A 2030 Vision for European Offshore Wind Ports

Trends and opportunities

WindEurope

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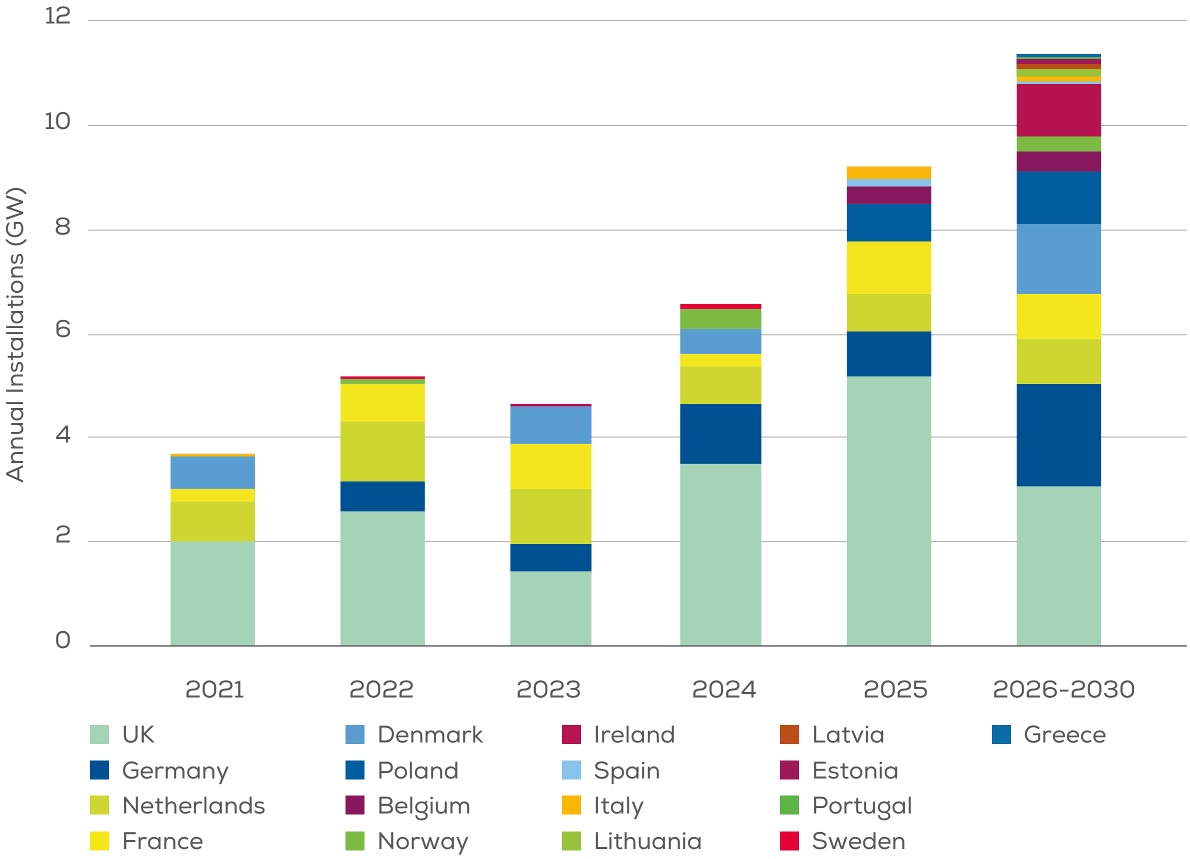
EXECUTIVE SUMMARY

The EU goal of climate neutrality by 2050 requires a 25 times increase in offshore wind. Already in the next 10 years the volume of offshore wind in Europe needs to rise from 25 GW to over 110 GW.

Ports are central to the development of offshore wind. They play a key role for the local supply chain, logistics and supporting infrastructure (e.g. storage of components). Ports are where operation and maintenance of offshore wind farms are run, where all offshore wind turbines and other equipment get transported, and where floating turbines are assembled. And they will have a prominent role in the production and distribution of renewable hydrogen.

European Offshore Wind Outlook to 2030: Annual installations (GW)



Source: WindEurope

Europe's ports today support the deployment of 3 GW of new offshore wind farms every year. By 2030 they need to be supporting the deployment of 11 GW of new offshore wind farms every year.

But ports can only deliver those services if they make significant investments to upgrade and expand their infrastructure. Crucially, ports need to expand their land, reinforce their quays, enhance their deep-sea berths and carry out other civil works. They need to do this to cater for operating and maintaining of a larger fleet (including training facilities), for upcoming decommissioning projects and to host new manufacturing centres for bottom-fixed and floating offshore wind. Ports also need to diversify their activities to support the decarbonisation of industries, transport and heating in coastal areas.

Europe's ports need to invest €6.5bn between now and 2030 to support the expansion of offshore wind. This investment could be paid back in just five years and would bring significant savings for electricity consumers and society as a whole.

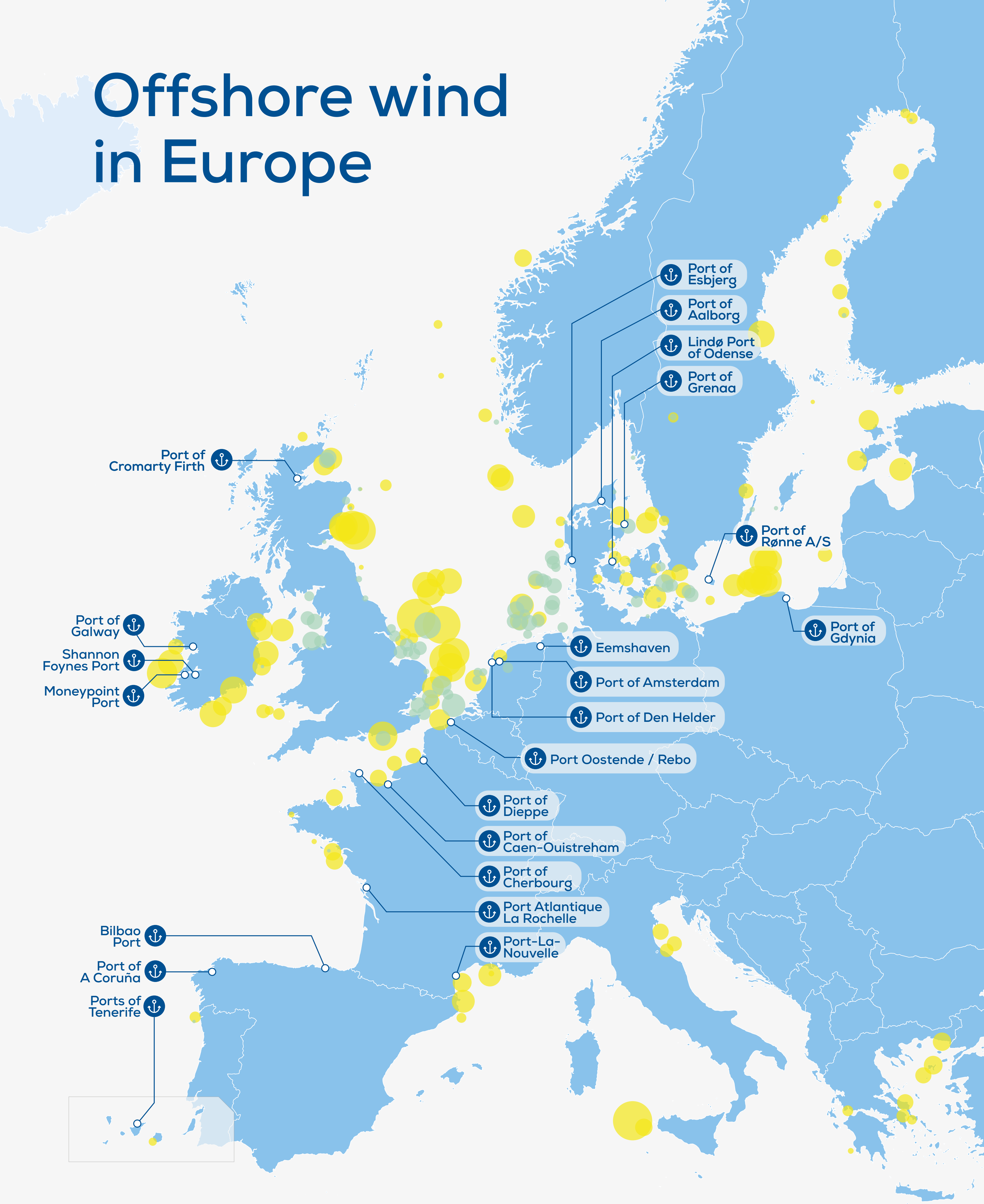
The European Union should develop a clear strategy for developing ports and recognise the strong societal value of these investments. It should prioritise finding and financing for ports and project developers notably in the context of the EU Recovery and Resilience Plan. This would attract investment and help reduce the cost of offshore wind energy.

Ports will be crucial in upscaling renewable hydrogen production and distribution, especially when linked with offshore wind generation. They provide a wide range of services and advantages that position them as key partners:

- Ports are located close to offshore wind farms and to the onshore grid landing points;
- Ports are well integrated into industrial ecosystems that can contribute to the uptake of renewable hydrogen;
- Ports can serve as a dispatching hub to reduce the emissions of other industries – using hydrogen as fuel or transforming it into other energy carriers;
- Ports can use hydrogen to decarbonise their operations and other local services such as heating for industry, waste and wastewater treatment and supplying refuelling stations for road and maritime transport.

Cooperation across the whole supply chain, from components production to renewable electricity generation, is vital to allow for smarter and more sustainable operations and products. This is key to the cost-effective delivery of a climate neutral economy while helping regenerate coastal communities.

Offshore wind in Europe



WindEurope Ports Platform Members

Offshore wind farms & status:

- In operation
- In development / planning

The map represents the status as of April 2021. The size of the wind farms is relative to capacity.
Access the latest Offshore Wind Farms database at WindEurope's Intelligence Platform: **windeurope.org/wip**

Source: WindEurope

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INTRODUCTION

Today offshore wind provides 3% of Europe's electricity consumption, with 25 GW of capacity across 116 offshore wind farms.. It'll have over 110 GW by 2030 and over 400 GW by 2050.

This huge expansion entails a major increase in how much new offshore wind Europe installs each year: from 3 GW a year today to 11 GW a year by 2030 and up to 18 GW a year by 2040. All the relevant equipment will be transported via ports. Ports will be central to the operation and maintenance of offshore wind farms and will play an important role in the wider supply chain. So the expansion of offshore wind in Europe requires huge investment in port infrastructure.

The expansion of offshore wind also required even closer cooperation between ports and the rest of the offshore wind value chain. WindEurope's **Offshore Wind Ports Platform (OWPP)** brings ports together with active operations and interests in offshore wind to **share best practices and work with industry and policy-makers**. Through the Ports Platform, offshore wind ports can share knowledge, align on communication priorities, and speak with a single voice to key stakeholders.

- **Section 1** of this report outlines what increased offshore wind activities will entail for ports and related services by 2030. It presents the key role of ports in the wider offshore wind supply chain and in the manufacturing and assembly of offshore wind turbines, including floating.
- **Section 2** presents the investments needed in ports to support the growth of offshore wind, including floating, operation and maintenance of wind farms, decommissioning, and upscaling renewable hydrogen.
- **Section 3** focuses on the role ports will play in the upscaling of renewable hydrogen and the links with offshore wind, its supply chain, and other sectors.

1. PORTS AND THE EXPANSION OF OFFSHORE WIND

1.1 OFFSHORE WIND OUTLOOK TO 2030

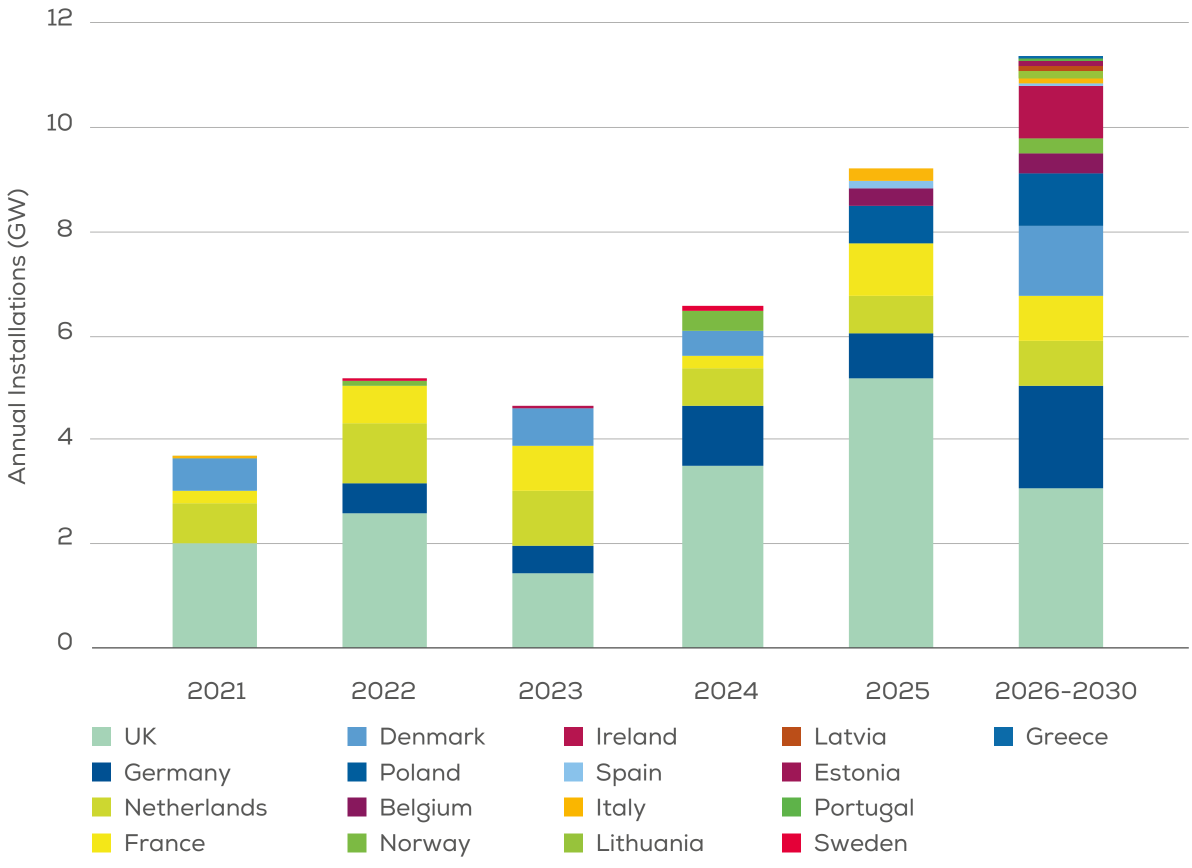
The European Union has committed to reducing CO_2 emissions by at least 55% by 2030. And to support that target it has also committed to deliver 38-40% of final energy demand with renewables. In 2020 Member States developed their National Energy and Climate Plans outlining their efforts towards reaching the previously agreed target of 32% renewables by 2030. Government commitments across Europe add up to 111 GW of offshore wind capacity by 2030. This requires a huge effort in accelerating the pace at which renewable energy and renewable technologies are developed.

The industry must ramp up offshore wind build-out from the current 3 GW/year to over 11 GW/year by 2026 and sustain this installation pace if we are to meet the goals set by Governments across Europe.

Six countries – the UK, Germany, the Netherlands, Denmark, France and Poland – will together account for 85% of the total capacity. But out of these France and Poland have no offshore wind farms at this stage, so they have a particularly big challenge in terms of strengthening this whole sector with investments in infrastructure, logistics and implementing enabling policies. Making ports suitable for this increased ramp up of activities is key as they are the interface between land and sea for offshore wind farms.

The UK Government has set the highest benchmark with a 40 GW target by 2030, including 1 GW of floating wind. Germany has pledged 20 GW relying heavily on activity in the North Sea. The Netherlands has a clear roadmap for the expansion of offshore wind to 11.5 GW by 2030. Denmark has a clear auction pipeline and the Government has backed this up with plans for two new energy islands in the North and Baltic Sea totalling over 10 GW of wind power for the country. Poland aims to add 5.9 GW and France could have 7.5 GW operational by the end of the decade, with an important contribution expected to come from floating offshore solutions.

FIGURE 1
European Offshore Wind Outlook to 2030: Annual installations (GW)



Source: WindEurope

TABLE 1
Annual European Offshore Wind Installation Forecast to 2030 (GW)

	2021	2022	2023	2024	2025	2026-2030 AVERAGE
Europe	3.7	5.1	4.6	6.5	9.2	11.4

Source: WindEurope

80% of the pipeline for the next five years is taken up by projects that have already secured some government support and in most cases have already reached Final Investment Decisions. We expect 29 GW of capacity to be built by 2025. Another 47 GW of capacity is already reserved for auctions that will be held over the next 5-6 years and could deliver projects by 2030.

TABLE 2
Upcoming offshore wind auctions in Europe

COUNTRY	TOTAL CAPACITY (MW)	TENDER YEARS
Belgium	2,100	2024-2026
Denmark	7,800	2021-2024
France[1]	3,750	2021-2023
Germany	9,688	2021-2025
Lithuania	700	2023-2025
Netherlands	6,100	2021-2025
UK	12,000	2021
Norway[2]	4,500	N/A
Spain[3]	250	2021
TOTAL	46,888	

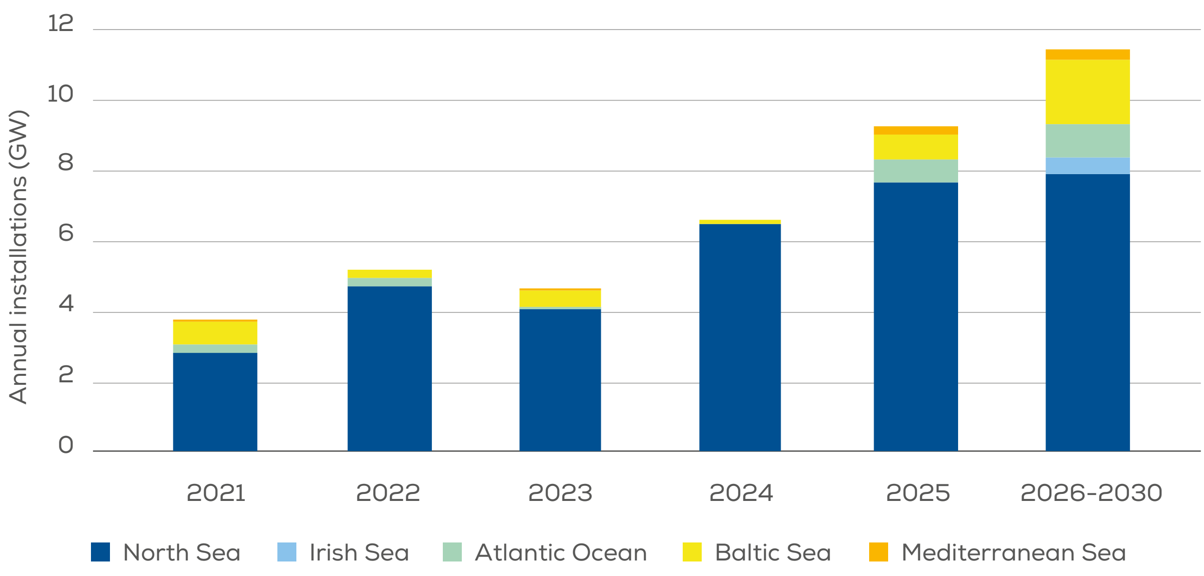
Source: WindEurope

The North Sea will continue to be the main hub of activity with 80% of all installations over the next five years, particularly as a result of its good wind resource and shallow waters. At the end of the decade, we expect that three-quarters of Europe's total offshore capacity will be located in the North Sea.

The Baltic Sea will come second, with annual installations at an average rate of 1 GW. The second half of the decade will see more activity with most Polish wind farms being planned for that period. At the end of the decade 12.5% of all the European offshore capacity could be in the Baltic Sea.

The Atlantic Ocean and the Irish Sea are expected to follow and together will host 10% of the future capacity. The Mediterranean Sea will host the remaining 2.5%.

FIGURE 2
Estimated offshore wind installations over the next decade (GW)

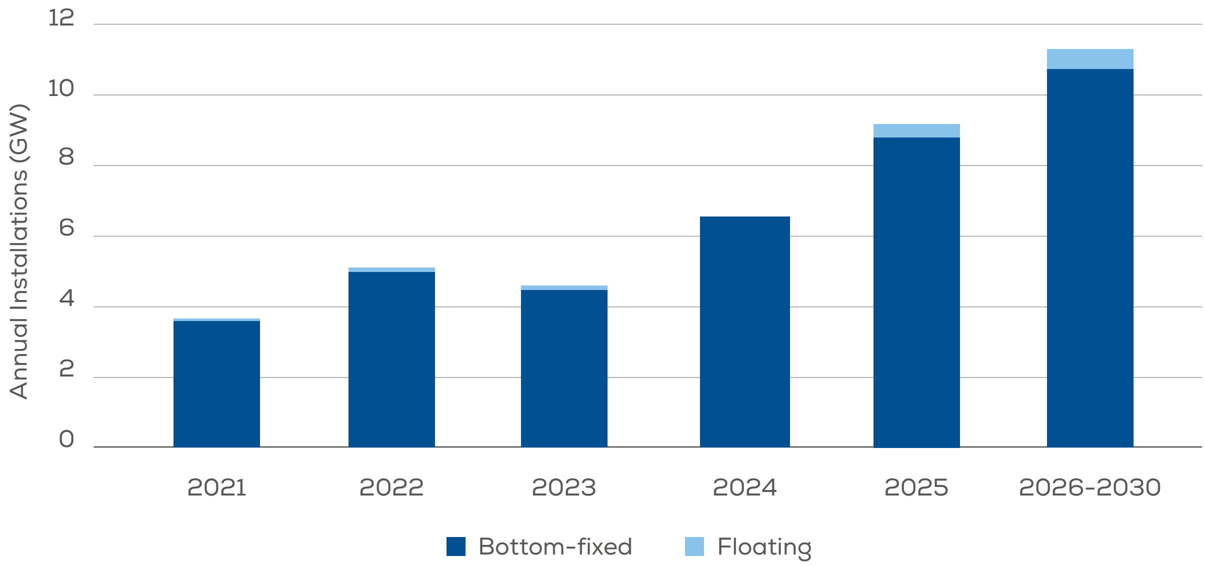


Source: WindEurope

1. Including auctions in National Energy and Climate Plan up to 2023 only
2. There is no tender system, but the Government has stated it envisages two areas (Utsira Nord and Sørlige Nordsjø II)
3. This is tentative and needs to be formalised by the Government of Spain.

Most of the installations by 2030 will be bottom-fixed as potential shallow-water sites in the North Sea remain mostly untapped, such as the Dogger Bank region. France, the UK, and Norway are set to lead the expansion of floating wind in the next decade. And most of the activity in Spain, Portugal, Italy, and Greece that will come after 2024-2025 is expected to rely strongly on floating solutions.

FIGURE 3
Estimated share of bottom-fixed and floating wind in the next decade



Source: WindEurope

1.2 PRODUCTION VOLUMES FOR KEY COMPONENTS

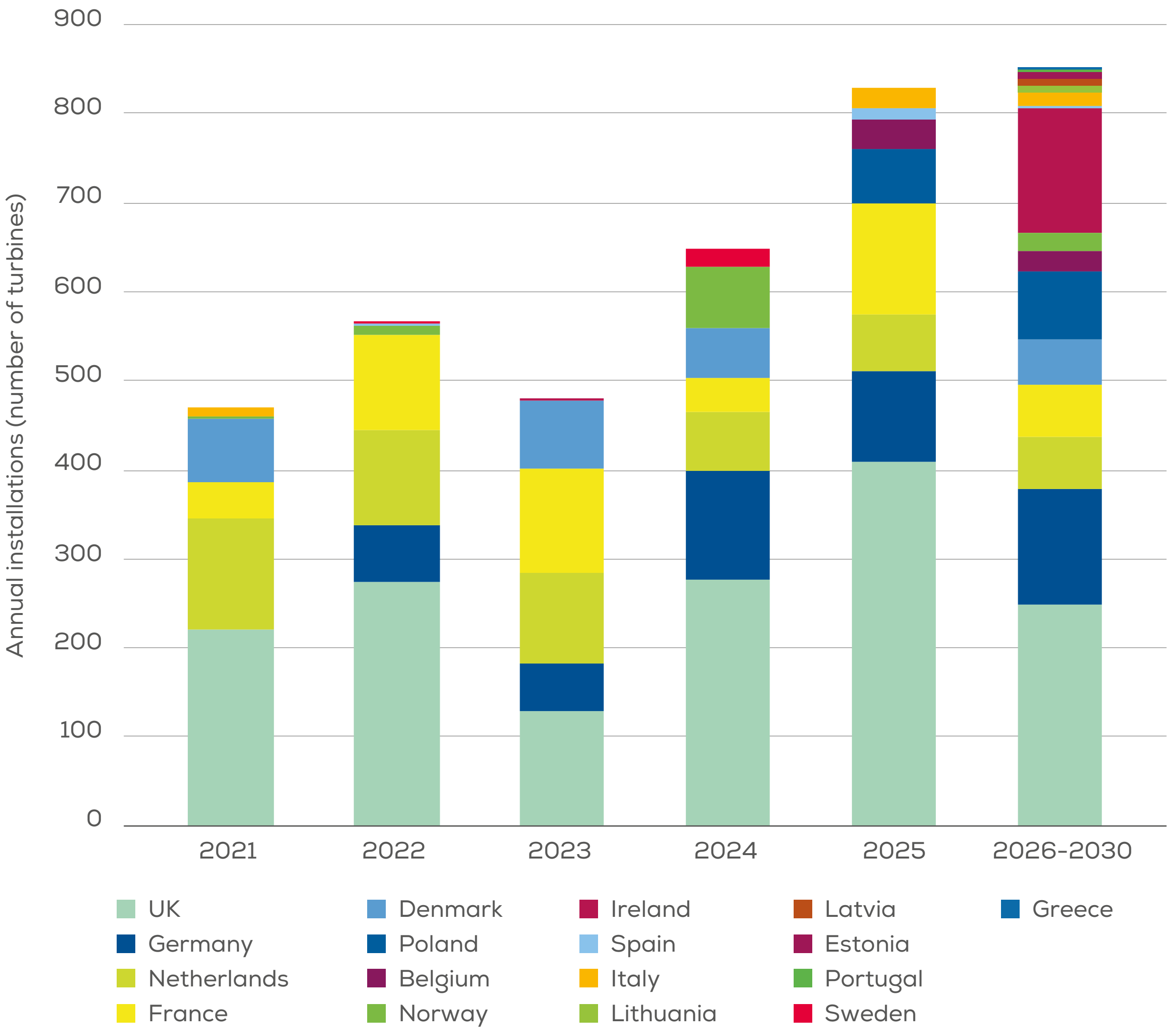
Ports need to plan logistics and infrastructure based on the number of turbines and type of foundations to be installed, rather than planning on additional megawatts.

In most cases, countries give the developer a certain degree of freedom when developing wind farms (Rochdale Envelope approach[4]). This allows auction submissions with different possibilities in terms of layout and the number of turbines rather than a fixed approach. It is a good practice because the developer can select the best commercially available turbines when making the financial investment decision, maximising annual energy production with fewer turbines and thus reducing the cost of energy (LCOE).

All projects planned to be commissioned over the next two years (2021 and 2022) have selected the turbine size and the supplier because, in general, developers formalise their turbine contracts after the financial close. Developers have pre-selected over 80% of the turbines for projects in the period 2023-2025.

4. The Rochdale envelope approach for permitting offshore wind projects allows developers to describe their project using general parameters that cater for uncertainties at the time of application.

FIGURE 4
Estimated number of turbines to be installed over the next decade



Source: WindEurope

Europe will gradually increase its offshore installations to nearly double the number of turbines installed yearly by 2025 (from 400 today to about 800 per year in 2025). In the second half of the decade, as turbines grow in size, we expect that Europe would need to maintain a constant yearly installation rate of 800-900 turbines to deliver 111 GW of offshore wind capacity by 2030.

The following table shows estimates of the production volumes of key components expected in the next ten years. The production and installation of these components impacts the whole supply chain. This is particularly true with the transportation and installation of components that directly impact vessels, ports, heavy lifting, and transport providers' needs.

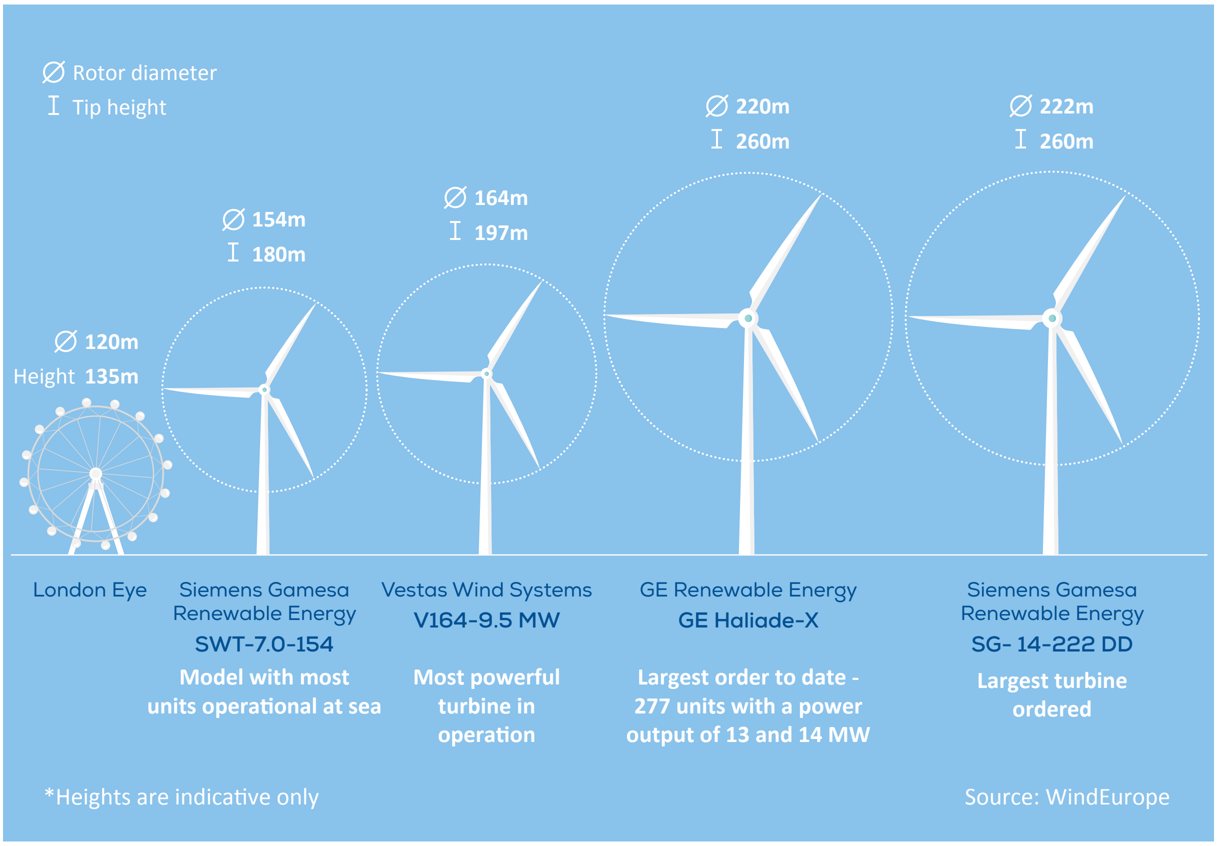
TABLE 3
Estimated average production volumes of key components in 2026-2030

COMPONENT	RATE OF SUPPLY	UNITS PER YEAR REQUIRED
Nacelle	One per turbine	800-900
Blades	Three per turbine	2,400-2,700
Towers	One per turbine	800-900
Transition pieces	One per turbine	800-900
Fixed foundations	One per turbine	800-850
Floating foundations		30-50
Array cable	Seven to nine rotor diameters cable per turbine (1.8 km)	1,500 km
Offshore export cable	Four per 1.5GW wind farm at average 70 km long	2,240 km
Dynamic array cable	Twice the water depth at an average 100m per turbine	8 km
Mooring lines and anchors	Three per turbine (with catenary configuration)	120
Offshore substations	Two HVAC or 1 HVDC per 1.5 GW wind farm	16 (or 8 if HVDC)

Source: WindEurope

Increases in turbine height and weight are not proportionate to increases in turbine rating (MWs). The trend for monopile weight per MW in Europe has reversed and is expected to drop by 23% over the next five years. This is largely down to leaner designs and innovative transition pieces (Wood Mackenzie for WindEurope, 2020).

FIGURE 5
Offshore Wind Turbine Highlights



For projects being built within the next three years, developers have already selected the type of foundation. In the long term, current trends suggest that monopiles will remain the standard. The UK, France, and Germany will install jackets, especially when working on bottom-fixed sites in deeper waters. Gravity base foundations could also be used for bottom-fixed. For floating wind projects, several designs are still under consideration, with semi-sub and spar being the most popular options taken so far.

Component suppliers will have to restructure capabilities and logistics to offer competitive solutions to tackle physical challenges around the volumes, size, and weight of offshore turbine components. This means that operating near a port, or in coastal areas, would provide suppliers with an advantage.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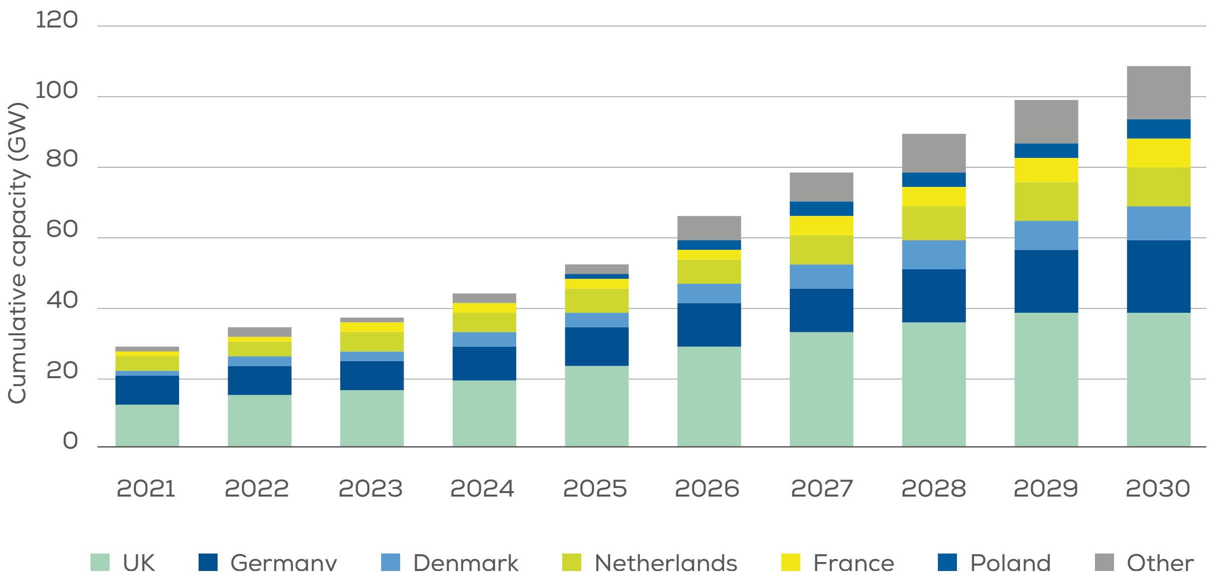
1.3 PORTS AND VESSELS SERVICES

Today 116 wind farms across Europe (5,402 turbines in total) need servicing.

Europe will commission nine wind farms per year on average over the next five years and this will increase during the second half of the decade to 12 per year. In 2030 there could be over 200 wind farms requiring Operation and Maintenance (O&M) services, equivalent to more than 12,000 turbines across Europe.

FIGURE 6
Cumulative installations for servicing offshore wind farms (GW)



Source: WindEurope

Most of these projects will be in six countries. The UK, Germany, Denmark, the Netherlands, France, and Poland will each have a market share of 5% or more by 2030.

The installation of these new turbines at sea will require different vessels to transfer the crew (CTVs), maintain technicians offshore (SOVs), lift large components such as blades and generators (jack-up vessels) and enable the wind farm's electrical connection (cable laying vessel). Jack-ups and cable laying are the largest vessels, and this also means higher cost rates per day. The development of larger turbine ratings has forced some of the installation vessels out of the turbine installation segment into the major component replacement market such as generator components and blades.

Floating wind projects require smaller vessels because most of the turbine-structure assembly is done onshore, at the harbour.

Ports and vessels will work closely to optimise the installation and maintenance of all these new wind farms. The next table shows some of the current and future trends for ports and vessels installing and servicing offshore wind farms.

TABLE 4
Trends for ports and vessels installing and servicing offshore wind farms

TREND	EXAMPLE	BENEFITS
Large component transport and pre-assembly	Siemens Gamesa Renewable Energy roll-on/roll-off vessel *Rotra Vente* is used to mobilise blades and nacelles from Hull and Cuxhaven respectively.	Ports will continue to increase the use of roll-on/roll-off (RO-RO) vessels particularly for transporting large components (i.e. nacelle, blades). This reduces time and logistical costs compared with traditional methods for component delivery. Onshore pre-assembly of turbines reduces installation logistics costs and will continue.
Floating installation vessels	Jan de Nul floating installation crane vessel *Les Alizés* with a crane capable of lifting 5,000 tonnes.	This method avoids interaction with the soil, making it possible to install turbines in almost any seabed and at any depth. Some designs will allow for turbine assembly onboard. Vessels will be larger, limiting the number of ports they can operate in.
Installation optimisation and collaboration	The *Saipem 7000* semisubmersible crane vessel can lift up to 14,000 tonnes and will be used in neighbouring Scottish projects Neart Na Gaoithe and Seagreen.	Vessels will be optimised for maximum working time (as opposed to transit, loading and servicing time). Some neighbouring wind farms will coordinate offshore installation for critical lifts.
Carbon-free O&M	CWind secured a long-term contract with Ørsted to use the first hybrid crew transfer vessel (CTV) at Borssele 1 and 2 in Vlissingen, the Netherlands. The ISHY project will test the first H2 bunkering facilities at the Port of Oostende for fuelling a hydrogen base powered CTV.	Companies are moving towards hybrid or electric Crew Transfer Vessels (CTVs), and Service Operation Vessels (SOVs), designs to reduce the carbon footprint of their offshore operations. The activity will depend heavily on the ability of ports to facilitate the charging operation.
Design innovations	Van Oord is testing the slip joint at the Borssele 5 *Innovation Site* as an alternative to connect foundation and tower without the use of grout or bolts.	Other design innovations in the turbine will make installation more efficient. These include new transition pieces and foundation designs that allow faster installation.

Source: WindEurope

Offshore O&M accessibility is crucial to OPEX optimisation and availability. Ports, and the offshore wind supply chain, will have to engage early on to optimise logistical solutions that can allow the industry to deal with a wider range of projects.

1.4 OFFSHORE DECOMMISSIONING

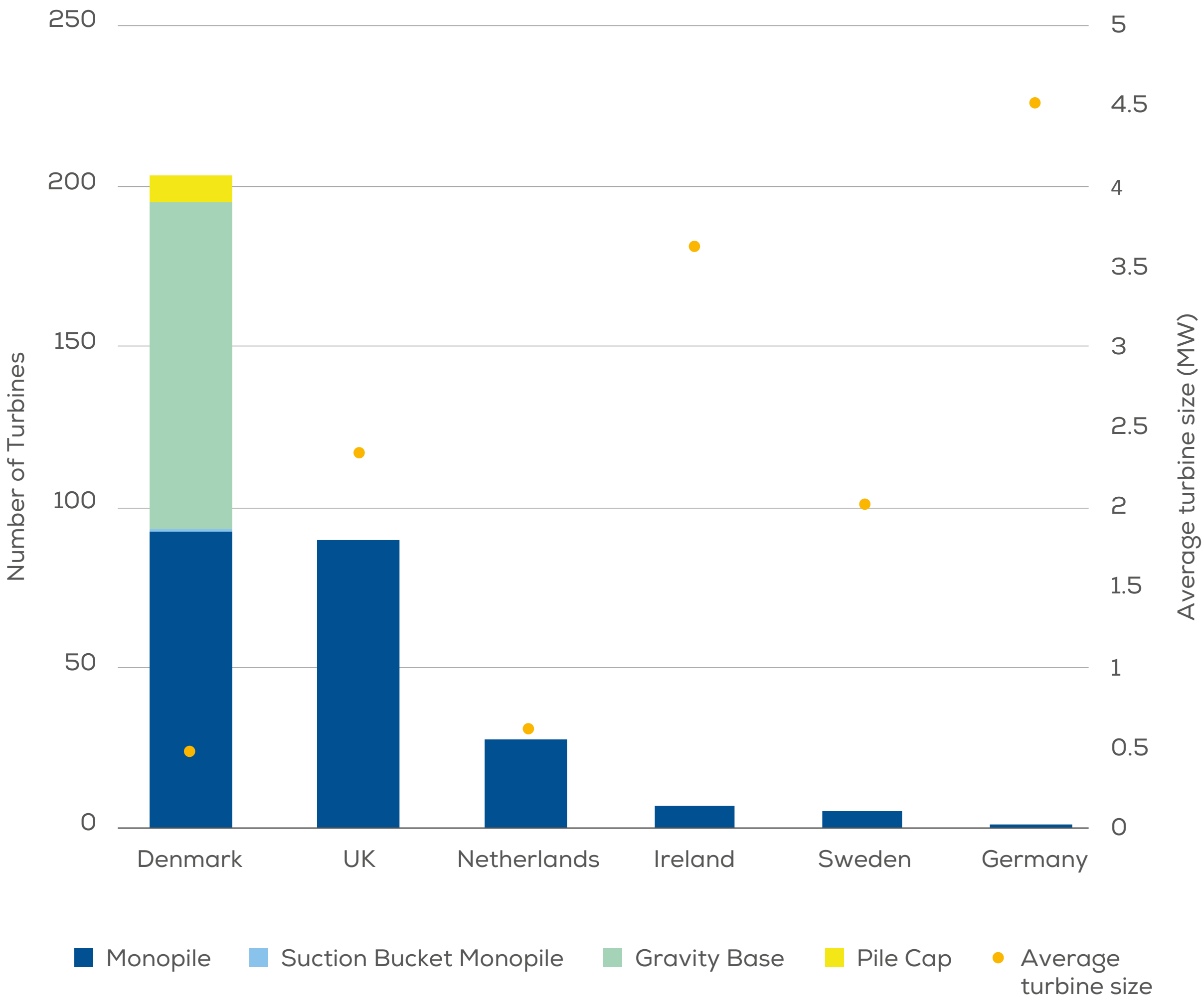
Today, about 300 installed turbines (700 MW of capacity in total) are more than 15 years old. We expect wind farm owners to decommission these installations within the next 10 years. Some might be repowered and other will be fully decommissioned. This presents opportunities for various parts of the supply chain, such as vessels that are designed for smaller turbines and can no longer support the installation of newer larger turbines but could be suited for transporting towers and blades from those sites. This is relevant as the size of these turbines is in the range of 0.5 to 4 MW. The decommissioning activity will also affect operations in ports, where storage space will need to be reserved until the blades can be further transported to waste management centres or be taken to other wind farms in secondary markets.

In terms of the foundations, most older sites have monopiles. It is unclear whether the complete removal of foundation is always the best option considering they have led to marine growth, biodiversity and new ecosystems.

The offshore wind industry must put in place an effective dismantling and transportation framework. Accommodation and processing near or within the port could prevent unnecessary transportation of materials. Ports will have to set aside space and capacity to accommodate the dismantled turbines.

FIGURE 7

Number of turbines older than 15 years due for decommissioning or repowering over the next decade



Source: WindEurope

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2. INVESTING IN PORTS

Europe urgently needs to invest in its port infrastructure to make it compatible with green deal ambitions and to allow for a more affordable energy transition. **€6.5bn in investment will be needed by 2030 to enable the effective delivery of offshore targets within the National and Energy Climate Plans and for future growth** (see breakdown in table 1). **This investment could be paid back in just five years**[5] and would bring massive savings for electricity consumers and society as a whole.

Upgraded or entirely new facilities are needed to host larger turbines and a larger market. They will need to cater for operating and maintaining of a larger fleet (including training facilities), for upcoming decommissioning projects and to host new manufacturing centres for bottom-fixed and floating offshore wind. **Ports will need to expand their land, reinforce quays, enhance their deep-sea harbours and carry out other civil works**. They will also attract investments in infrastructure for renewable hydrogen generation and distribution (this topic is addressed in Chapter 3).

Space is and will become a bigger issue for ports, not just on land but also on water. To overcome this, ports will require new strategies and regional collaboration efforts.

Due to the infrastructure challenges and costs associated with readying ports for the growth of the offshore sector, **it is very important to provide long-term revenue certainty** for the exploitation of these facilities as part of the national energy policies. But port development policy is often hidden away at the regional level since offshore activities compete with other industry activities that might provide higher returns in the short term (e.g. cargo logistics).

The European Commission should develop a clear strategy for port development and recognise the high societal value of investing in ports. To this end, it should prioritise funding and financing for ports and project developers. This would attract investment and help reduce the cost of offshore wind energy.

The **€673bn Recovery & Resilience Facility** (RRF), which is part of the EU Recovery Plan, represents an unprecedented EU-level fiscal intervention to revive the European economy in the wake of the COVID-19 pandemic. Crucially, the objective of the RRF is not to return the EU to business-as-usual but to lay the foundations of a greener, more digital, and stronger economy.

5. According to BVGA for WindEurope (2017) *Ports and port services for offshore wind in 2030*, the role of ports, port service and vessels has direct and indirect impacts in offshore wind LCOE reduction to 2030, for a combined saving of 5.3% of LCOE, which can be translated into a saving of approx. €2/MWh and or about €110,000/MW installed.

TABLE 5
Overview of investment needs and costs for infrastructure works in ports.

INVESTMENT ITEM	COST PER INVESTMENT	NUMBER OF INVESTMENTS (NO OF PORTS)	TOTAL INVESTMENT
Upgrading/extending facilities for a port already in the bottom-fixed offshore wind business	€20-80 million	30	€1 billion
Building a new energy port/terminal for bottom-fixed offshore wind (around 15-20ha)	€80 - 110 million	15-20[6]	€2 billion
Building a decommissioning facility/ refurbishing an existing facility in the port	€5-10 million	5	€50 million
Floating port adaptations or new terminal	€200 million	6	€1.5 billion
Infrastructure for renewable hydrogen production in ports	€100 million	10	€1 billion
Accommodating energy island operations, products, and related infrastructure	€500 million	2	€1 billion

Source: WindEurope

Of the €673bn in the RRF, €313bn will take the form of grants and the remaining €360bn will come in the form of loans (2018 prices). The grants are pre-allocated by Member State as set out in the regulation.

- **Grants** are a vital tool in preparing port facilities for offshore wind development, ensuring a viable business case based on longer return of investments.
- **Loans** are equally important as they provide attractive pricing and a signalling effect, helping the project attract the necessary capital for large investments.

This is a great example of providing financial backing for ports infrastructure development as a key element in the offshore wind supply chain, and in supporting a just transition in regions moving from fossil fuels to renewable sources.

There are many sensible and smart reasons for investing in ports and port ecosystems. But investments will only be fully unlocked by a favourable regulatory environment and a strong political effort. Together these will give the supply chain and other industry players a confidence boost, lowering the investment risk and mobilising activities and products servicing coastal clusters, cities, and communities.

6. Including emerging markets (e.g. Greece and Italy)

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3. PORTS AND RENEWABLE HYDROGEN

This section will give an overview of hydrogen production trends and costs across Europe. It will then focus on the benefits of renewable hydrogen production in ports, linking local production with offshore wind energy generation, its supply chain, and other sectors.

3.1 HYDROGEN GENERATION AND DEMAND

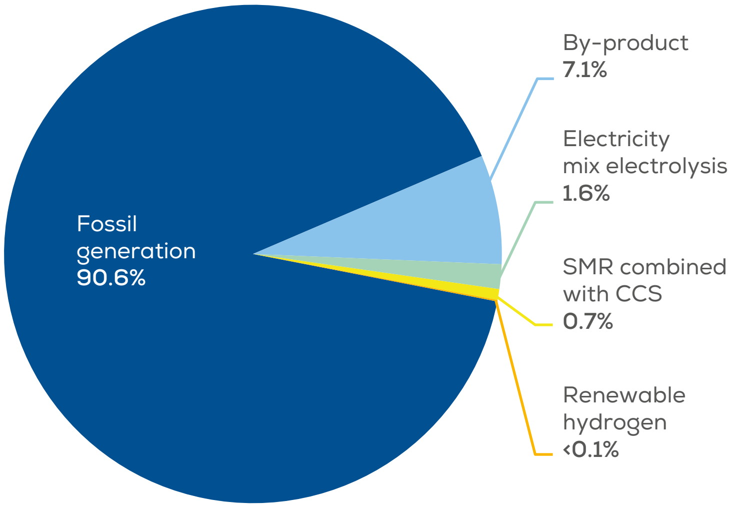
Hydrogen today accounts for less than 2% of Europe's energy consumption although its role is expected to increase significantly by 2050[7]. By then the European Commission expects hydrogen to meet 9% of final energy demand. And its role is even larger considering that much of the expected contributions from e-fuels (9% of final energy demand by 2050) will be derived from renewable hydrogen.

The total hydrogen production capacity in Europe at the end of 2018 was around **11.5 million tonnes (Mt) per year**[8]. Two thirds of this is "captive" hydrogen, which means it is produced onsite for own consumption. The rest is split between hydrogen as a by-product (20%) and merchant hydrogen (15%).

More than 91% of this hydrogen is supplied by fossil fuels, out of which only 0.7% is produced in combination with Carbon Capture, Usage and Storage Technologies (CCUS). Electrolysers – producing hydrogen from electricity and water - account for 1.6% of the total hydrogen production, for a total of around 1 GW of installed capacity[9]. Where the electricity to operate the electrolyser comes from renewable energy sources, it is described as "**renewable hydrogen**". Its production today is marginal, and mostly limited to R&D and pilot projects, accounting for only 58 MW at the end of 2018[10], less than 0.1% (figure 8).

7. European Commission (2020) The Hydrogen Strategy
8. Hydrogen Europe (2020) Clean hydrogen monitor 2020
9. K. Kanellopoulos y H. Blanco Reano, "The potential role of H2 production in a sustainable future power system", EU Joint Research Centre, 2019
10. Hydrogen Europe (2020) Clean hydrogen monitor 2020

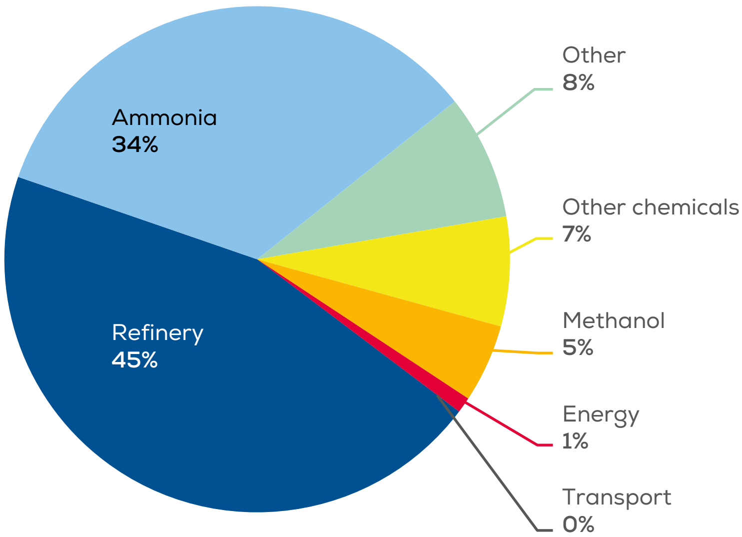
FIGURE 8
Hydrogen generation capacity by technology



Source: Hydrogen Europe, 2020

The total demand in Europe for hydrogen in 2018 has been estimated at 8.3 Mt[11]. Refineries and Ammonia alone account for 79% of the market share. Refineries (45%) mostly use hydrogen to lower the sulphur content of diesel fuels and to transform heavy and complex hydrocarbon feedstocks in lighter fuels and products. Ammonia (34%) is produced by combining hydrogen and nitrogen. Ammonia today is mostly used into fertilisers and other chemicals. It is gaining particular attention as maritime fuel and for its potential for storing and transporting hydrogen. The remaining demand of hydrogen is mostly for methanol (5%) and other chemicals, while demand for energy is as low as 1% (figure 9).

FIGURE 9
Total demand for hydrogen in 2018



Source: Hydrogen Europe, 2020

11. Hydrogen Europe (2020) Clean hydrogen monitor 2020

3.2 HYDROGEN COSTS

The cost of hydrogen depends primarily on the technology with which it is produced. Producing hydrogen from natural gas through steam methane reforming is the cheapest option today. Large consumers, e.g. Ammonia plants and refineries, can get high quantities of raw hydrogen at the lowest cost, around €1.5/kg in Europe. When combined with CCS – the price rises to €2-3/kg, due to extra CAPEX and OPEX costs for capture, storage, and transport of CO_2, as indicated by many industry reports[12], although its use is not widely developed at this stage. But the cost of hydrogen depends on other factors too, such as its application and end-use. Some applications require high purity hydrogen (e.g. semiconductors industry), which can hardly be met by steam reformed natural gas. Electrolysers instead provide higher levels of purity and given their distributed nature, can better serve these applications, albeit at a higher production cost.

To be competitive in the market, renewable hydrogen must achieve costs comparable to Steam Methane Reforming combined with CCS (€2-3 /kg). The cost of renewable hydrogen is based on multiple factors. CAPEX, full load hours, cost of electricity, including possible grid tariffs, taxes and levies (OPEX). Together these bring the cost of renewable hydrogen today to €3.5 – 6.5/kg[13]. This is up to three times the target price of natural gas-based hydrogen with CCUS. **Reducing these costs is crucial**. Many projections see the cost of renewable hydrogen falling to around €2/kg[14] by 2030 thanks to technological development, decreasing costs of renewable electricity and more favourable market conditions. **This would make renewable hydrogen competitive with** Steam Methane Reforming combined with CCS **by 2030**.

3.3 RENEWABLE HYDROGEN POTENTIAL

Renewable hydrogen is becoming increasingly important due its potential for **reducing emissions in hard-to-abate sectors**. In these sectors, which include heavy industry (cement, steel, and chemicals), heavy-duty road transport, aviation and shipping, direct renewables-based electrification is not always technologically or economically feasible.

Another area where renewable hydrogen can play a major role is in **sector coupling**, which refers to the integration of energy supply-side sectors with all end-use energy consuming sectors. **One of the major enablers of sector coupling is the conversion of power to gas (PtG or P2G)**. As the volumes of variable wind and solar in the system increase, the production of hydrogen could be matched by the production of renewable electricity, avoiding potential renewable energy curtailment.

These benefits are well understood by he European institutions, who see renewable hydrogen as the missing link to fully decarbonising our energy system. In July 2020, the European Commission published the Hydrogen Strategy and the Energy System Integration Strategy, underlining the prominent role that renewable hydrogen could play in the future.

These strategies define a series of actions making renewable hydrogen an integral part of the European energy transition.

In particular, **the Hydrogen Strategy**, sets strategic objectives and actions to upscale renewable hydrogen, in **three phases**:

1. **2020 to 2024** – aims for at least 6 GW of renewable hydrogen electrolysers in the EU and the production of up to 1 million tonnes of renewable hydrogen, with a focus on decarbonising the current hydrogen system and promoting new end-use applications such as transport.

2. **2025 to 2030** – at least 40 GW of renewable hydrogen electrolysers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU.

3. **2030 onwards** – renewable hydrogen will have reached maturity and will be used in all hard-to abate sectors.

12. Hydrogen Europe (2020) Clean hydrogen monitor 2020
13. Hydrogen Europe (2020) Clean hydrogen monitor 2020
14. IEA Hydrogen Roadmap (2019); BNEF, 1H-2021 Hydrogen Levelised Cost update (April 2021)

This strategy can only be achieved with the simultaneous growth of renewable energy generation and with the consolidation of offshore wind, which according to the International Energy Agency (IEA)[15], will become the leading electricity source in Europe from the early 2040s.

3.4 RENEWABLE HYDROGEN IN OFFSHORE WIND PORTS

To scale up renewable hydrogen production different industrial sectors need to coordinate their efforts. Only in this way can producers and consumers make renewable hydrogen cost-effective by 2030. Ports provide a wide range of services and advantages that position them as key partners. They are familiar with the offshore wind industry; they are well located, and they can facilitate coordination between various players.

Offshore wind ports across Europe are already involved in planning renewable hydrogen projects in their facilities. Out of the 22 members of WindEurope's Offshore Wind Ports Platform, six are in the assessment or pre-development phase. The full list of ports and their case studies is available in Annex I.

Most of these ports are located the North Sea, which has been recognised by the IEA[16] as an attractive starting point for scaling-up renewable hydrogen supply and demand. This is due to many factors including a strong industrial base, a high potential for offshore wind and CO_2 underground storage sites, ambitious climate policies and the political will of some countries to repurpose part of their obsolete gas network as hydrogen infrastructure.

But most EU countries **currently lack a favourable regulatory framework, and the hydrogen infrastructure needed to connect clusters and regions is not yet in place**. Considering the ambition of the Commission's Hydrogen Strategy and the focus on hydrogen as a gateway to a green recovery in some of the National Recovery and Resilience Plans, it's vital we get underway with important infrastructure projects in the second half of the decade. **The supply chain needs to start coordinating as soon as possible, building on the experience gathered in deploying the first pilot projects**.

This section gives an overview of the advantages of locating these projects in offshore wind ports across Europe.

3.4.1 THE LINK WITH OFFSHORE WIND

With the expansion of offshore wind in Europe, it is vital to **make efficient use and dispatch of the electricity produced at sea**. Renewable hydrogen production in coastal areas could help relieve congestion and allow for a faster uptake of wind energy, as transmission grid build-up and availability are some of the main barriers to the expansion of wind energy.

Offshore wind ports are by their very nature located close to offshore wind generation. As a consequence, landing points for offshore wind farms are often located in ports, or in the immediate vicinity. This makes it convenient to source offshore wind electricity in the areas surrounding ports. Electrolysers located in these ports would then benefit from this.

The offshore wind industry is already involved and is expected to drive the upscaling of renewable hydrogen. It is also already present in offshore wind ports. Renewable hydrogen provides the opportunity to strengthen interactions between offshore wind industry partners, ports in ***primis***. This increases efficiency in the sector and in its operations.

To maximise synergies between the two sectors, offshore wind farms can be designed to account for part of the electricity generated for renewable hydrogen production. This is the case in the Netherlands, where the latest tender for the Hollandse Kust North area has been awarded to CrossWind, whose winning bid included plans to create a renewable hydrogen hub in the **Port of Rotterdam** with an electrolyser

15. IEA (2019) Offshore wind outlook
16. IEA (2019) The Future of hydrogen. Report prepared by the IEA for the G20, Japan

capacity of around 200 MW[17]. The Dutch Government is now exploring the possibility of combining offshore wind and onshore renewable hydrogen production in upcoming offshore wind tenders.

The sector is already preparing for this, as in the case of **Groeningen Seaports** and **North Sea Port**, where offshore wind industry players have started planning for extra volumes to feed into renewable electrolysers in ports (case studies in Annex I). In the long-term , hydrogen could be produced directly offshore, and ports could serve as dispatching hubs. A number of research projects are looking into this possibility[18].

3.4.2 PRESENCE OF DEMAND

Ports are well integrated into industrial ecosystems that can strengthen the uptake of renewable hydrogen. The chemical and steel industries, ammonia production plants, refineries and other power plants are already present in Ports. Hinterlands also contribute through higher demand and can benefit from the green transition occurring in the vicinity of the port area.

Ports are also well integrated into coastal industrial environment. In fact, **ports are usually located near other industrial clusters** in a radius of 20-30 km, which could also benefit from a renewable hydrogen distribution system. This is especially true in view of the conversion of other industries to hydrogen, such as iron and steel production, shipbuilding, and data centres. In the long term, these coastal industrial clusters are set to expand, with more and more industries expected to relocate to coastal areas as consequence of the rapid expansion of offshore wind. An example of port coordination with a local industrial cluster is the case of **Port of Cromarty** (Case study in Annex I).

The demand for renewable hydrogen in Ports could be further boosted by the production and export of its derivates for other uses, such as other chemicals, electrofuels or e-fuels, and other energy vectors. In fact, **Ports are natural hubs where different modes of transport meet**. They are logical settings for hydrogen and its derivatives to access import/export opportunities. This puts Ports centre-stage in the renewable hydrogen supply chain, regardless of whether production takes place within their borders.

3.4.3 DISTRIBUTING HYDROGEN

Ports' models of energy management vary based on a number of factors. In terms of electricity, and potentially hydrogen, **ports can serve as:**

- **facilitators**, between new and existing clients and grid operators,
- **investors**, with local investments related to the supply and demand of organisations in the port area; and
- **partners** such as in shared energy platforms, where industry players can share their overcapacity of energy or demand for energy and ensure the most efficient energy usage in the area.

Ports will be key in supporting industries and must be ready to offer facilities that allow fast and direct sourcing of offshore wind electricity, renewable hydrogen and alternative fuels.

The construction of new hydrogen distribution infrastructure is the preferred choice for early renewable hydrogen plants located in Ports that can count on local demand. The IEA also confirms that for local distribution, pipelines are cost-effective options; in other cases, trucks are likely to be the cheaper option.

Ports that cannot count on local demand might opt for alternative options. This could include using hydrogen to green their own operations, or distributing hydrogen within the region/inland - as in the case of **Port of Port la Nouvelle** (Case study in Annex I).

17. www.windeurope.org/newsroom/press-releases/combined-offshore-wind-hydrogen-project-wins-dutch-hollandse-kust-noord-tender/
18. Examples are the OYSTER project, and Tractbel/Engie's concept

In certain country-specific or even site-specific cases it could be useful to invest in repurposing existing gas pipelines. This could be true for ports that are currently serving as natural gas dispatch hubs and/or are already connected to depleted – or almost depleted – gas fields. This is the case of **Port of Den Helder** (Cast study in Annex I).

Investing in distribution infrastructure should also account for future uses of the system. Connecting industrial clusters can help to increase the efficiency of dispatch and ensure better matching of supply and demand. This is the case of **Hydroports**, a project currently being developed between **Port of Den Helder, Groningen Seaports and Port of Amsterdam**, which aims to set up a hydrogen backbone between these seaports.

3.4.4 OTHER BENEFITS

Renewable hydrogen offers a great opportunity for ports to **increase their services' portfolio, offering advantageous business opportunities to reduce the emissions of various industries**. This will lead to increased efficiency in the supply chain, improved environmental performance, and increased synergies with other activities and industries, contributing to their decarbonisation:

Hydrogen as fuel and its derivates are an example of this, since it concerns a wide range of sectors both at land and sea. Hydrogen can directly supply fuel cells (FCEV) for heavy-duty vehicles, buses, trains, ships, and vessels. Several projects are under development: hydrogen in conventional combustion engines and the development of new types of hydrogen ships, e.g. HydroCat, a Crew Transfer Vessel fuelled by renewable hydrogen.

Hydrogen can also be converted to ammonia, which can also be used as fuel, has a higher energy density and is easier to handle. Its potential is particularly promising for deep-sea transport. Ammonia can even be used to transport hydrogen by ship over long distances, although this would require an additional conversion. Synthetic methane and synthetic diesel can also be produced from hydrogen and used in internal combustion engines. Ports are the natural hub where all these fuels can converge.

Hydrogen can also help **decrease the carbon footprint of local port operations**. For example, shore-side power, also called cold ironing, could make use of renewable electricity or renewable hydrogen. In this way, CO_2 emissions from ships and vessels when docking in ports can be dramatically reduced. This is the case for **Port of Oostende** (Case study in Annex I).

Ports are also close to very densely populated areas. Renewable hydrogen could support green services for national, regional, and local administrations. This could include heating for industry, waste and wastewater treatments, refuelling stations, and other public services. It also allows for the creation of new synergies between industrial clusters and cities, as is the case for the **Port of Amsterdam** (Case study in Annex I).

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ANNEX I

CASE STUDIES IN PORTS

Annex I presents examples of renewable hydrogen projects in ports members of the Offshore Wind Ports Platform. The projects are listed in order of appearance in the text of Chapter 3.

PORT	LOCATION	NAME OF PROJECT	PARTNERS	YEAR OF DEPLOY-MENT	PLANNED ELECTROLYSER CAPACITY
Groningen Seaports	Netherlands	NorthH2	RWE, Shell, Equinor, Gasunie, and Groningen Seaports.	2030	1 GW by 2027 4 GW by 2030, 10+ GW by 2040
North Sea Port	Netherlands and Belgium	SeaH2Land	Ørsted, Smart Delta Resources, ArcelorMittal, Dow Benelux, Zeeland Refinery	2030	2 GW by 2030
Port of Cromarty Firth	UK	North of Scotland Hydrogen Programme	Pale Blue Dot Energy, Port of Cromarty Firth, Scottish Power, Glenmorangie, and Whyte & Mackay.	2022	100 MW initially
Port of Port la Nouvelle	France	Hyd'Occ	QAIR, AREC, DEME	2024	50 MW
Port of Den Helder	Netherlands		Engie, Liander, Total (Pitpoint), Damen	2021	2 MW, up to 15 MW
Port of Oostende	Belgium	Hyport	Port of Oostende, DEME Concessions and PMV	2024 - 2025	70 MW
Port of Amsterdam	Netherlands	H2ermes	Port of Amsterdam, Nouryon, Tata Steel	2021 FiD	100 MW
Port Authority of Bilbao	Spain		Petronor (Repsol Group), Port Authority of Bilbao	2024	N/A

GRONINGEN SEAPORTS - NORH2 PROJECT
"A PROJECT TAILOR-MADE FOR OFFSHORE WIND"

CASE STUDY

PARTNERS: RWE, Shell, Equinor, Gasunie, and Groningen Seaports

1 GW BY 2027
4 GW BY 2030,
10+ GW BY 2040

2030

NETHERLANDS

NorthH2 aims to establish a system converting electricity from offshore wind to green hydrogen, which is then stored and transported to industrial centres in north-western Europe. The partners are **RWO, Shell, Equinor, gas network operator Gasunie, and Groningen Seaports**. New offshore wind farms would generate the green power and could gradually grow in capacity from 1 GW in 2027, to 4 GW by 2030, **to more than 10 GW in 2040**. These wind farms would complement the already planned wind farms for the renewable electricity supply. **They would be directly linked to the hydrogen plant and all power would be used to produce green hydrogen**. With this, the consortium aims to produce 1 million tonnes of green hydrogen per year by 2040.

The feasibility study – focusing on 2030 - concludes that NorthH2's integrated approach could lead to a 20% reduction in societal costs compared to a smaller-scale approach. In addition, according to a recent study by the University of Groningen, the project could involve between 700 and 1,200 structural jobs in the province of Groningen. The second phase of the feasibility study focusing on the period after 2030 got underway in 2020.

https://www.north2.eu/en/

NORTH SEA PORT - SEAH2LAND VISION "PLANNING OFFSHORE WIND FOR RENEWABLE HYDROGEN"

CASE STUDY

PARTNERS: Ørsted, Smart Delta Resources, ArcelorMittal, Dow Benelux, Zeeland Refinery

2 GW BY 2030

2030

NETHERLANDS AND BELGIUM

SeaH2Land aims to construct a 1 GW electrolyser to produce renewable hydrogen in the **North Sea Port**. To provide the large volumes of electricity required, Ørsted will build 2 GW of additional offshore wind farms solely dedicated to producing hydrogen directly linked to the electrolyser facilities. The SeaH2Land partners supported by the regional industry association **Smart Delta Resources** will work in close cooperation with **TSOs** towards creating a regional hydrogen network. Some 45 km of pipelines should run from Vlissingen (NL) to Ghent (BE). With that the whole North Sea Port cluster can be provided with renewable hydrogen. The industrial partners – **ArcelorMittal, Dow Benelux, Zeeland Refinery** – support the SeaH2Land vision and the development of a regional hydrogen network to decarbonise the production of steel, ammonia, ethylene and fuels.

The industrial cluster in Zeeland is the largest consumer of fossil hydrogen in the Netherlands (580,000 tonnes per year). SeaH2Land can replace 20% of that with renewable hydrogen and achieve a significant CO_2 reduction. SeaH2Land will help the Netherlands work towards the ambition of 3-4 GW of electrolyser capacity by 2030, accelerate the roll-out of offshore wind and help the two countries to realise their 2030 climate targets.

https://seah2land.nl/en

PORT OF CROMARTY - NORTH OF SCOTLAND HYDROGEN PROGRAMME "GREEN H2 FOR A REGIONAL INDUSTRIAL CLUSTER"

CASE STUDY

The North of Scotland Hydrogen Programme is a series of scalable green hydrogen projects based in the Cromarty Firth which will produce hydrogen from renewable energy for regional, national and export use. The Highlands is rich in renewable energy, offshore wind in primis. The initial project will supply green hydrogen to distilleries in the region. It is a partnership between **Pale Blue Dot Energy, Port of Cromarty Firth, ScottishPower, Glenmorangie, Whyte & Mackay, and Diageo**. The end users are the distilleries, which operate seven sites in the region and want to develop 'net-zero' whisky for their customers around the world. Future projects include the potential to decarbonise wider regional hydrogen transport applications and the potential for hydrogen export to other regions and countries, particularly Germany and the Netherlands.

PARTNERS: Pale Blue Dot Energy, Port of Cromarty Firth, Scottish Power, Glenmorangie, and Whyte & Mackay

100 MW INITIALLY

2022

UK

https://www.pocf.co.uk/2021/03/05/port-of-cromarty-firth-launches-bold-new-plan-for-highlands-green-hydrogen-hub/#:~:text=The%20North%20of%20Scotland%20Hydrogen,in%20the%20region%20with%20hydrogen

PORT OF PORT LA NOUVELLE - HYD'OCC PROJECT "RENEWABLE HYDROGEN FOR REGIONAL DISTRIBUTION AND EXPORT"

CASE STUDY

Hyd'Occ is developing the first hydrogen production unit by water electrolysis in Port-La-Nouvelle. Hyd'Occ will oversee the construction and operation of the 50 MW electrolyser, allowing for the production of 6,000 tonnes of green hydrogen per year by 2030. The hydrogen production unit will be connected to an electric substation, where more than 90 MW of electricity from renewable sources (PV plant, offshore and onshore wind) are injected. This commitment will enable the production, storage, transportation, and commercialisation of **regional renewable hydrogen** to meet the needs of future targeted uses. Accompanied by a storage solution and adapted logistics, Hyd'Occ will be able to deliver green hydrogen in large quantities, several tonnes per day and at a competitive price. Production is expected to start in the second half of 2023, in a distribution area within a 250 km-radius of Port-La-Nouvelle.

PARTNERS: QAIR, AREC, DEME

50 MW

2024

FRANCE

https://www.agence-adocc.com/actualites/hydocc-met-en-oeuvre-la-strategie-regionale-pour-un-deploiement-massif-de-lhydrogene-vert-a-echelle-industrielle/

PORT OF OOSTENDE - HYPORT PROJECT "RENEWABLE HYDROGEN FOR GREENING LOCAL OPERATIONS"

CASE STUDY

PARTNERS: Port of Oostende, DEME Concessions and PMV

70 MW

2024 - 2025

BELGIUM

Hyport is a project under consideration by **Port of Oostende, DEME Concessions and PMV**, which aims to reduce CO_2 emissions in Flanders by around 500,000 to 1,000,000 tonnes per year by producing green hydrogen. Renewable hydrogen at the Port of Oostende will serve as both an energy source for electricity, transport, heat, and fuel purposes and as a raw material for industrial purposes.

In the first phase of the process, the general feasibility will be further investigated, and a development plan will be worked out. By 2022, the roll-out of a large-scale **shore-based power project**, running on green hydrogen, will commence. The installation of the hydrogen bunkering for CTV will be done in close cooperation with the Belgian wind park operators. The project's finishing line will be crossed in 2025 with the completion of a commercial 70 MW renewable hydrogen plant in the context of the planned new offshore wind concessions.

https://www.portofoostende.be/en/news/hyportr-green-hydrogen-plant-in-ostend

PORT OF AMSTERDAM - H2ERMES PROJECT "RENEWABLE HYDROGEN FOR A MORE SUSTAINABLE AMSTERDAM"

CASE STUDY

PARTNERS: Port of Amsterdam, Nouryon, Tata Steel

100 MW

2021 FID

NETHERLANDS

Hydrogen plays a key role in Port of Amsterdam's plans and strategies for decarbonisation. Three major market players - **Nouryon, Tata Steel and port of Amsterdam** - are exploring the possibility of constructing a 100 MW green hydrogen plant project: H2ermes. From 2024, Hydrogen will be produced in the Tata Steel site using green electricity. This will provide a clean energy source with many applications. The expertise needed to build the plant is supplied by the chemical firm Nouryon, which is a market leader in large-scale electrolysis. **Wind farms near Ijmuiden will supply the plant with 100 MW of electricity which is then fed to Nuryon's electrolysers**. Tata Steel, a steel manufacturer, will be one of the green hydrogen consumers. The company strives for fully climate neutral production by 2050. Tata Steel can also make use of the oxygen produced in the same process. Port of Amsterdam sees opportunities for green hydrogen in the Amsterdam port area. The port has attracted many new sustainable and circular initiatives. Examples include **plastics recycling, the production of biofuels and synthetic kerosene**. The Port, together with the industries, seeks to shift industrial processes from using natural gas to green hydrogen. Projects are underway to use hydrogen and CO_2 to produce green fuels for shipping and aviation. Additionally, the first hydrogen refuelling station, which arrived in 2020, is promoting the transition to clean transport in both the port and the city.

https://www.portofamsterdam.com/nl/nieuws/h2ermes-groene-waterstof

PORT OF DEN HELDER "RENEWABLE HYDROGEN FROM PV"

CASE STUDY

PARTNERS: Engie, Liander, Total (Pitpoint), Damen

2 MW, UP TO 15 MW

2021

NETHERLANDS

Together with consortium partners ENGIE, Total/PitPoint clean fuels and Damen Shipyards Group, Port of Den Helder is working hard on to develop a hydrogen filling station at Kooyhaven. The project is supported by Liander N.V., New Energy Coalition and Ontwikkelingsbedrijf Noord-Holland Noord (NHN).

The project covers the generation and use of sustainable electricity (including the use of congestion surpluses on the network), via electrolysis to green hydrogen from PV, the construction of a filling station for both road traffic and shipping and finally a demonstration vessel from Damen that will run entirely emission-free on hydrogen.

All efforts are going towards achieving the hydrogen strategy of Port of Den Helder by 2022, and achieving net-zero emissions in the Wadden Sea and for wind farms in the North.

https://portofdenhelder.nl/news/blue-hydrogen-factory-in-den-helder-in-sight

PORT AUTHORITY OF BILBAO “HYDROGEN IN INNOVATION AND DECARBONISATION”

CASE STUDY

PARTNERS: Petronor (Repsol Group), Port Authority of Bilbao

N/A

2024

SPAIN

The Board of Directors of the Port Authority of Bilbao has decided to award Petronor, a subsidiary of the Repsol group, the tender for a 46,700 m² plot of land in Punta Sollana, within the Port of Bilbao.

The project consists of constructing one of the world’s largest plants for the production of synthetic fuels using renewable hydrogen generated with renewable energy.

The first phase of the investment will amount to EUR 67 million, with the facilities planned to come into operation as from 2024. Later, Phases II and III, to be developed alongside the first phase, will involve an additional investment of EUR 76 million on the construction of a plant for the generation of gas from urban waste, such as paper, cardboard, plastic and textiles, which will avoid the use of traditional fuels and promote a circular economy.

https://www.bilbaoport.eus/en/news/the-port-authority-of-bilbao-awards-petronor-a-plot-of-land-for-the-development-of-strategic-innovative-and-sustainable-projects/

WindEurope is the voice of the wind industry, actively promoting wind power in Europe and worldwide. It has over 400 members with headquarters in more than 35 countries, including the leading wind turbine manufacturers, component suppliers, research institutes, national wind energy associations, developers, contractors, electricity providers, financial institutions, insurance companies and consultants. This combined strength makes WindEurope Europe's largest and most powerful wind energy network.

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