins was not yet clear, confirmed by a range from 10.4 GW to 47.5 GW in 2050 given by the MS. This goal of 40 GW considered by the ONDP at the national level was re-affirmed by president Macron during the North Sea Summit of 24 April 2023 as the French contribution to the **300 GW target of the EC** by 2050.

At a later stage (June 2023), France updated its official targets[1]. The differences by time horizon for the Atlantic Offshore Grid corridor may be summarised as follows:

	2030	2040	2050
Non-binding target (Jan 23)	1.7	4.2 to 7.5	4.2 to 16.5
ONDP data collection (March 23)	1.7	7.9	17.9
Official updated targets (June 23)	1.7	8.5 to 15	24 to 36

Table 2 – National targets including the three sea-basins now range from 18,5 to 30,5 GW in 2040 and from 40 to 59 GW in 2050.

Ireland

Irish offshore windfarms (OWFs) are being developed in both the North Seas and Atlantic basins. The table shows the non-binding ambitions provided by the Government of Ireland for the Atlantic Offshore Grid corridor. By 2050, a total of 15 GW of offshore wind is targeted in the Atlantic Offshore Grid corridor. A further 20 GW is targeted for the North Seas basin. For both sea basins, the ONDP data that has been included for Ireland's offshore wind capacity development closely matches the non-binding goals.

Portugal

The Portuguese government plans to auction, until 2030, an offshore renewable capacity of up to 10 GW capacity. The first auction is expected to be launched until the end of 2023. Nevertheless, the draft update from the Portuguese NECP 2030, published in June 2023, anticipates an installed offshore wind capacity of 2 GW by 2030 that was updated for the ONDP data, while initial values reflected 10 GW in this time horizon.

Spain

The table includes the non-binding offshore RES targets provided by the Spanish government for the Atlantic Offshore Grid corridor, which includes a total amount of 1,560 MW for the 2030, 2040 and 2050 horizons. Those targets have been provided at national level; that is, considering insular territories as well. The slight differences between those numbers and the final ones considered in ENTSOE's models are due to the forecast for the installation of offshore in the Canary Islands being discounted from the total figure.

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[1] 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

3 Offshore RES Capacities and Infrastructure in the Atlantic Offshore Grid corridor today and in the coming years

The EC adopted the "EU Strategy on Offshore Renewable Energy"[2], which sets the objective of increasing offshore wind energy production capacity in the EU, starting from 12 GW to at least 60 GW by 2030, with a view to reach 300 GW by 2050.

Nevertheless, MSs' non-binding goals for offshore renewable energy set a higher ambition level for installed capacity compared to the strategy: the 2030 goals are nearly twice as high as the 60 GW ambition set out in the strategy, giving an overall ambition of installing approximately 111 GW of offshore renewable energy b 2030, 232 GW by the end of 2040 time horizon and around 317 GW by mid-century[3].

In this context, offshore wind is accelerating its technological and industrial development, making its implementation viable thanks to the concepts associated with floating offshore wind and allowing its deployment in deep waters.

The Atlantic Offshore Grid corridor often features deep water sites, where fixed bottom foundations are impractical. Floating technology in offshore wind energy represents an alternative that is transforming the renewable energy sector. Floating wind turbines enable wind energy to be harnessed at these deeper locations, expanding the potential for OWFs.

The main advantages of floating technology are as follows:

- Floating wind turbines have a smaller environmental footprint compared to traditional fixed-bottom foundations. They minimise disturbance to marine ecosystems and seabed habitats, and can be located further offshore, reducing visual impacts on coastal landscapes.
- Floating platforms for offshore substations, once available, will allow wind turbines to access stronger and more consistent winds found farther out at sea. This could result in increased energy production and efficiency.
- Floating technology is scalable and adaptable to various water depths and sea conditions. This versatility allows for the deployment of OWFs in a wider range of locations, optimising energy production.

Due to its high capacity factors, offshore wind can generate electricity in a stable and predictable manner, increasing its production in the autumn and winter seasons, when solar radiation is lower and consumption is higher. It is therefore highly complementary to other renewable energies, contributing to security of supply, adding value to the needs of the energy system and allowing the greater harnessing of available endogenous resources.

In the following sections, the situation of the OWFs already in operation or to be commissioned by 2030 up to 2050 is described for each country in the Atlantic Offshore Grid corridor.

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[2] COM(2020) 741 final of 19.11.2020 "An EU Strategy to harness the potential of offshore renewable Energy for a climate neutral future"

[3] COM_2023_668_1_EN_ACT_part1_v7.pdf (europa.eu)

France

In France, 3 bulks of generations of offshore grids are being developed in the Atlantic Offshore Grid corridor:

First bulk, with 3 radial 225 kV HVAC connections and one expandable HVAC 225 kV hub, totals **1.75 GW** offshore wind capacity already connected or to be connected before 2030. It is expandable to **2.25 GW** thanks to the 750 MW HVAC hub connecting two floating OWFs, the first one exporting 250 MW in 2029 and the second one 500 MW at a later stage. The wind farm areas cover a total surface of 560 km² and entail 450 km of offshore and onshore cable routes. Eleven years was needed between the award of the Saint Nazaire OWF and the final commissioning;

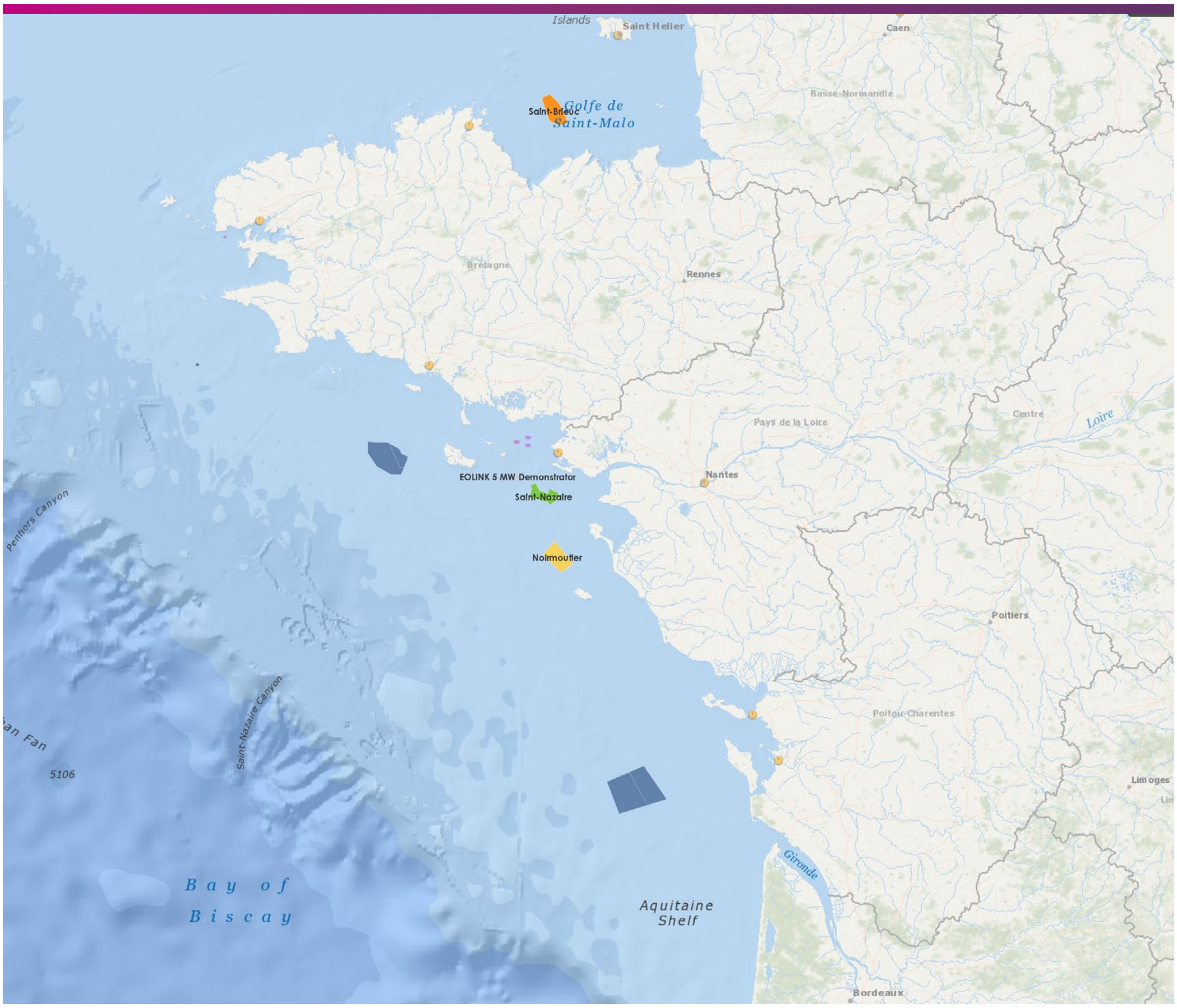


Figure 4 – Map of offshore wind capacities in the French part of the Atlantic Offshore Grid corridor by 2032.

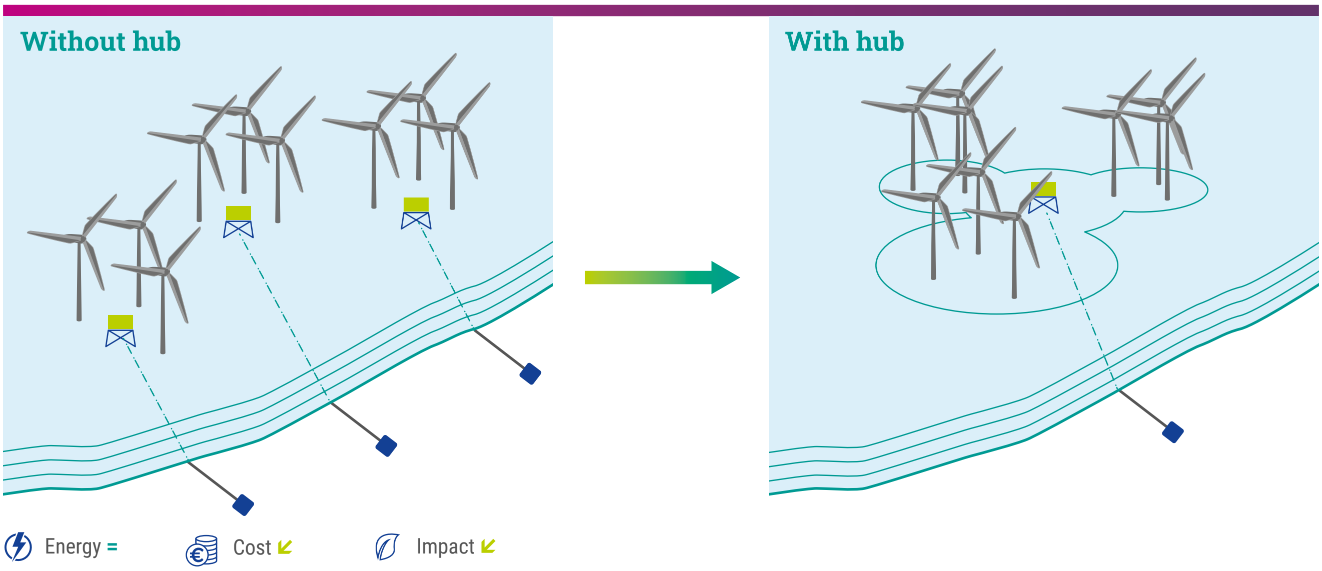


Figure 5 – Radially connected offshore windfarms (left) compared to radially connected offshore windfarms optimised in hub configuration (right).

The **second bulk**, composed of 320 kV HVDC connections, offers at this stage **1.2 GW** offshore wind capacity to be connected by 2032. These standardised 320 kV HVDC links, due to be replicated by other projects in these Sea Basins, represent a first change of scale, doubling the capacity per OWF connection. The wind farm area in South Atlantic (Oléron 1) covers a surface of 180 km² and the cable routes total 130 km of offshore and onshore. Eight years are expected between the award of the South Atlantic (Oléron 1) (2024) and the final commissioning; and

The additional capacity needed to reach the governmental targets updated in June 2023, i. e. respectively between 8.5 and 15 GW in 2040 and between 24 and 36 GW in 2050 according to the updated values, will form the **3rd generation** of offshore grids. For the purpose of the ONDP study, standardised 525 kV conceptual projects can be considered.

The 525 kV projects are considered as "offshore grid ready" projects. The precise number and locations will be confirmed by a ministerial decision following the French public debate regarding offshore wind development and marine spatial planning, and will be considered in the next edition of the ONDP.

	Name of RES Project	Connection capacity (MW)	Cable connection Technology	Commissioning year
A01	Saint Nazaire	480	HVAC 225 kV	2022
A01	Saint Brieuc	500	HVAC 225 kV	2023
A02	Yeu Noirmoutier	500	HVAC 225 kV	2026
A05	South Britanny	250 (expandable to 750 MW)	HVAC 225 kV	2030 (2032)
A07	South Atlantic Oléron 1	1200	HVDC 320 kV	2032

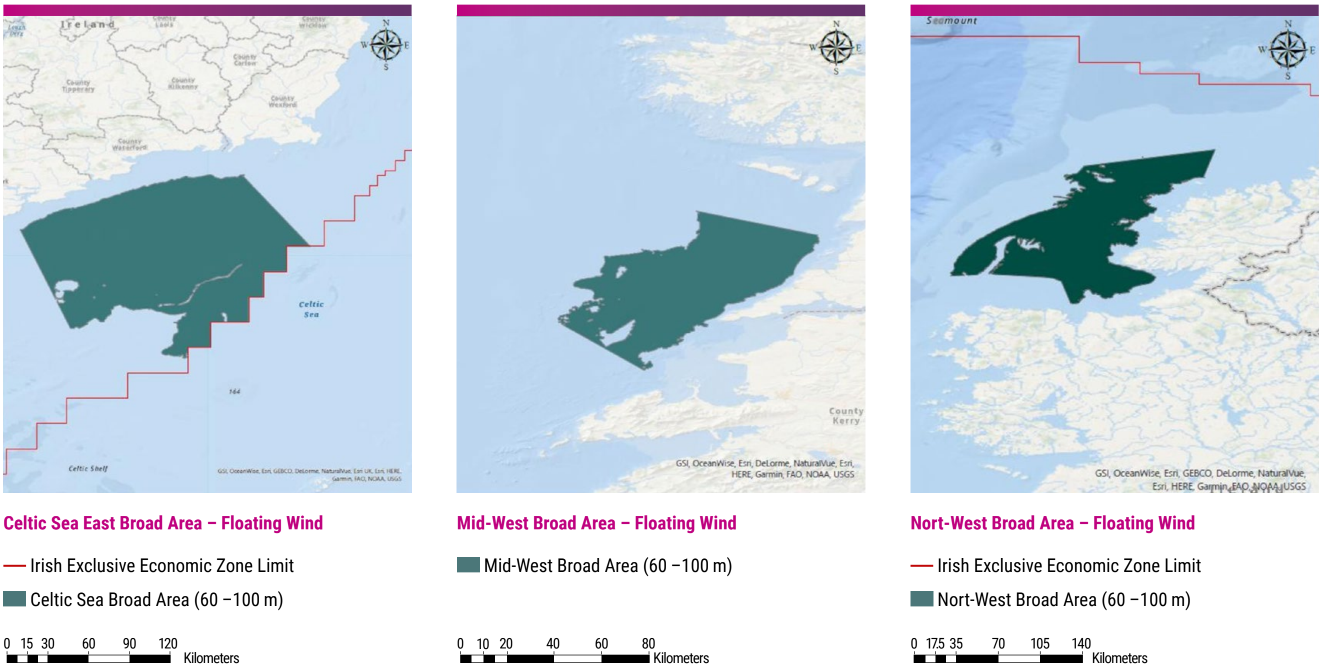
Table 3 – Connection and commissioning detail of French offshore bulk generation being developed in the Atlantic Offshore Grid corridor.

Ireland

Ireland currently has an installed capacity of ca. 25 MW located on the East Coast, in the Celtic Sea. Several phases of offshore RES development are planned for Ireland:

- **Phase 1** should be completed by 2030 and would include an initial group of windfarms intended to deliver much of the overall 5 GW Irish ambition for 2030 including development of an initial 0.5 GW of capacity on the Western side of Ireland in the Atlantic Offshore Grid corridor. Offshore wind 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). One of these projects, with a capacity of 450 MW, is located off the West Coast of Ireland (in the Atlantic Offshore Grid corridor) and is intended to be AC radially connected to the onshore transmission system. The remaining Phase 1 projects are largely sited off the East Coast of Ireland in the Irish Sea;
- **Phase 2** includes 2 further windfarms with a total capacity of around 800 – 900 MW. These would be located off the South West Coast of Ireland, part of the Atlantic Offshore Grid corridor. The two projects are intended to be operational by 2030, with radial connection to the on-shore Irish transmission system; and
- **Phase 3** includes 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 to reach the 7 GW in 2040 and 15 in 2050 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 via hybrid arrangements. Potential areas identified under the initial mapping exercise are identified below.



Celtic Sea East Broad Area – Floating Wind

Mid-West Broad Area – Floating Wind

Nort-West Broad Area – Floating Wind

Figure 6 – Potential broad areas of interest based on proposed criteria identified in the OREDP II.

Portugal

Currently, Portugal has an installed capacity of 25 MW. This capacity relates to the Windfloat Atlantic Project consisting of 3 wind turbines (8.4 MW each), supported by 3 semi-submersible floating structures located off the coast of Viana do Castelo. The project was commissioned in 2020.

A first version of the Portuguese NECP revision was disclosed last June, where the objective of installing up to 2 GW of new capacity in an oceanic location by 2030 was defined. For this, capacity allocation models for the injection capacity in the electricity grid are being studied, with a first auction foreseen to the end of 2023 to allocate 10 GW.

An inter-ministerial working group for offshore wind was created by the Portuguese government as part of the process and a report was issued, presenting several areas in the maritime space that could accommodate 10 GW of offshore wind capacity. That report was submitted to a public consultation. In July 2023, the **Final Report** on offshore wind areas was published, and Figure 8 shows the results of this assessment.

Figure 7 – Windfloat Atlantic Project location (Source: 4C Offshore).

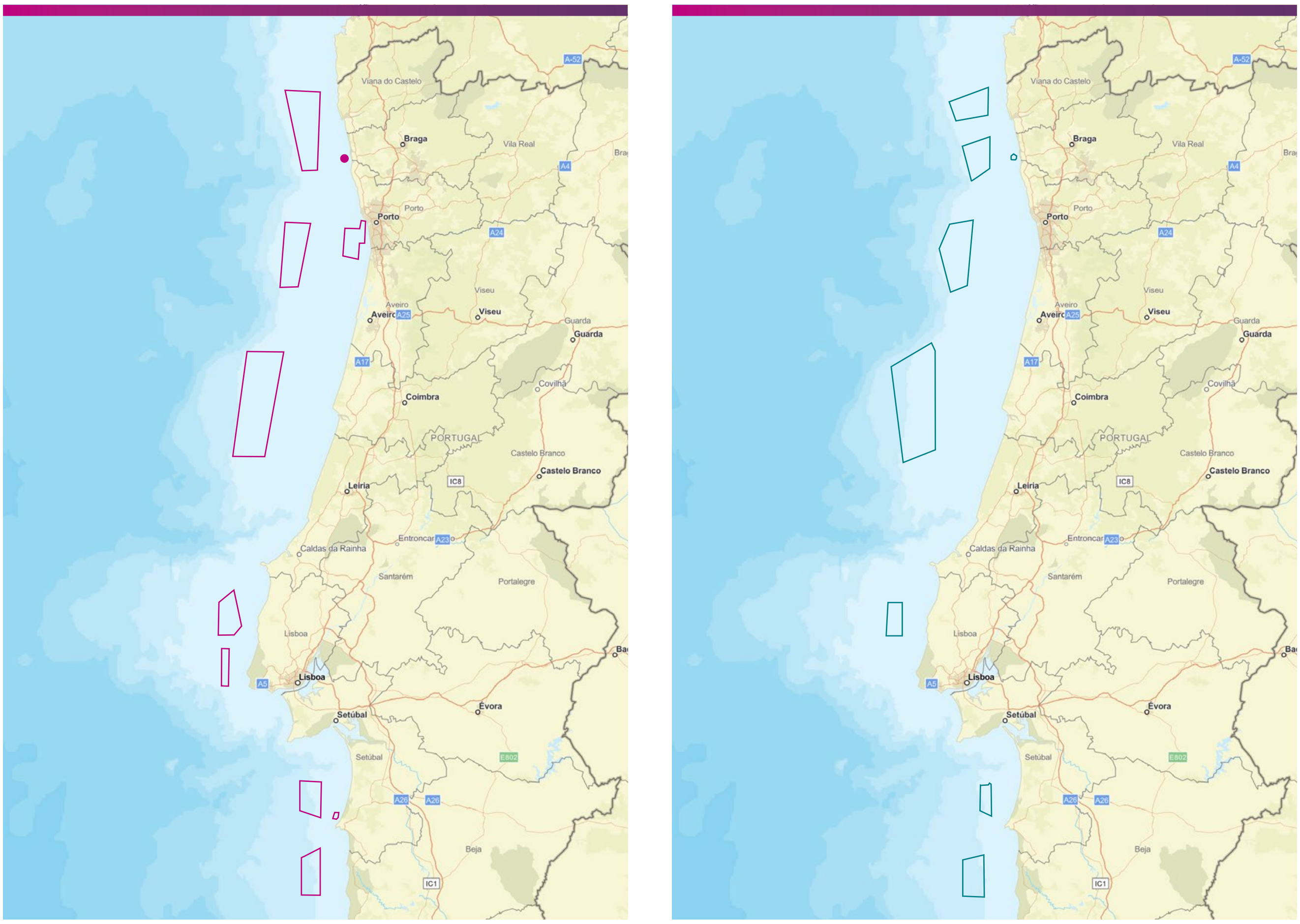


Figure 8 – Map with the areas submitted to public consultation (left) map with the new areas proposed by the working group (right).

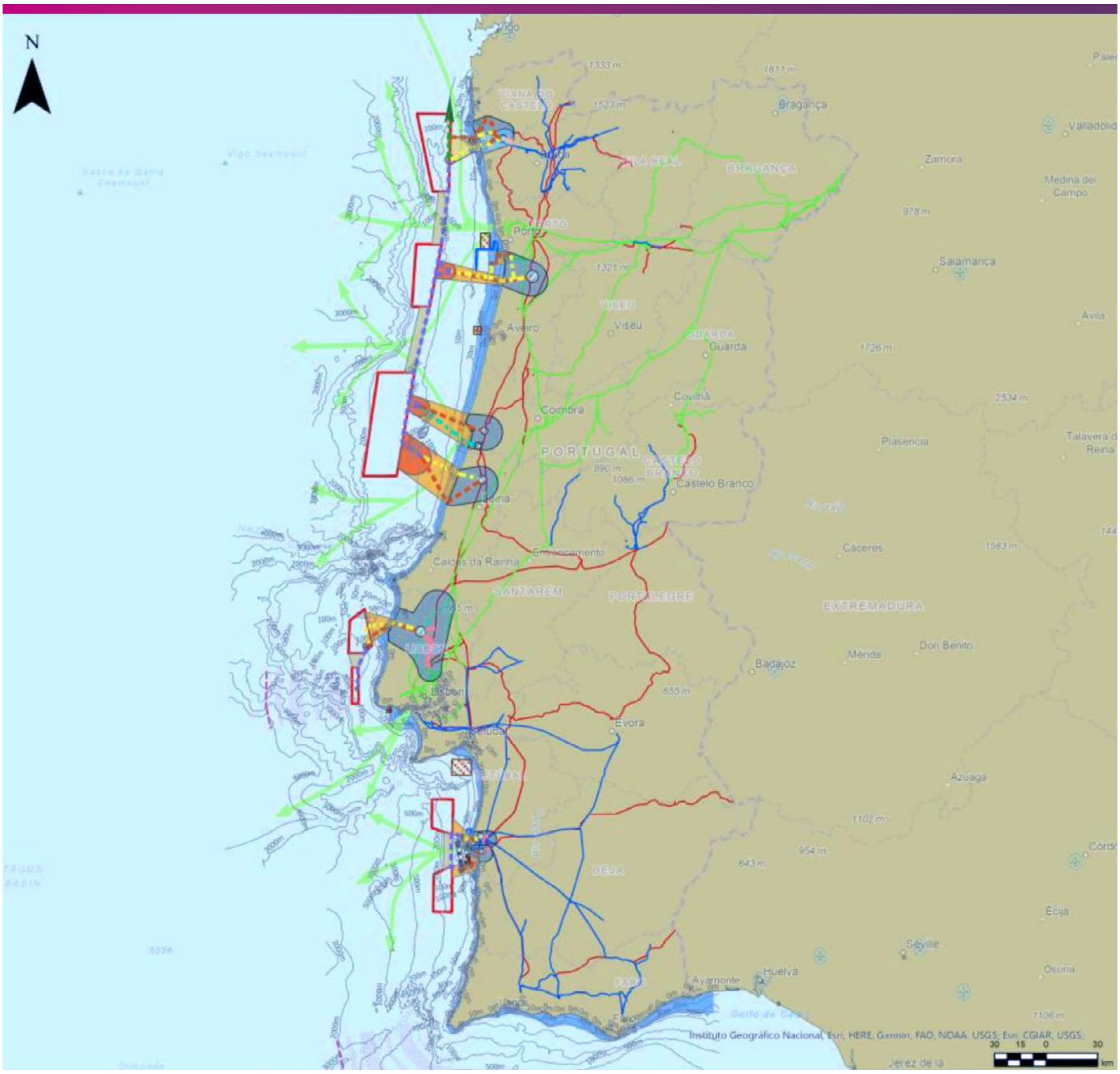


Figure 9 – Map with the proposed offshore network and connection to the onshore network.

The working group developed some preliminary studies, identifying best locations for OWFs and resource potentials, considering the limitations due to maritime activities and environmental impacts.

A preliminary study to evaluate possible solutions to connect the offshore areas to the onshore grid was also performed. Among other topics, this preliminary study looked for establishment costs, operation costs, transmission energy losses and needs relating with decommissioning of offshore wind farms and the related infrastructure, in addition tot he reliability aspects of the expected performance of the network.

The working group will continue the technical work to further refine the areas selected for the production of offshore wind energy, in addition to the auction models to be adopted and the development needs of the electrical grid and seaport infrastructures.

Spain

In Spain, the first floating offshore wind turbine has recently connected to the grid (August 2023) and generating power. It is a pilot programme called DemoSATH, a floating offshore wind project of 2 MW. The offshore wind turbine is located two miles off the Basque coast and its annual production is equivalent to the annual electricity consumption of approximately 2,000 Spanish households.

The Spanish MS objectives provided aim to have 1,400 MW of wind farms by 2030 in the Atlantic Offshore Grid corridor and maintain that value stable from 2030 to 2050. In the following Figure 11, the distribution of the Spanish OWFs in the Atlantic Offshore Grid corridor is shown according to the polygons identified in the Marine Spatial Planning for offshore development.

The location proposal is based on the offshore target figure established in the offshore generation roadmap, as well as in the areas of high potential for the development of offshore wind energy established in the Spanish maritime spatial plan (MSP) approved (POEM) in 2023.

These projects will connect radially to the onshore transmission system. The current National Development Plan plans the extension of the substations where these offshore wind farm could be connected. Further investigations regarding technology to be used (AC, DC, voltage, etc.), and potential internal reinforcements will be defined in the coming future.

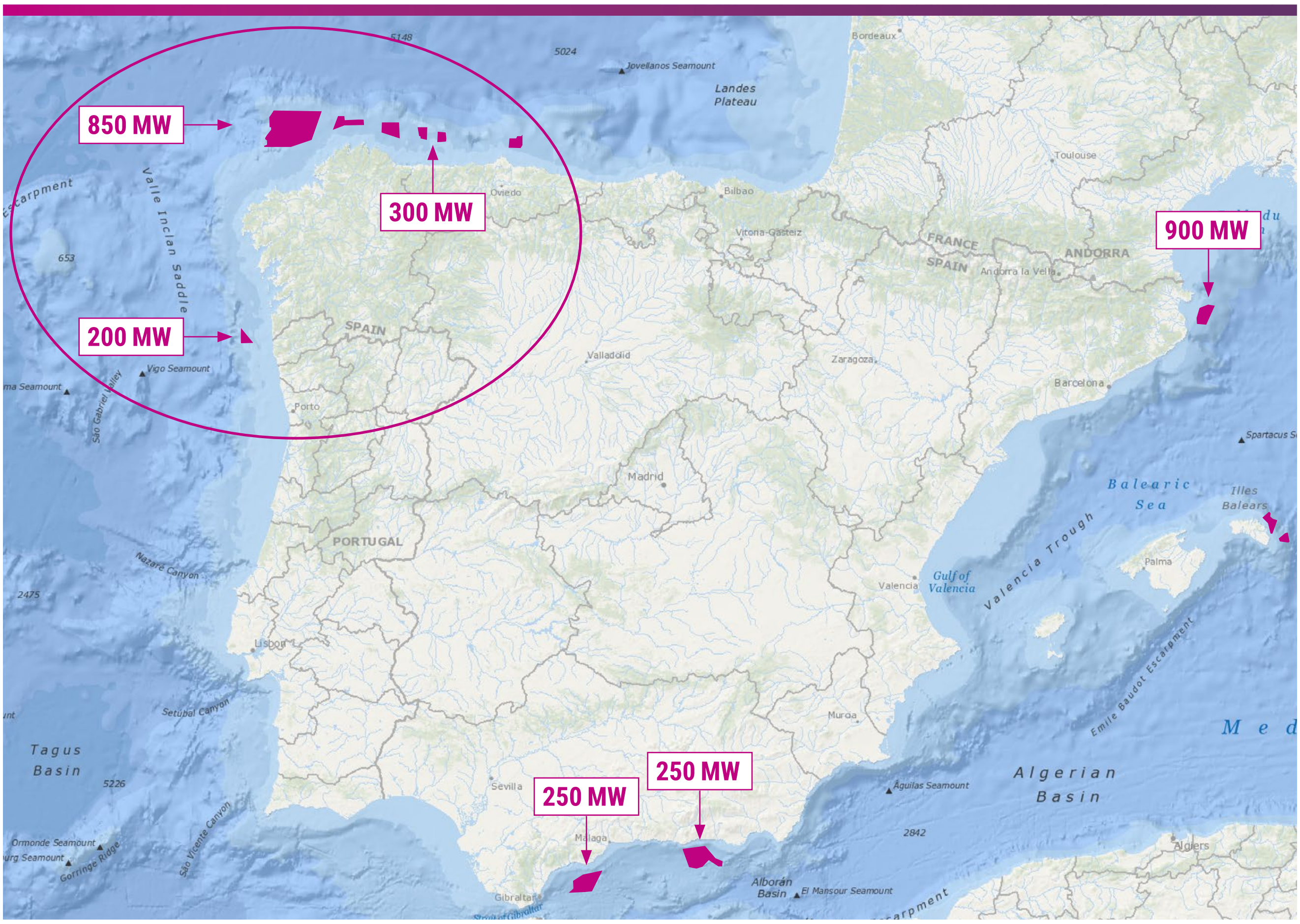


Figure 10 – Map with the areas identified for offshore generation in the Spanish maritime spatial plan.

4 Potential Environmental Impacts – specific to Sea Basin Atlantic Offshore Grid corridor

The European Atlantic, which borders four MSs (France, Ireland, Portugal and Spain), is a vast and ecologically diverse region that plays a pivotal role in the geography, economy and culture of Europe. The European Atlantic Sea Basin is rich in marine biodiversity. It supports diverse ecosystems, including cold-water corals, kelp forests and an array of fish species. In terms of sea uses, fishing is a major sector within the Atlantic, whilst coastal tourism and shipping are of great importance to all Member States bordering this area.

France

In France, the Atlantic Ocean Sea Basin is divided into two parts: the South Atlantic and the North Atlantic West Channel. It has a coastline of 3,451 km, from the Norman–Breton Gulf to the Spanish border. The North coast is mainly rocky with numerous deep estuaries, islands, bays and capes. Unlike the south coast, which is much more linear and sandy. The continental shelf is 150 – 300 km wide and has a gentle slope. The seabed is between 0 and 200 meters deep. It is home to a number of geomorphological features, such as rocky plateaus and canyons. Thirty-eight percent of the Atlantic French Sea waters are environmentally protected areas, including the first French Marine Natural Park (Parc naturel marin d'Iroise) and several Natura 2000 and RAMSAR areas. The coastline plays a key role in maintaining populations of marine mammals and birds, with wintering sites, colonies of nesting birds and the presence of remarkable species.

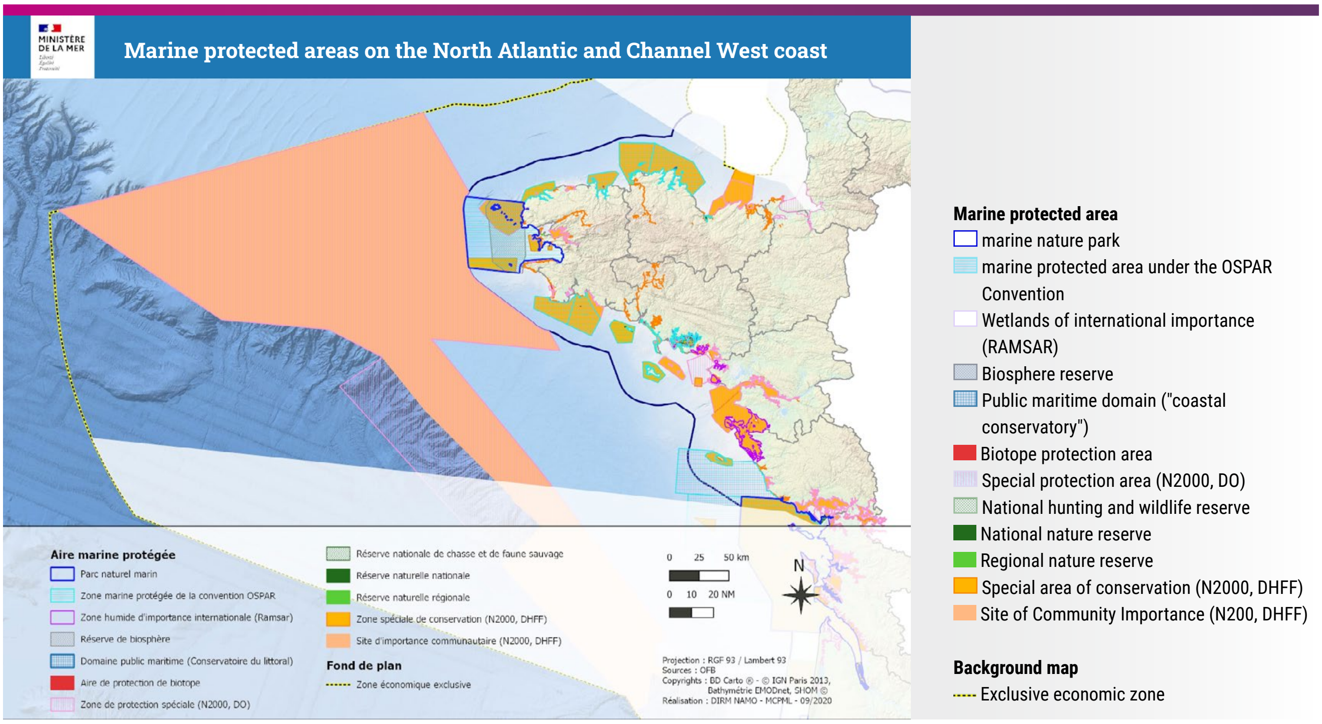


Figure 11 – Marine protected area in the North Atlantic West Channel area.

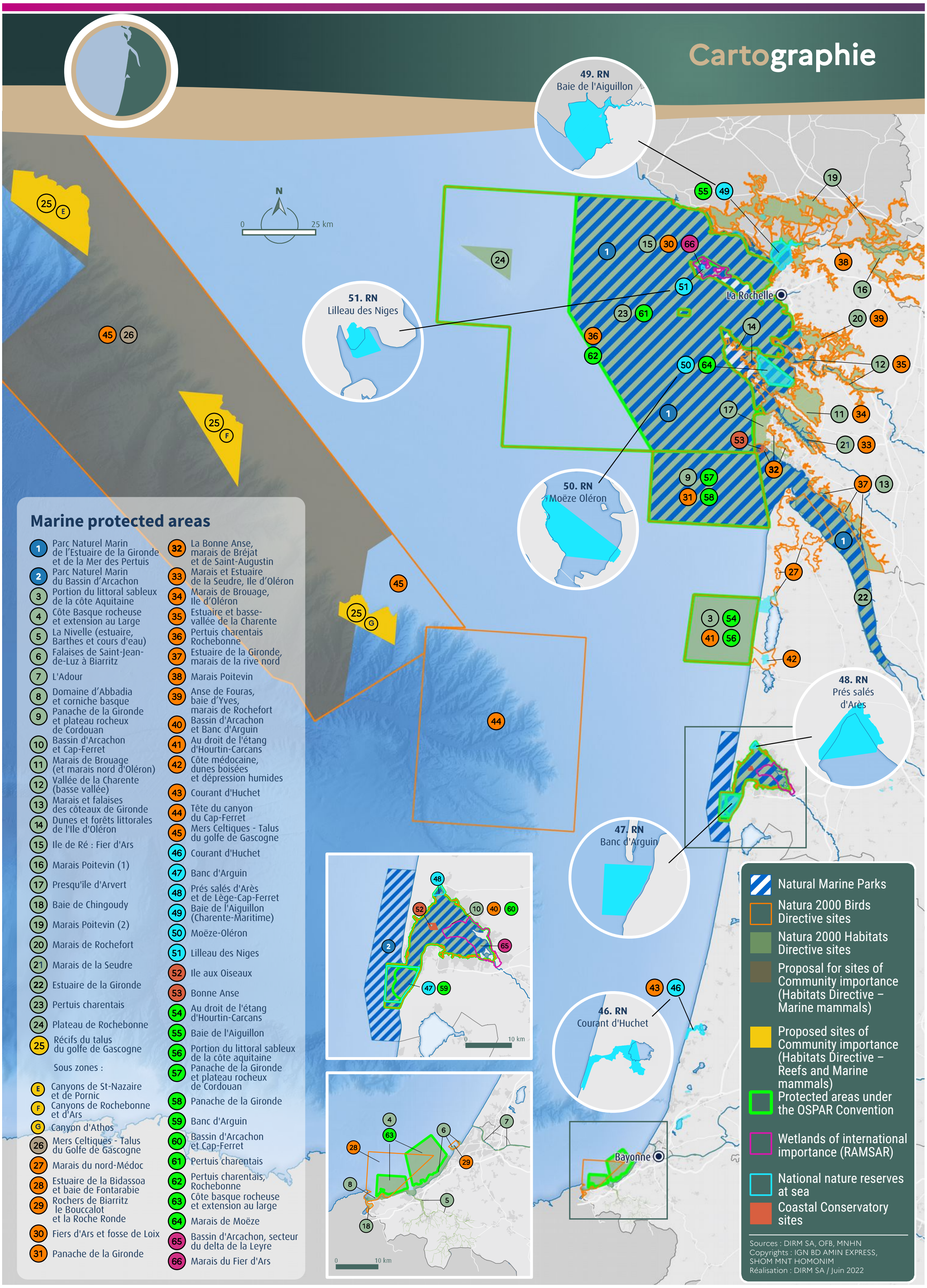


Figure 12 – Marine protected area in the North Atlantic West Channel area.

Ireland

The planned deployment of OWFs and the supporting offshore energy infrastructure will have an impact on the marine ecology and other marine based economies such as shipping and fishing, the operation of which can be highly localised (with more detail provided in Chapter 6). The environmental factors for specific consideration when planning ORE generation show a greater concentration along the West, Southwest and East coasts of Ireland, as per Figure 14. In accordance with the EU Habitats Directive, projects with a potential impact on the integrity of a Natura 2000 site require an Appropriate Assessment. It is important to note that these sites do not expressly preclude renewable generation, but development will be subject to additional considerations and monitoring, which may diminish ambition in the areas.

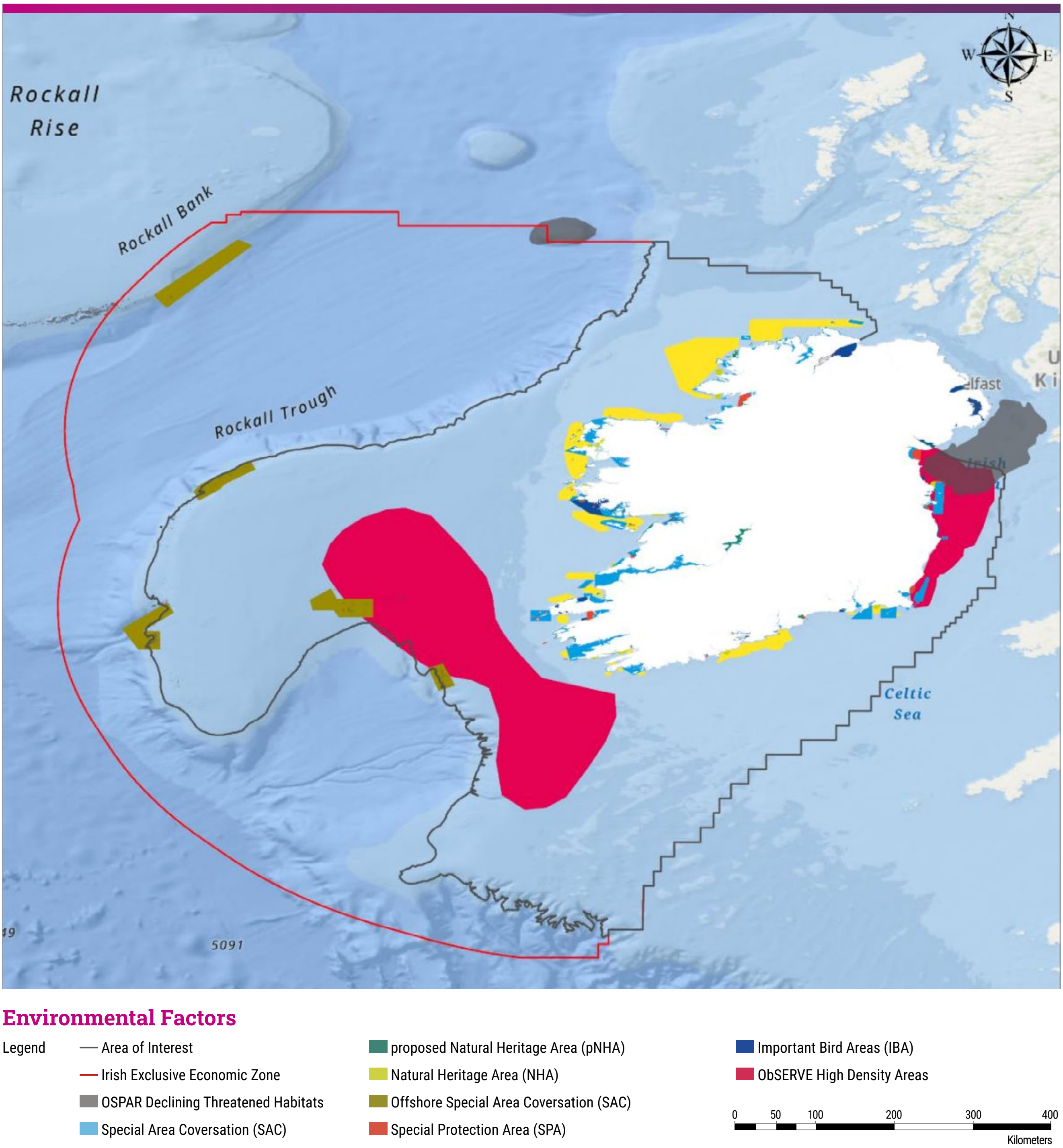


Figure 14 – Environmental factors for consideration when planning ORE generation in Irish waters.

Broadly, the potential impacts upon fauna in the offshore ecosystem need to be assessed across a range of concerns:

1. Spatial design of both OWF and associated grid infrastructure resulting in barrier formation for migrating birds and marine mammals;
2. Stratification, large-scale development can influence the stratification of the water column, thus upsetting the balance of the ecosystem;
3. Sedimentation, development of both OWF and associated grid can influence sediment deposition, thus upsetting the balance of the ecosystem; and
4. Spatial design of both OWF and associated grid infrastructure compromising key wildlife breeding sites or feeding grounds.

Portugal

The deployment of OWFs and the supporting offshore electrical infrastructure (offshore substations, cables) will have an impact on the marine ecology and marine based economies such as fishing. The need to define spaces for OWFs and the electrical infrastructure requires an effort to make activities compatible and, in some cases, there may even be synergies between uses of maritime space. Compatibility of uses involves continuous monitoring of the effects of activities located in the same maritime space, particularly on biodiversity and water quality descriptors.

One of the biggest challenges for making uses compatible with OWFs is related to commercial fishing. The compatibility of fishing activities must be duly taken care of when designing each of the wind farms and the electrical infrastructure, and it is absolutely critical to define safety protocols for access to possible fishing areas. The installation of offshore fixed-bottom\floating platforms for wind energy should provide synergies between the renewable energy sector and the aquaculture sector.

Regarding the marine ecology, the most relevant impacts are habitat disturbances, mainly during the construction phase, production of underwater noise and vibration, collision of wildlife with infrastructure and vessels. Electrical infrastructure on the seabed can also induce electromagnetic field (EMF) and heat emissions, affecting marine life. Those impacts should be minimised during the project design (routing/sitting process) by identifying sensible ecosystems and environmental constrains or by applying mitigation measures, particularly to the construction phase, such as choosing the right timing and cable laying techniques.

The installation of wind farms and the supporting offshore electrical infrastructure could result in Cultural Heritage impacts, and to avoid that effect, archaeological campaigns should be undertaken in the project design phase and further monitoring should occur during the construction activities. The places identified during this process should become places of visitation in a structured or free manner, such as the practice of scientific and recreational diving. Safety conditions for practice must be guaranteed, requiring coordination with the competent captaincies. It should also be noted that these places usually promote the biological productivity of the oceans.

Figure 15 – Spanish coastline of the North Atlantic subdivision.

Spain

The Spanish Atlantic Offshore Grid corridor covers one of the five subdivisions in which is divided the Spanish maritime space: the North Atlantic subdivision.

The North Atlantic subdivision covers the coastline of the autonomous communities of Galicia, Asturias, Cantabria and Basque Country, with 2,429 km of coast between the border with Portugal and the border with France. It also comes into cross-border contact with Portuguese and France waters. The area covered by this subdivision is about 315,000 km². The seabed of the North Atlantic subdivision is characterised by the presence of seamounts and sea banks, in addition to deep submarine canyons.

The development of the wind energy sector in the marine area with structures founded or fixed on the seabed faces a physical limitation in the Spanish Atlantic Offshore Grid corridor given that the continental shelf descends very quickly with depths soon exceeding technical limits. The use of floating solutions, thanks to the development of floating foundations that allow the implementation of wind farms in areas of great depth (exceeding 60 meters) seems to be the solution in the Atlantic Offshore Grid corridor. Floating technology multiplies the wind energy potential several times, due to a better use of the energy resource and higher capacity factors. The extra cost associated with floating offshore wind with respect to other technologies is expected to be progressively reduced, and it is expected that in a few years it will become a very competitive alternative.

5 Spatial Planning Needs – specific to Sea Basin Atlantic Offshore Grid corridor

Maritime Spatial Planning is understood as the process by which competent authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives.

Maritime Spatial Planning is therefore configured as a cross-cutting strategic instrument that allows public authorities and stakeholders to apply a coordinated, integrated and cross-border approach, allowing for a more optimal use of maritime space and reducing conflicts, in addition to enhancing coexistence and synergies. Maritime Spatial Planning is also a very useful tool to ensure the protection of sensitive and vulnerable ecosystems, habitats and species, including those protected by regional, national or supranational regulations.

Among the main elements of the European strategy is the fostering of regional cooperation mechanisms, including the improvement of maritime spatial planning for the large-scale deployment of offshore renewable energy and for the sustainable use of Europe’s marine space and resources. Furthermore, the strategy envisages and encourage MSs to integrate objectives of offshore renewable energy development in their national MSPs.

In the following paragraphs, the status and details of the MSPs of each country are described:

France

Within the Atlantic Offshore Grid corridor, a large number of jobs are linked to the maritime economy, which has a strong influence on the identity of this coastline. They are mainly linked to fishing and shellfish farming in addition to shipbuilding and ship repair (ships and pleasure boats). The maritime transport of goods and passengers is relatively underdeveloped, compared with the Eastern Channel – North Sea and Mediterranean seaboards.

Both the South Atlantic and the North Atlantic Basin Strategy Document were approved in October 2019, following a large consultation process. They will be updated in 2024. The current documents address the requirements of two European framework directives (MSFD and MSPD) and include a “vocation map” of maritime areas.

It is worthwhile noting that the pooling of grid connections (establishing offshore hubs) was identified as one of the strategic socioeconomic goals of the North Atlantic Sea Basin.

Achieving offshore development targets means being able to accelerate the rate at which these wind farms are commissioned. This led the French State to issue two laws supporting this increased trend:

- 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; and
- 2023’s law for the acceleration of the production of renewable energies (APER) makes it possible to pool public debates regarding the 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.

Ireland

The NSEC study due to be published in Autumn 2023 assesses the potential spatial impact of offshore wind development towards 2030 on the regional sea scale of the North Seas. The offshore wind ambitions specific for the Atlantic Ocean, Continental South West region has the potential to conflict with other legitimate marine uses. Of particular concern, the operation of fisheries, shipping and tourism stand to be impacted the most through the development of offshore wind. The map illustrates the range of economic activities within the Irish exclusive economic zone (EEZ). These factors will not preclude ORE project delivery but may factor in the consideration of proposed projects within the areas identified.

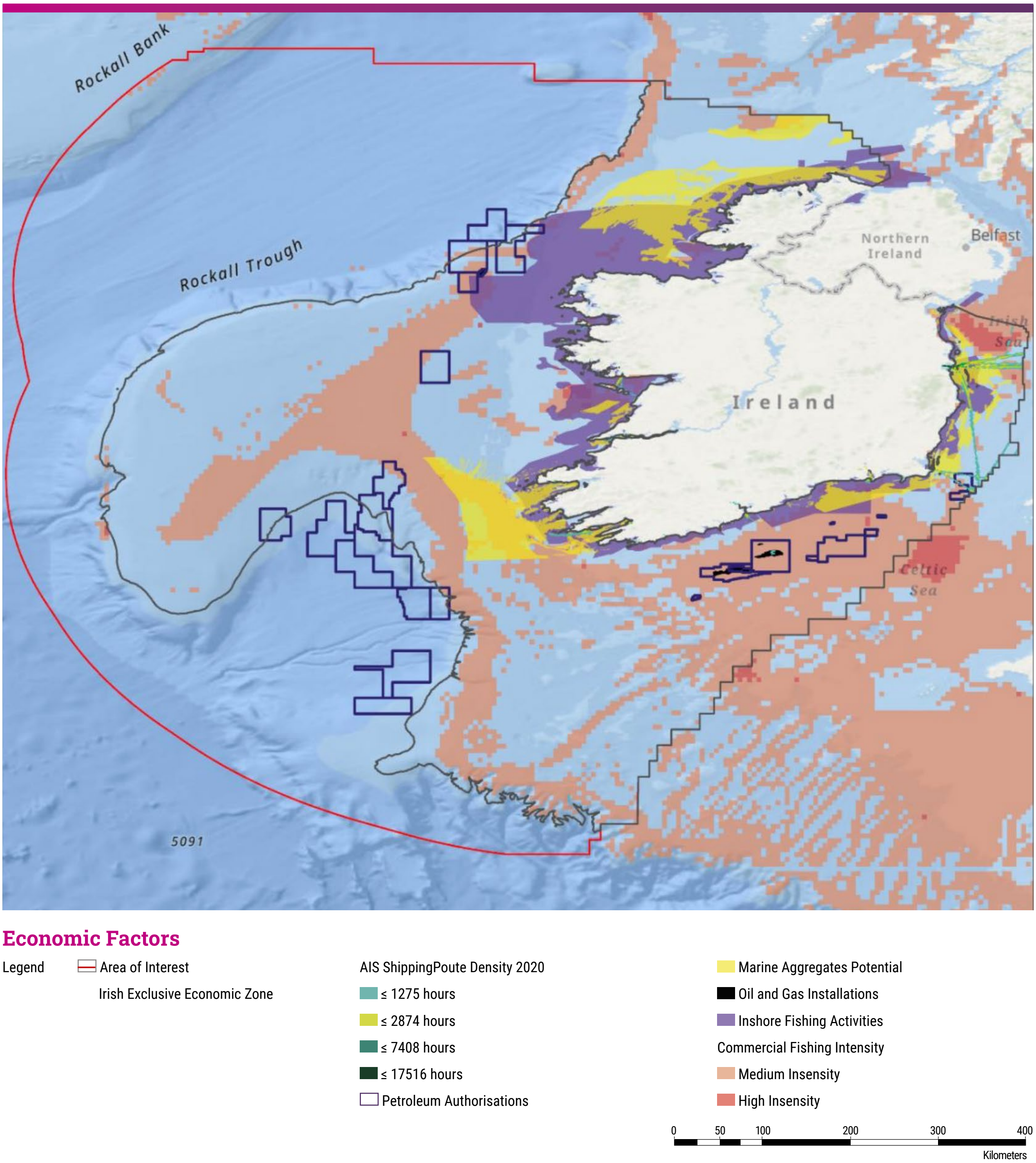


Figure 16 – Economic activities within the Irish exclusive economic zone.

In general, spatial conflicts between different sectors arise from direct competition over limited space, or when one sector negatively impacts another. It is understood that some of the pre-existing operational activities can be spatially very specific, for example fisheries in the pursuit of species linked to particular substrates. Detailing the spatial planning needs can help to resolve conflicting sector interests,

The specific considerations relevant to the industries of Shipping, Fishing and Tourism are detailed in the Spatial study North Seas 2030 report, Chapter 4. Due to the array of different sea area users, there are numerous potential conflicts in developing offshore wind and the associated infrastructures. The various interests and impacts on the sea areas need to be balanced by policy makers and new policies are likely to result as area studies are completed.

Ireland is in the process of finalising the *Offshore Renewable Energy Development Plan II*. This sectoral spatial plan for ORE is intended to guide strategy, aiding in the delivery of Ireland's climate ambitions. The National Marine Planning Framework (NMPF), was approved by the Government of Ireland in 2021 and sets out the overall decision-making framework, seeking to manage Ireland's maritime environment. The core principles of the NMPF are the protection of the marine environment and recognising the potential for co-existence with other maritime activities.

Ireland's legislative framework for MSP is summarised in the table below.

EU member state and Links to Policy	**Summary Approach to MSP**
Ireland **Link to NMPF** **Link to OREDP** **Link to I/C Policy Statement**	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) is to be issued shortly to facilitate the identification of areas most suited for the development of fixed wind, floating wind, wave and tidal resources. OREDP II will cover all of Ireland's EEZ. It will not specify areas for ORE development but will provide the means to identify potential areas and streamline exploratory works and data collection. After OREDP II, Designated Marine Area Maps (DMAPs) will be 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), MSP is being carried out ahead of designated areas being identified. These early wind parks 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, 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 and will publish a statement on hybrid arrangements imminently. 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.

Portugal

Portugal adopted its MSP, the "Plano de Situacão do Ordenamento do Espaço Maritimo Nacional (PSOEM)", corresponding to the subdivision of the mainland, the subdivision of Madeira and the subdivision of the Extended Continental Shelf in December 2019 by the Council of Ministers[4].

The MSP covers the entire national maritime space, from the baselines to the outer limit of the continental shelf, integrating inland maritime waters, the territorial sea, the EEZ and the continental shelf, including beyond 200 nautical miles.

The Portuguese MSP is an instrument for planning the national maritime space and constitutes an essential tool for the policy of the sea. The Plan identifies the spatial and temporal distribution of existing and potential uses and activities, also identifying areas relevant to nature conservation, biodiversity, underwater cultural heritage and the networks and structures essential to national defence, internal security and civil protection.

The Plan promotes compatibility between competing uses or activities, with a view to contributing to a better economic use of the marine environment and minimising the impact of human activities on the marine environment. This plan is also the instrument that allows the attribution of a Permit of Private Use of the National Maritime Space (TUPEM), which is the right to the private use that may take the form of a concession, license or authorisation.

A Geographic Information tool is available; it shows the updated distribution of the uses, activities and constraints in the national maritime space.

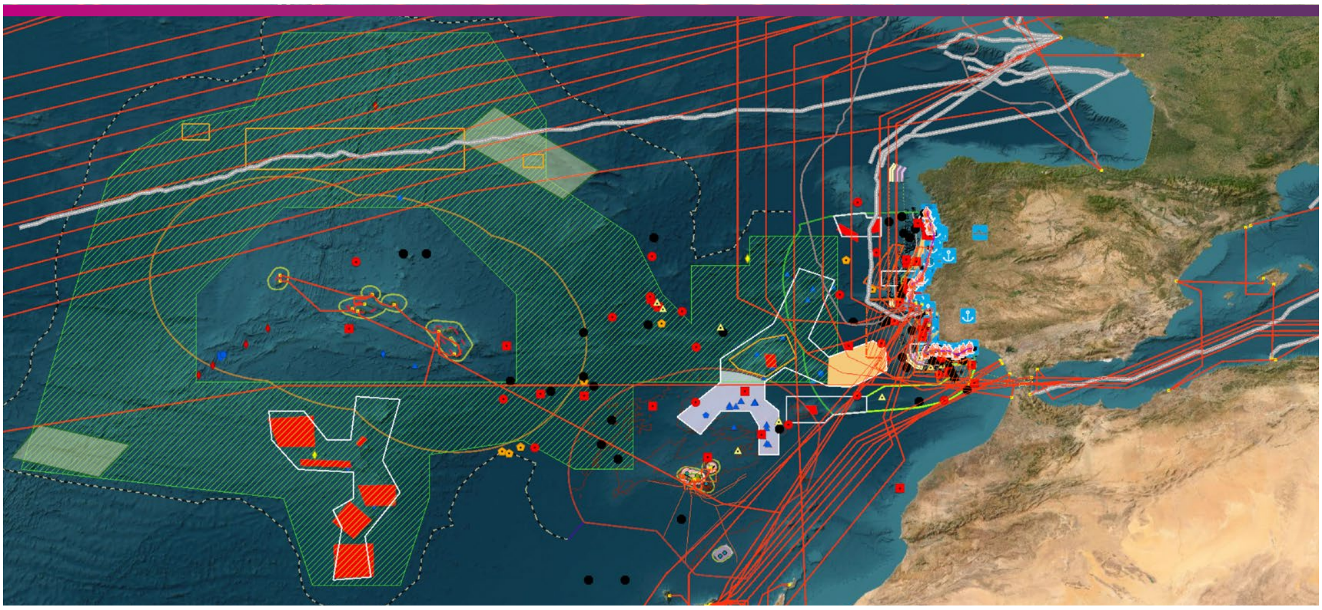


Figure 17 – **Geographical Information System (GIS)** for the Portuguese MSP.

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[4] **Resolution No. 203-A/2019**

Spain

Spain adopted its MSP, the **Planes de Ordenación del Espacio Marítimo (POEM)**, in **February 2023** by Royal Decree. They establish a plan for each of the five Spanish marine subdivisions:

- North Atlantic;
- South Atlantic;
- Estrecho and Alboran;
- Levantine-Balearic; and
- Canary Islands.

The POEM provides relevant information establishing high potential areas for offshore wind energy development. The delimitation of these zones for the development of offshore wind energy has been carried out after a detailed analysis in which multiple variables have been considered: availability of the wind resource, impact on marine biodiversity, safety in the navigation, air safety, and National Defense; and reduction of conflicts between other present and/or future uses and activities, such as aquaculture, tourism, or fishing.

The areas of high potential for offshore wind energy meet the following technical criteria:

- The wind resource is suitable for commercial exploitation as wind speeds exceeding 7.5 m/s are recorded at a height of 100 m for the four peninsular marine subdivisions, and a height of 140 m in the Canary Islands subdivision;
- The depth does not exceed 1,000 m;
- If possible, they are close to an onshore area with the adequate electrical infrastructures for the evacuation of the generated energy; and
- They have been delimited as such in these plans.

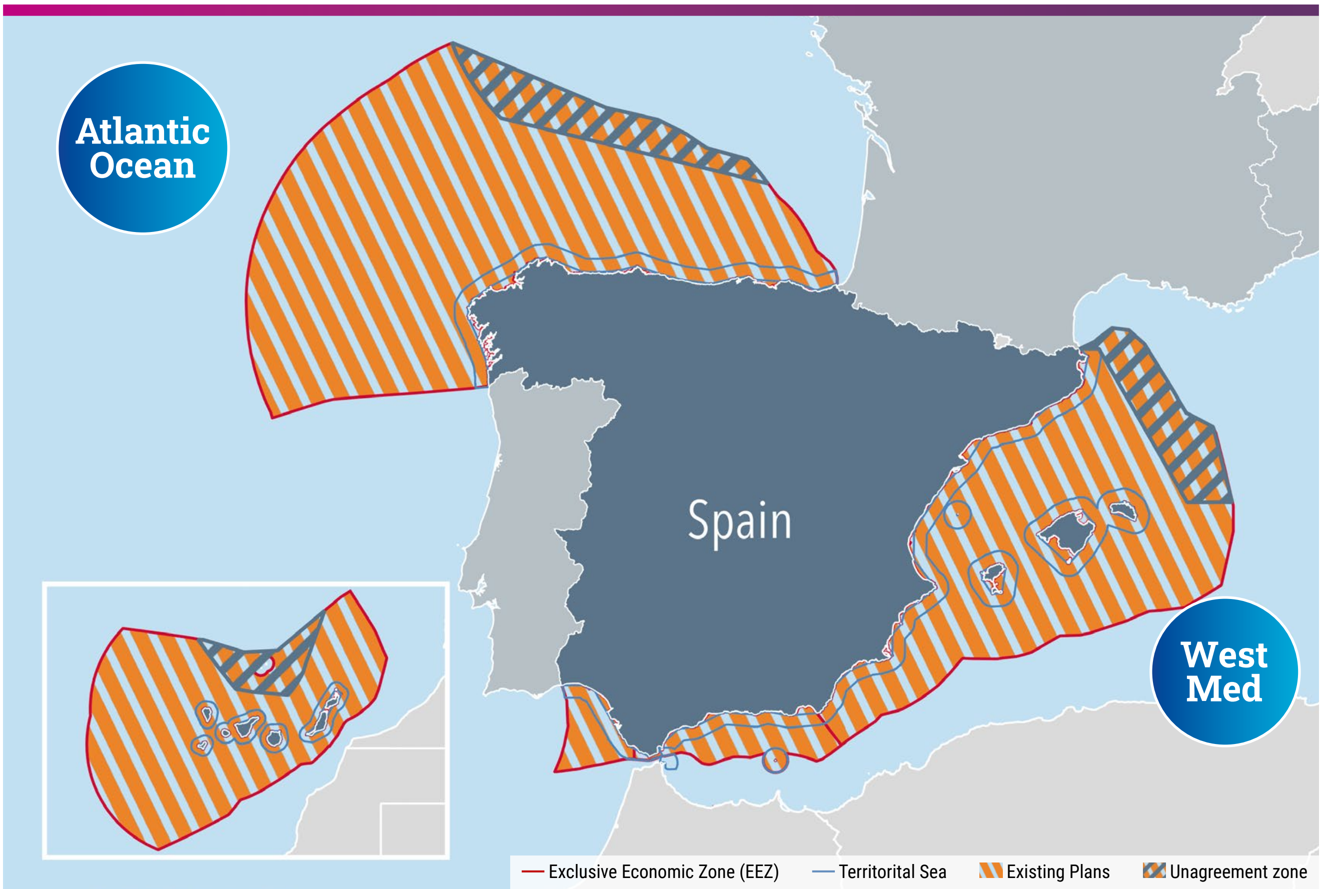
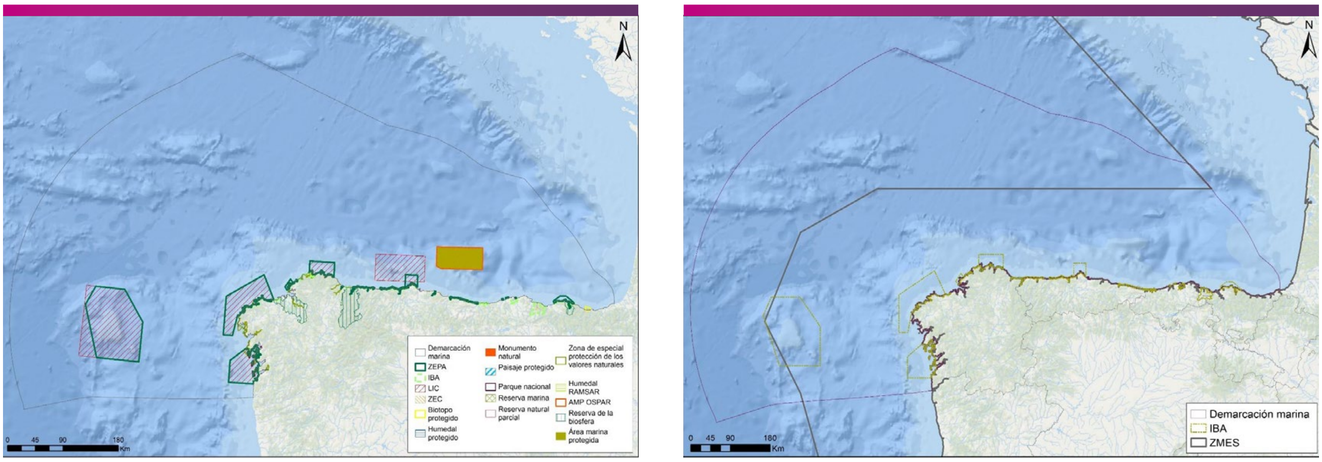


Figure 18 – Spanish maritime subdivisions.



☐ Maritime boundary
☐ SPA (special protection areas)
⬚ IBA (important bird area)
▨ SCI (site of community importance)
▨ SAC (special area of conservation)
☐ Protected biotope
▤ Protected wetland
🟧 Natural monument
▨ Protected landscape
☐ National park
☒ Marine reserve
☐ Partial nature reserve
☐ Areas with special protection of natural values
▤ RAMSAR site
☐ MPA OSPAR
◫ Biosphere reserve
■ Marine protected area

☐ SPA (special protection areas)
⬚ IBA (important bird area)
☐ PSSA (particularly sensitive sea area)

Figure 19 – Maritime-terrestrial protected areas (left) and other areas of interest (right) in the Nort Atlantic subdivision of Spain.

In addition, with the sole purpose of facilitating the development of offshore wind energy for commercial exploitation, while guaranteeing its coexistence with other marine uses and activities, the following criteria have been established:

- Commercial OWFs will occupy as little marine space as possible;
- Projects will progress where prospective analysis verifies the impacts on communities of seabirds within designated areas are minimised. Acoustic studies will also be performed to characterise the average levels of background noise;
- Offshore wind projects must take into account for the proper evaluation of its environmental impact a set of environmental aspects such us: birdlife and wildlife studies, characterisation of the marine habitats affected by the project, analysis of the cumulative effects of other nearby offshore wind projects, acoustic study before installation, during installation and during the operation of the OWF, impact study and landscape integration and an analysis of the fishing activity in the area;
- In cases where an area of high potential for offshore wind energy overlap with protected marine areas, the projects must carry out a detailed analysis of the alternatives that are technically and environmentally viable;
- Efforts will be made to identify, whenever possible, those fishing gears that could coexist with the commercial wind farm or with other renewables to be implemented. Such coexistence should be facilitated by the promoter;
- In areas where a relevant interaction with fishing grounds is confirmed, options will be proposed in order to minimise the impact;
- Efforts will be made to identify, whenever possible, those modalities of aquaculture that could coexist with the commercial wind farm or with other renewable energies that are implanted. Such coexistence should be facilitated by the promoter;
- Efforts will be made to identify the types of vessels that could navigate within the space occupied by the wind farm and, in those cases, facilitate their operation;
- The routes to land for generation will be designed to minimise the marine space occupied, using whenever possible existing wiring traces or other pre-existing infrastructures on the seabed, avoiding affecting habitats of community interest and respecting the environmental and terrestrial plans; and
- In addition, criteria established in the strategic environmental assessment of the Spanish National Energy and Climate Plan must also be considered.

6 High-Level Results on Offshore Network Infrastructure Needs

Under the revised TEN-E regulation (Regulation (EU) 2022/869), ENTSO-E is tasked with developing ONDPs which are essential for ensuring the efficient integration of offshore RES into the European electricity grid. This first ONDP for the Atlantic Offshore Grid corridor is focused in the expansion and enhancement of the offshore grid infrastructure, enabling the efficient transmission of electricity from offshore generation sites to onshore areas and across borders. The related necessary onshore infrastructure needs will be investigated under the framework of the TYNDP 2024 in the IoSN.

The 2024 ONDPs were built on the following set of data:

The 2040 and 2050 time horizons, based on the TYNDP2022 edition of the DE2040 and DE2050 simulation models and scenario results. In this sense, cross-border capacities considered among different borders within the Atlantic Offshore Grid corridor are shown below:

Spain-France	11,000 MW
Spain-Portugal	4,700 MW
France – Ireland	700 MW
Ireland – United Kingdom	1,754 MW
Ireland – United Kingdom northern Ireland	1,250 MW

The **offshore RES capacities** data gathered by the TSOs in line with non-binding agreements signed by the respective MSs and the national strategies.

The **offshore transmission infrastructure**, existing and planned, based on input from TSOs in the 2030, 2040 and 2050 time horizons. This infrastructure was then expanded via centrally executed simulations, the results of which were post-processed by ENTSO-E Regional Groups, for the 2040 and 2050 time horizons.

The expansion of the transmission infrastructure considers investment options to neighbouring nodes that could be available for expansion from radial to hybrid configuration, in compliance with the location and specification of the offshore generation nodes.

The grid model is expanded through a linear optimisation, meaning that the size of the candidates is not defined beforehand, but individuated by applying the standard costs of the infrastructure to the distances of each candidate, with the objective of minimising the target function. The linear expansion algorithm assesses, for each technical configuration and costs set, the amount of additional transmission infrastructure to decrease the system costs (CAPEX+OPEX), assessing also the increase in the energy dispatched and the reduction in CO_2 emissions.

The additional transmission capacity connects the offshore nodes to neighbouring market zones, allowing the increase in the dispatched energy and decreasing in overall system emission due to thermal generation powered by fossil fuels.

The linear results are the basis for the definition of the transmission corridors. However, as they come in form of continuous values of transmission capacity, these results need to be assessed to find the reasonable discrete technical sizes which allow the evaluation of the potential infrastructural needs.

For additional information regarding the methodology, consult the “Offshore Network Development Plans 2024 – Methodology” report.

6.1 2030 Offshore Network Infrastructure Needs

In the Atlantic Offshore Grid corridor, a total of 5.66 GW offshore wind capacity is expected to be installed in 2030, of which 1.76 GW are expected in France, 0.5 GW in Ireland, 1.4 GW in Spain and 2 GW in Portugal, as shown in Chapter 3. Comparing these 2030 ambitions to today's installations of 0.51 GW, this implies, for the next seven years, an 11-fold increase of what is in operation today. An annual installation of 0.74 GW is required to reach 2030 targets.

According to the methodology of the ONDP expansion assessment, it should be noted that no expansion loop has been performed for the 2030 horizon, as 2030 is a year so close that no additional projects not already launched would arrive on time.

Acceleration is not only needed for offshore RES installations but for the related infrastructure as well. Connecting the additional 5.16 GW offshore RES radially to the Atlantic Offshore Grid corridor countries means an estimation of 1,100 km cable would be needed.

Figure 20 provides an overview of the current RES ambition of the Atlantic Offshore Grid corridor by 2030 horizon. The bubbles provided for each country inform the manner in which these objectives are to be integrated: the bubbles indicated in yellow are 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. Bubble size corresponds to generation capacity.

As can be seen, the offshore RES capacity to be installed by 2030 in the Atlantic Offshore Grid corridor is currently foreseen to be all radially connected.

The infrastructure costs are very dependent on different factors such as technology development, regulatory and political environment, etc. Nevertheless, an estimation of the cost of the offshore infrastructure by 2030 is expected to be around 9 bn€ .

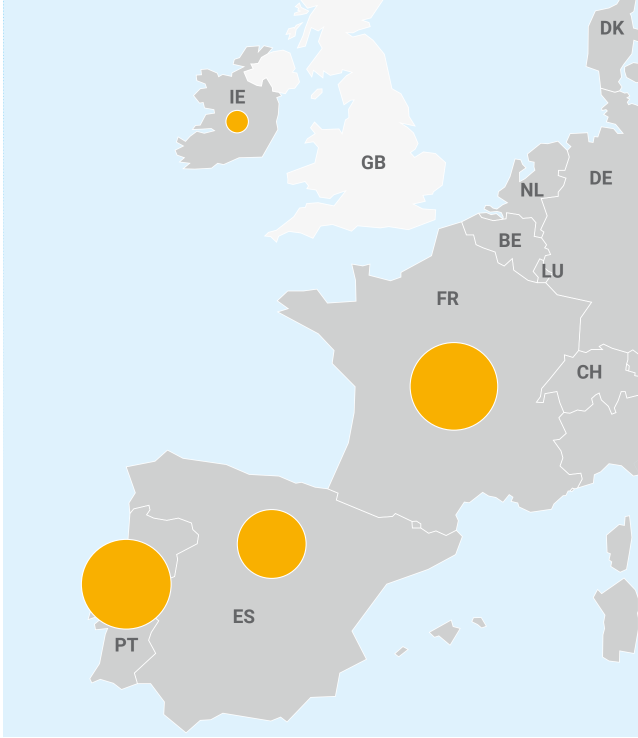


Figure 20 – Generation capacity per country and connection type in the Atlantic Ocean Sea Basin by 2030.

6.2 2040 Offshore Network Infrastructure Needs

A total of 26.26 GW of offshored wind capacity is expected to be installed by 2040 in the Atlantic Offshore Grid corridor, of which 7.86 GW are expected in France, 7 GW in Ireland, 1.4 GW in Spain and 10 GW in Portugal. These 2040 targets mean around a 5-fold increase of the 2030 offshore wind expected capacity. Annual installations of 2.1 GW, between 2030 and 2040, are needed to reach the 2040 offshore wind objectives. To install the additional 20.64 GW by 2040, an estimation between 1,000 and 1,500 km cable would be needed.

Figure 21 provides an overview of the current RES targets of the Atlantic Offshore Grid corridor by 2040 horizon. The bubbles indicate in yellow the current share of offshore RES radially connected without any possibility of further expansions, 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. Bubble size corresponds to generation capacity.

For the 2040 horizon, an expansion loop has been performed on top of the starting grid considered in the optimisation. The starting grid of the 2040 expansion loop accommodates the integration of 26.26 GW of offshore wind capacity, as previously noted. The starting grid is divided into 17.5 GW radial connections and 8.8 GW of potential hybrid connections (radially connected but with a possibility of further expansion). There are two transmission candidates considered in the expansion:

- One hybrid project between Ireland and France, connecting wind farms on both sides. The length of the project would be approximately 500 km. Connection point in France would be located in north Britany and connection point in Ireland in the Celtic Sea; and
- One between Spain and Portugal, which consists in connecting a 250 MW offshore Spanish wind farm west of Galicia to Portugal.As stated in Figure 22, the model only identifies radial connections for Portugal and Spain (in the case of Spain there is no evolution of RES capacity from 2030 so the grid also remains the same. In fact, among the various potential connections considered in the analysis to link countries and OWFs within the Atlantic Offshore Grid corridor, the model supporting ONDP (expansion loop) highlighted the following for the 2040 horizon:

Between Ireland and France, a hybrid interconnection project linking a French farm in the North Atlantic zone to the east coast of Ireland appeared to be of interest with the so-called "DC grid' (namely, anticipating the availability of DC circuit-brakers or accepting the loss of the link) configuration only. This project would cover a distance of approximately 500 km and would allow a power transfer of the order of 700 MW. This project does not seem interesting if the hybrid link installation costs are high, which is the case in particular of the "DC link' (namely, requiring a DC converter station on each extremity of each expansion) configuration.

By 2040, the additional wind offshore infrastructure is expected to be in a range of 10.6 – 11.5 bn€.

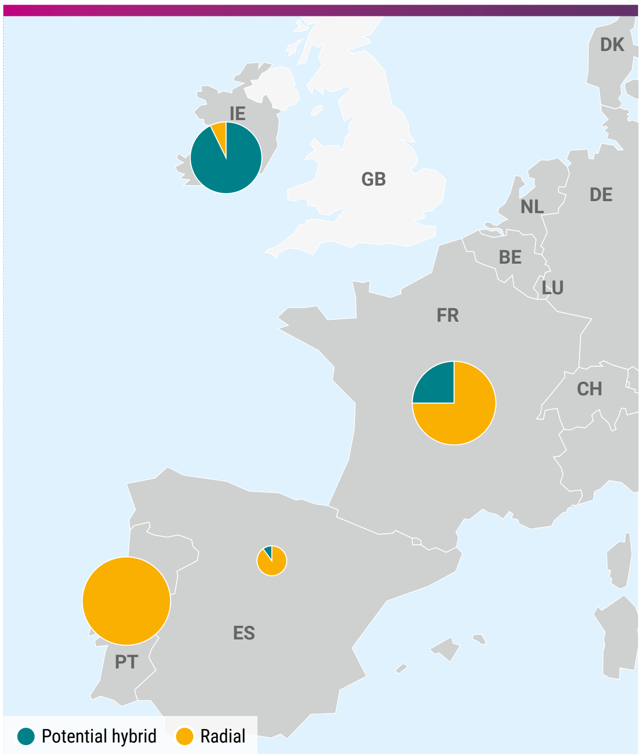


Figure 21 – Generation capacity per country and connection type in the Atlantic Offshore Grid corridor by 2040.

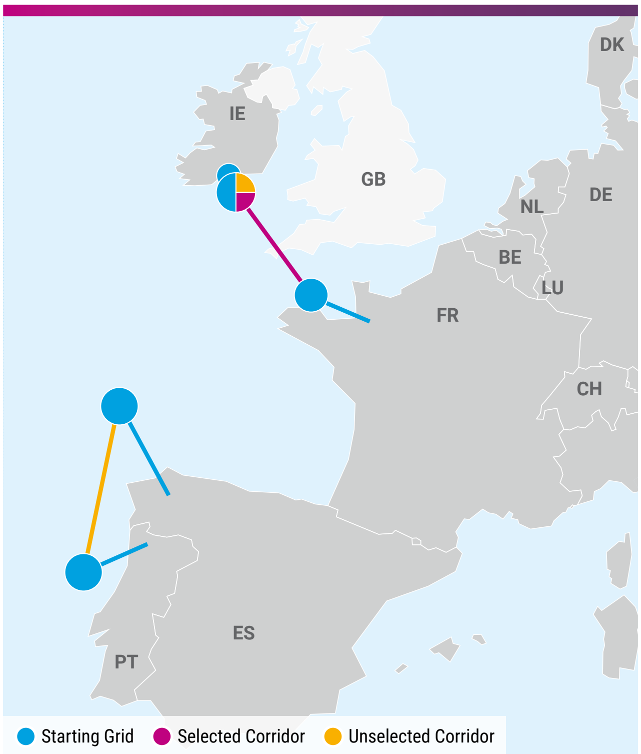


Figure 22 – Expansion results in 2040 time horizon in the Atlantic Ocean Sea Basin.

6.3 2050 Offshore Network Infrastructure Needs

By 2050, a total of 44.26 GW of offshored wind capacity is expected to be installed in the Atlantic Offshore Grid corridor, of which 17.86 GW are expected in France, 15.15 GW in Ireland, 1.4 GW in Spain and 10 GW in Portugal. These 2050 goals mean a less than 2-fold increase in the 2040 offshore wind capacity expected. Annual installations of 1.8 GW, between 2040 and 2050, are needed to reach 2050 offshore wind objectives. To install the additional 18 GW by 2050, around 600 km cable would be needed.

Figure 23 provides an overview of the current RES ambitions of the Atlantic Offshore Grid corridor by the 2050 horizon. The bubbles provided for each country indicate how targets are to integrated: yellow represents the share of offshore RES radially connected without any possibility of further expansions, blue gives the share of offshore RES connected to a hybrid system and in green the share of offshore RES is radially connected but with a possibility of further expansion.

Bubble size corresponds to generation capacity. In the Atlantic Offshore Grid, corridor projects are divided into 27.8 GW of radial connections and 16.5 GW of potential hybrid connections (radially connected but with a possibility of further expansion) by 2050.

Again for the 2050 horizon, an expansion loop was performed in addition to the starting grid which includes 44.26 GW of offshore wind capacity. Hybrid project candidates are the same as for the 2040 simulations:

- One hybrid project between Ireland and France, connecting wind farms on both sides. The length of the project would be approximately 500 km. The connection point in France would be located in north Britany and connection point in Ireland in the Celtic Sea.
- One between Spain and Portugal, which consists in connecting a 250 MW offshore Spanish wind farm west of Galicia to Portugal.

The 2050 analysis again shows that the previous hybrid interconnection project linking an offshore French transmission node in the North Atlantic to an offshore transmission node off the South of Ireland returned reasonable capacities for the so-called “DC grid’ configuration.

By 2050, the additional offshore wind infrastructure is expected to be in a range of 9.4 – 10.6 bn€.

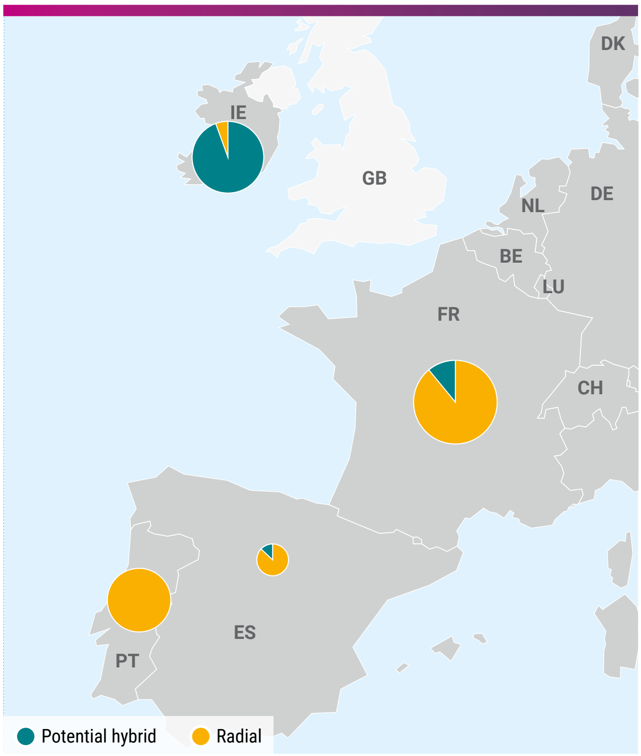


Figure 23 – Generation capacity per country and connection type in the Atlantic Offshore Grid corridor by 2050.

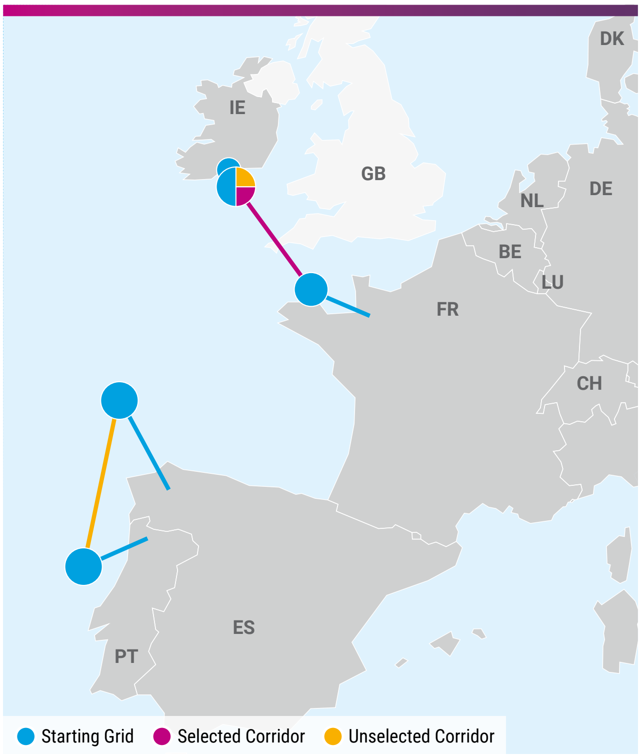


Figure 24 – Expansion results in 2050 time horizon in the Atlantic Offshore Grid corridor.

7 Reflections for the Region

The potential benefits of harnessing offshore wind energy in the Atlantic are substantial. It not only reduces greenhouse gas emissions and lessens the reliance on fossil fuels but also contributes to energy security. However, several challenges persist, necessitating further research and technological innovation to make them more economically competitive with other energy sources.

Environmental concerns also require attention. The impact of OWFs (and their connection to land) on marine ecosystems, navigation routes and local communities must be thoroughly studied. Mitigation strategies and responsible planning are crucial to ensure the long-term sustainability of these projects.

In addition, advancements in energy storage and transmission systems are needed to ensure a reliable and consistent energy supply from OWFs. The growth of offshore wind energy in the Atlantic Offshore Grid corridor is a significant step toward a cleaner and more sustainable future.

8 Conclusions

The purpose of this study is to identify the offshore network infrastructure needs in order to support the long-term MS goals for the deployment of offshore renewable energy through the years 2030, 2040 and 2050. To achieve the EU goal of climate neutrality by 2050, MSs will need to balance offshore development with other maritime uses to ensure coexistence can be successfully achieved.

The results of this study indicate an optimised offshore grid structure with additional offshore transmission capacity connecting France to Ireland. The study assumes for the latter case the availability of DC circuit-breakers, and these high level results will need to be confirmed at a later stage, in particular taking into account onshore grid reinforcements.

Integration of the offshore network infrastructure will ultimately require joint development with MSP activities to ensure the efficient use of maritime resources and thus minimise potential conflicts. The ONDP, as a biennial product, will iteratively present a high-level infrastructure that will evolve over time, as will the MSs' non-binding agreements.

Appendix

In the following tables, equipment needs in terms of route length and costs for the development of the offshore plan in the Atlantic Offshore Grid corridor are shown. Nevertheless, 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.

Equipment overview

Equipment Needs Route Length, Number	Radial (route length)			Expansion		Radial – considered in the expansion loop			Total			Total Sum [km] or nr.
DC Grid [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)	164	370	600	0	0	0	555	0	164	1,485	600	2,249
Offshore DC Cables (updated)				560	0							
Onshore AC Cables (updated)	959	77	0						959	77	0	1,036
Offshore AC Cables (updated)												
Offshore DC converters	3	3	5			0	3	0	3	6	5	14
Onshore DC converters	3	3	5	0	0	0	3	0	3	6	5	14
Offshore AC substation	12	1	0						12	1	0	13
Offshore node expansion (incl. DC breaker)				1	1				0	1	1	2
											Total Route Length	**3,285**

Equipment Needs Route Length, Number	Radial (route length)			Expansion		Radial – considered in the expansion loop			Total			Total Sum [km] or nr.
DC LINK [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)	164	370	600	0	0	0	555	0	164			1,689
Offshore DC Cables (updated)				0	0					925	600	
Onshore AC Cables (updated)	959	77	0						959	77	0	1,036
Offshore AC Cables (updated)												
Offshore DC converters	3	3	5			0	3	0	3	6	5	14
Onshore DC converters	3	3	5	0	0	0	3	0	3	6	5	14
Offshore AC substation	12	1	0	0	2				12	1	2	15
Offshore node expansion (with converter), E18	0	0	0	0	2				0	0	2	2
											Total Route Length	**2,725**

Investment cost overview

Costs	Radials			Expansion		Radial – considered in the expansion loop			Total			Total Sum [M€]
DC Grid [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)	550	746	1,855	0	0	–	–	–	550	3,269	2,513	
Offshore DC Cables (updated)				659	0	0	1,864	0				5,674
Onshore AC Cables (updated)	776	52	0						776	52	0	
Offshore AC Cables (updated)												828
Offshore DC converters	3,300	1,980	5,060			0	3,300	0	3,300	5,280	5,060	13,640
Onshore DC converters	1,500	900	2,300	0	0	0	1,500	0	1,500	2,400	2,300	6,200
Offshore node expansion (incl. DC Breaker) E20				231	231				0	231	231	462
Offshore AC substation	2,937	221	0						2,937	221	0	3,158
												29,961

Costs	Radials			Expansion		Radial – considered in the expansion loop			Total			Total Sum [M€]
DC LINK [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)	550	746	1,855	0	0	–	–	–	550			
Offshore DC Cables (updated)				0	0	0	1,864	0		2,610	2,513	5,015
Onshore AC Cables (updated)	776	52	0						776	52	0	
Offshore AC Cables (updated)												828
Offshore DC converters E18	3,300	1,980	5,060			0	3,300	0	3,300	5,280	5,060	13,640
Onshore DC converters	1,500	900	2,300	0	0	0	1,500	0	1,500	2,400	2,300	6,200
Offshore node expansion (with converter), E18	–	–	–	0	770				0	0	770	770
Offshore AC substation	2,937	221	0	0	617				2,937	221	617	3,775
												30,228

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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