Spring 2024

Ports & Offshore Wind

Capacity at Danish ports is pivotal to realising goals for offshore wind power

CIP foundation

Photo: Port of Grenaa

1. Preface

In this report, the CIP Foundation presents an analysis of the capacity of Danish ports with respect to plans and political goals for the deployment and expansion of Danish offshore wind energy. A requirement for realising these ambitious plans for the expansion of offshore wind energy in Danish waters is that port capacity is sufficient to deal with the manufacture of turbine components, installation of turbines, and subsequent servicing and maintenance. The point of departure is that Danish ports are to have the necessary areas and capacities; not only to be able to install and service Danish offshore wind farms, but also to maintain the stronghold of Danish ports in international competition.

The analysis is partial, and it only addresses port areas for the installation of offshore wind turbines. There are no analyses of the role of ports as enablers, for example for cargo and passenger transport, for tourism, for the fishing industry, for the energy sector, etc. Furthermore, there are no analyses of the need for port capacity arising from the defence agreement or for manufacture of offshore wind turbine components and shipping of foundations.

The majority of global carbon emissions stem from the production and consumption of energy. This makes energy pivotal in the green transition with respect to electricity for households, fuels for transport and energy consumption in industry.

The green transition requires massive deployment of renewable energy. Denmark currently has 2.3 GW offshore wind power installed. The ambition is to develop the North Sea to its full potential of 35 GW offshore wind power up to 2050. Besides this, there is deployment of 6.3 GW in the Baltic Sea, construction of energy islands, PtX installations and hydrogen piping systems. Up to 2030 alone, renewable energy corresponding to 9 GW, an energy island, and probably a number of open-door projects, are to be established.

In other words, over the next five years, Denmark is to complete a five-fold expansion of current wind capacity that was built up historically over more than 20 years. Neighbouring countries have similar challenges and plans.

Common for all these development plans is that they depend on the ports from which elements and components for wind farms are to be shipped. Over the next few years, expansion will accelerate, and offshore turbines will become larger. This puts pressure on the capacity of ports, as ports will be a vital hub in the green transition of energy production.

Ports will have more, larger and new tasks requiring considerable capacity development, and this will have to be financed.

In this report, the CIP Foundation presents an analysis of Danish port capacity in light of the Danish goals for deployment of offshore wind energy, and expected developments in the size of turbines. The analysis also includes a mapping of competition in northern Europe, as well as a description of the socio-economic benefits Denmark could achieve, if Danish ports win in the competition and become preferred ports for installation of offshore wind power for both Danish projects and nearby foreign projects.

Installation of offshore wind capacity not only generates both growth and employment in itself; it also generates activity across the entire value chain for offshore wind power through development, production and maintenance. The wind turbine industry today generates annual revenues of more than DKK 100 bn. in Denmark, but the potential is larger. Furthermore, there is a risk of loss of market share if Denmark fails to create a good framework for development of the industry.

As a society, Denmark has a unique opportunity to win a good part of the business arising from the historically huge increases required by the Oostende Declaration of 300 GW offshore wind in the North Sea. Therefore, it is vital to expand and upgrade port capacity with strong quays and deep channels.

The CIP Foundation's analysis should be considered in context with goals for security of energy supplies, a faster green transition and consequential accelerated carbon reductions. There is also the objective for Denmark to remain a green front-runner and to maintain its strong green value chain.

We hope you'll find this report interesting.

Torben Möger Pedersen
Chairman of the CIP Foundation

Charlotte Jepsen
Managing partner of the CIP Foundation

CIP FOUNDATION: ROADMAP FOR A DANISH HYDROGEN INFRASTRUCTURE FOR THE FUTURE

In May 2023, the CIP Foundation presented its Roadmap for a Danish hydrogen infrastructure for the future. The roadmap charts the way to establishing a Danish hydrogen economy with pipe connections between production areas in Denmark and export countries to the south. Expansion of the infrastructure will facilitate an export potential of around DKK 100 bn., although this is subject to considerable deployment of new renewable energy sources, particularly offshore, where realisation of the plan will require deployment of 52.5 GW in the North Sea and 6.9 GW in the Baltic.

Reaching this goal of new deployment and development of a Danish hydrogen industry requires sufficient port capacity to deal with installation of the turbines. This report could therefore be considered as a natural follow-up, but also an important prerequisite, for the CIP Foundation's Roadmap for a Danish hydrogen infrastructure for the future.

2. Summary

Danish port capacity is not sufficient to meet the goals for deployment of new offshore wind energy to which Denmark is committed through international declarations. The combination of under-dimensioned ports, uncertain and uneven planning of Danish offshore wind energy deployment, and relatively few port areas means that there will be considerable bottlenecks in the expansion.

Even with investments in Danish installation ports, the pressure for new deployment around 2030 will be in excess of what is possible in the areas available.

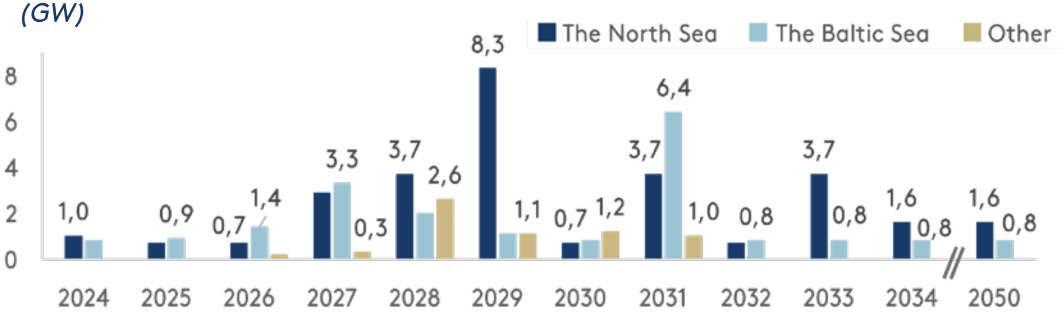
However, the Danish ports are competitive internationally, and with investment in port infrastructure, clear signals from politicians, and long-term and transparent planning of future offshore wind deployment, Danish ports will be able to contribute to meeting political goals, and generate thousands of new jobs and exports worth DKK 35 bn.

This is the result of this report from the CIP Foundation, which, on the basis of deployment goals for offshore wind, maps Danish port capacity, international competition in nearby waters, and the socio-economic impacts.

2.1 Major plans for offshore wind

Under the Oostende Declaration and the Marienborg Declaration, Denmark has committed itself to a considerable expansion of offshore wind power in the North Sea and in the Baltic Sea. Up to 2050, Denmark is expected to deploy a total of 52 GW of Danish offshore wind power, and including nearby foreign wind farms that are closest to the Danish ports, a total of 91 GW will have to be shipped in the period. The known political goals for expansion concentrate around 2030. This means that the rate of deployment will be uneven. See figure 2.1. At the same time, turbines will become bigger and heavier. This will put unprecedented pressure on the ports from which the turbines are to be manufactured and installed.

Figure 2.1: *Deployment goals and foreign offshore wind close to Danish ports, (GW)*



Note: Deployment of offshore wind after 2030 is uncertain and in practice the rate of deployment is very likely to be more uneven.

Source: KPMG (2023)

Main conclusions

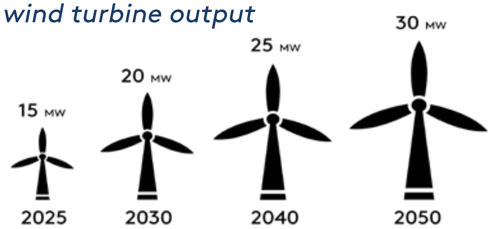
- Danish installation ports are currently very competitive internationally, and they are an important player in European offshore wind energy deployment.
- From as early as 2025, when the 15 MW offshore turbine is expected to be the industry standard, the majority of Danish Ports will neither have quays with adequate bearing capacity nor channels of sufficient depth to install offshore wind turbines.
- Therefore, in order to meet the political expansion goals, considerable investments in Danish installation ports are required to enable ports to cope with larger turbines and heavier components.
- However, even if there is sufficient investment in all relevant wind-power ports, expansion goals are unlikely to be realised, as these are concentrated in a few years, around 2030.
- By investing in upgrading Danish installation ports, reducing time spent on processing by authorities, and bringing forward tendering procedures for offshore wind power, Denmark could meet the expansion goals, while also generating growth and exports worth DKK billions.

Data basis
The data basis for this report and its analyses is information from the individual ports. Data collection and processing was completed on 31 December 2023 Specific decisions regarding port expansion and specific investments in port facilities after this date are not included in the analyses. This includes the decision to dredge the Port of Esbjerg to 12.5 m and reinforce the bearing capacity of quays to 40 tonnes per square metre.

2.2 Danish ports are not geared up for the expansion

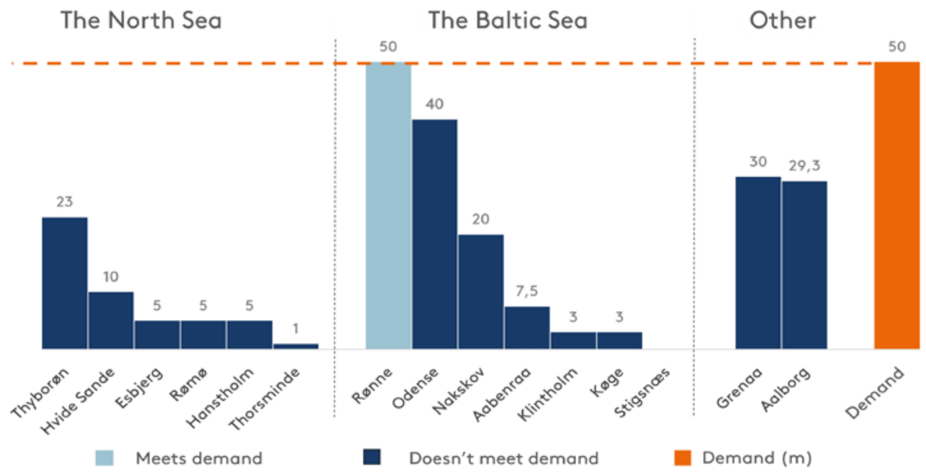
From 2025, 15 MW offshore wind turbines are likely to be the industry standard. A weight increase of 50% will put new demands on the bearing capacity of quays and the depth of channels, as developers call for ports that can manage larger and heavier components.

***Figure 2.2:** Expected development in wind turbine output*



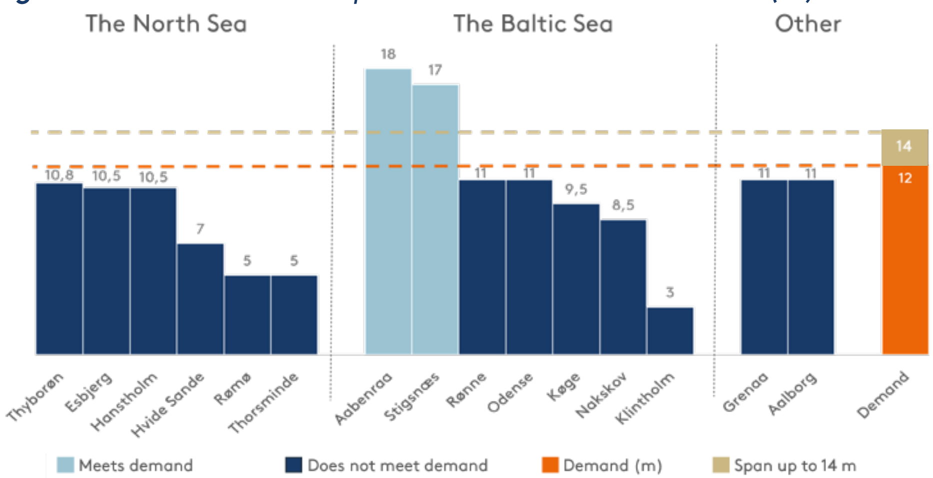
Note: The 15 MW turbine is expected to gradually become industry standard in the years after 2025.
Source: KPMG (2023)

***Figure 2.3:** Port bearing capacity in relation to demand 2025 - (t/m²)*



Source: KPMG (2023)

***Figure 2.4:** Ports' channel depth in relation to demand 2025 - (m)*



Source: KPMG (2023)

Only very few harbours currently can meet the demands, and therefore significant investment will be required in all Danish production and installation ports if they are to maintain their strong competitive position. The alternative is to adapt the installation process, and this will make it more expensive to install offshore wind farms: costs which will have to be borne by the developers and installers.

However, even with an upgrade of all Danish installation ports, Denmark will not be able to realise deployment goals, as bottlenecks will arise in the peak years around 2030. There will also be a need for additional port areas, for example to produce and ship turbine foundations.

The precise time when bottlenecks arise is sensitive to how rapidly the 15 MW turbine becomes the industry standard, and to whether the necessary tendering procedures for offshore wind projects are conducted and/ or bids for projects are tendered. With regard to the Danish deployment goals, this will simply displace when bottlenecks arise and possibly exacerbate the size of the challenge, since deployment will then have to be carried out over a shorter period.

***Figure 2.5:** Bottlenecks in the North Sea, Baltic Sea and other areas, divided by investments in upgrades of quay bearing capacity and channel depth in all Danish installation ports, (GW).*

Source: The CIP Foundation based on KPMG (2023)

2.3 Danish ports among the best in Europe

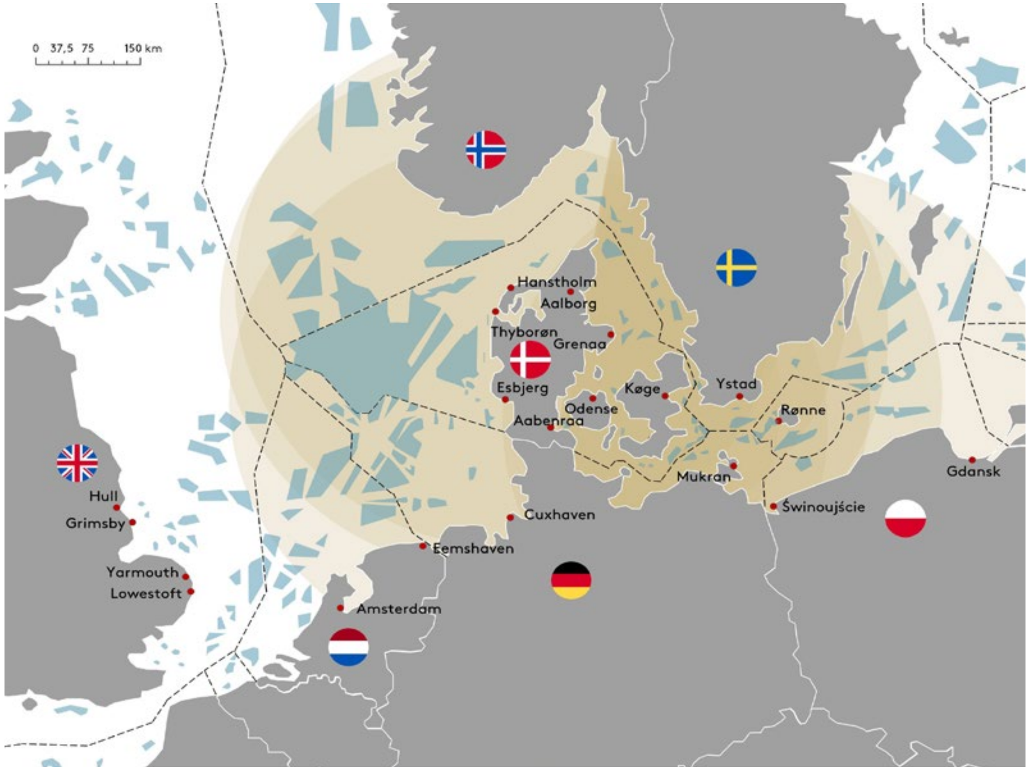
Danish installation ports are well positioned in the international competition in northern Europe, which faces increasing shortages of port capacity. Both the capacity of Danish installation ports and their many years of experience with installing offshore wind turbines make Danish ports significant players in the North Sea and the Baltic.

In the North Sea, the Port of Esbjerg is particularly prominent with high annual capacity of 2.5 GW, while in the Baltic Sea, the Port of Rønne dominates with an annual installation capacity of around 1.5 GW, which is primarily used for Polish and German offshore wind farms.

The Danish installation ports are currently competitive, but by as early as 2025, when 15 MW turbines are expected to be the industry standard, their competitive edge risks being significantly undermined unless there is investment in upgrading channels and quays at all relevant ports.

The strongest competitors to Danish ports are Eemshavn in the Netherlands for the North Sea and Mukran in Germany for the Baltic Sea. The Danish edge provides good opportunities for Danish ports to continue to have a role in installing foreign wind farms. The competition is very much subject to the political and economic framework countries set for ports, and in this context, the foreign ports seem to be able to focus infrastructure investments and implement them more rapidly, thereby strengthening their competitiveness in the future. This also applies for Danish marine areas, all of which are subject to competition.

***Figure 2.6:** Danish installation ports can compete on foreign land*



Note: Circles illustrate the range of Danish ports (≈370 km)
Source: The CIP Foundation

2.4 Investment in Danish installation ports generates growth, employment and exports

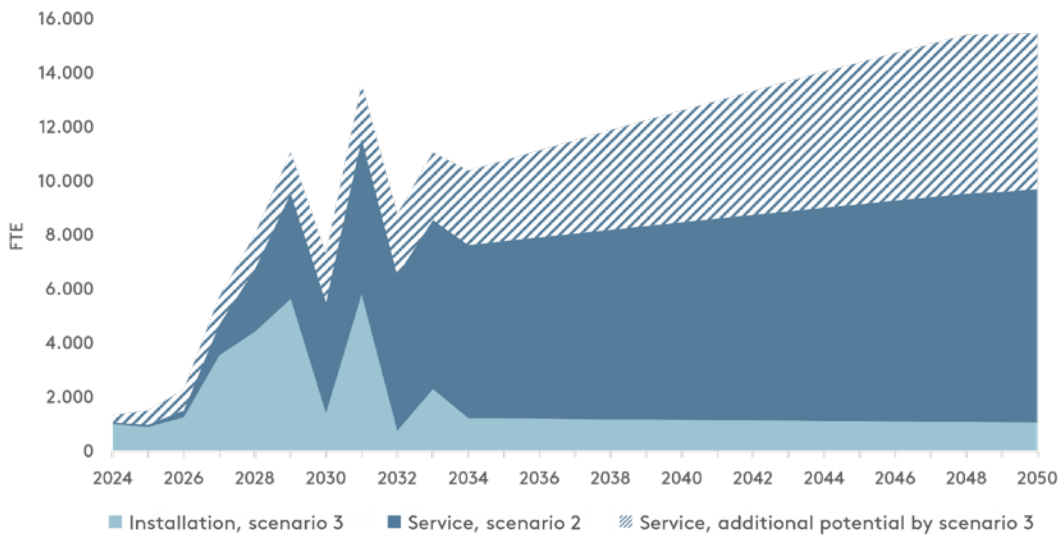
Considerable offshore wind power is already being installed from the ports in Esbjerg and Rønne, and this is generating growth and employment. This analysis reveals that there is a potential to invest further in Danish installation ports to bring total capacity up to about 10 GW per year. This will generate further growth and employment, both while the deployment plans are being realised, and later when the turbines need maintaining.

Installation of Danish wind projects alone has been estimated to have a total Danish employment effect of 27,000 FTE up to 2050, corresponding to around 1,000 FTE per year in the period.

In total, installation of Danish offshore wind energy from Danish ports will generate an accumulated GDP contribution of DKK 48 bn. up to 2050, of which around DKK 32 bn. is linked to the North Sea, 10 bn. to the Baltic Sea and DKK 6 bn. to other areas.

If Danish ports gain a share in foreign offshore wind deployment, this will generate an additional Danish employment effect of 19,400 FTE over the entire period. Overall, exports of port capacity may provide an additional contribution to Danish GDP of DKK 35 bn. in 2050, and such exports could entail long-term maintenance requirements for the offshore wind farms totalling 14,000 FTE. In this context, smaller ports in particular, for example Thorsminde Harbour in the North Sea and Klintholm in the Baltic Sea, may be relevant in realising the potential.

***Figure 2.7**: FTE related to installation and service*



Source: The CIP Foundation

2.5 Need for long-term planning

Ports are currently facing a serious challenge: Driven by political objectives, large amounts of offshore wind power are to be deployed, but only few projects are known about. Uncertainty about where specific projects are to be completed, when they are to be completed and who is to be responsible for development causes uncertainty throughout the entire value chain.

This uncertainty and the absence of an investment signal from politicians means that it is not possible to make decisions about these large, irreversible infrastructure investments in Danish port capacity.

There is also no full overview of projects, and this can make overall expansion more costly because the total port capacity will not be exploited efficiently. If the market is to be able to manage the major development plans, there is a need for long-term planning and allocation of roles, so that investment decisions in port infrastructure can be made on a reliable basis.

The CIP Foundation recommends:

1. **Investing in an upgrade of Danish wind-power ports, so that port capacity allows for installation of up to 10 GW offshore wind power annually.**
Investment should secure adequate and future-proofed channels and quay bearing capacity, and the geographical orientation should be based on areas available and wind expansion planned. The upgrade could be anchored through investments in:
   a. North Sea: Esbjerg, Thyborøn and Hanstholm (≈4.6 GW/year)
   b. Baltic Sea: Rønne, Odense, Køge and Aabenraa (≈4.1 GW/year)
   c. Coastal waters: Grenaa and Aalborg (≈1.9 GW/year).

2. **Convert expansion goals to expansion plans** by conducting tendering procedures up to and including 2031 in order to cement investment signals in the value chain. The expansion plan can be adapted and any projects can be brought forward so that Denmark can meet its expansion goals with the port capacity available.

3. **Reduce time spent on processing by the authorities**, so that Danish ports can have permits, licences and appeals determined more rapidly, with consequential contributions to meeting Denmark's expansion goals.

Contents

1. Preface..........2

2. Summary..........3

3. Danish port capacity..........8
3.1. Ports play several key roles for offshore wind..........8
3.2. Offshore wind turbines are getting larger and heavier..........9
3.3. International goals increase the rate of offshore wind deployment around Denmark..........10
3.4. Larger turbines and higher rates of deployment change demand for port capacity..........11
3.5. Denmark has many relevant offshore wind ports..........12
3.6.Danish offshore wind ports will be under-dimensioned in the future..........14
3.7. Danish ports have potential to install large amounts of offshore wind..........16
3.8. Deployment plans cause bottlenecks in Danish ports..........17
3.9. Conclusion: Danish Ports cannot realise Denmark's goals..........20

4. International competition..........21
4.1. Several important competitive parameters..........21
4.2. The Danish part of the North Sea is exposed to competition..........22
4.3. Esbjerg, Eemshaven and Cuxhaven dominate the north-eastern North Sea..........23
4.4. Denmark has few installed wind turbines and relatively low goals..........24
4.5. Port capacity in the North Sea is under pressure – especially in 2029-2030..........24
4.6. Danish and Dutch ports must compete for the German market..........25
4.7. The Danish part of the Baltic Sea and other areas are exposed to competition..........26
4.8. The Port of Rønne dominates the Baltic Sea..........26
4.9. Denmark has many turbines and ambitious goals..........26
4.10. Denmark and Germany can compete for areas in Poland and Sweden..........27
4.11. Political and economic frameworks affect the rate of competition developments..........28
4.12. Conclusion: Denmark is at the forefront internationally, but is under threat..........29

5. Socio-economic impacts of offshore wind installation..........31
5.1. Offshore wind generates growth and jobs..........31
5.2. Danish ports can generate huge benefits from Danish offshore wind power..........32
5.3. Danish ports can generate an export boom..........33
5.4. Danish ports generate sustainable growth and employment..........33
5.5. Offshore wind concentrates growth in outlying areas of Denmark..........33
5.6. Huge potential..........34
5.7 Conclusion: Offshore wind installation generates growth and massive exports..........35

6. Danish Ports - challenges and opportunities..........36
6.1. Ports have several key roles for offshore wind power..........36
6.2. Defence and energy production take up new areas..........36
6.3. Global supply chains under pressure..........36
6.4. Lack of investment signals..........37
6.5. Danish ports can deliver competition and synergies..........38
6.6. From deployment goals to deployment plan..........38

7. Conclusion..........39
7.1. Deployment plans and technological development are putting pressure on Danish ports..39
7.2. Danish ports are not geared for the deployment..........39
7.3. Denmark cannot realise deployment goals..........39
7.4. The challenges repeat in Europe..........40
7.5. Danish ports have a strong position in the North Sea and in the Baltic Sea..........40
7.6. Political and economic frameworks impact development..........40
7.7. Investments can generate jobs and growth..........40
7.8. Danish ports can generate an export boom..........41
7.9. Ports can generate sustainable growth..........41
7.10. Need for long-term planning..........41

8. Sources..........42

At the CIP Foundation we conceive and implement long-term projects that support the transformation of Danish society towards a more sustainable future. We are an independent and non-profit organisation that delivers tangible and implementable solutions for a long-term transformation of Danish society.

For more information, visit cipfonden.dk

3. Danish port capacity

Ports are vital for the installation of offshore wind power, and Danish port capacity therefore determines the amount of offshore wind power that can be installed in Danish waters, the rate at which offshore wind power can be expanded, and whether political expansion goals can be met. This chapter analyses Danish port capacity in relation to the plans for offshore wind deployment laid down by politicians as part of the green transition in Denmark and Northern Europe. The chapter is based on the analysis in December 20231 by KPMG for the CIP Foundation of Denmark's port capacity, expectations about technological developments and planned offshore wind deployment in the waters around Denmark up to 2050, as well as on individual dialogues with a number of important players in and around the ports.

3.1 Ports play several key roles for offshore wind

Ports have several roles in the value chain for offshore wind. Their functions can generally be grouped into three categories: manufacture of wind turbines, installation of wind turbines offshore, and the subsequent maintenance of offshore wind farms in the operating phase. The three functions place different demands on ports and therefore, in practice, but not always, they are managed by different ports.

MANUFACTURING PORTS

Subcomponents such as turbine towers, nacelles and blades are becoming ever larger and heavier. This makes transport by road difficult, and, in future, turbines will therefore increasingly be manufactured at or near ports, so that they can be transported by sea instead. When the turbine components have been manufactured, they can be moved directly from the manufacturing facility to a cargo ship, and then transported to an installation port. A manufacturing port can also function as an installation port.[2] The foundations for wind turbines are often shipped directly from the same port where they were manufactured.

Manufacturing ports require large areas and production halls, strong quays and adequate depths of channels and port basins. There must also be access to a large, qualified labour force.

Klintholm and Thorsminde

The ports at Klintholm and Thorsminde are both small ports, in the past primarily for fisheries and tourism. In step with the expansion of wind power, the ports have developed as service ports for wind projects. Klintholm port is currently a service port for the Baltic 2 and Kriegers Flak offshore wind farms in the Baltic Sea, while Thorsminde has been selected as the service port for Thor Offshore Wind Farm in the North Sea, which is expected to be completed as Denmark's largest wind farm in 2027.

Sources: Holstebro Municipality, City & Port of Thorsminde, and Business Vordingborg.

Port of Odense

At 8.5 million m², Denmark's largest port measured by area is the Port of Odense, the former Lindøværft. More than 100 companies operate at the port.
Odense is today Northern Europe's largest manufacturing port for offshore wind turbines. Vestas has manufactured more than 600 nacelles at the port, and Bladt Industries has produced more than 110 foundations.

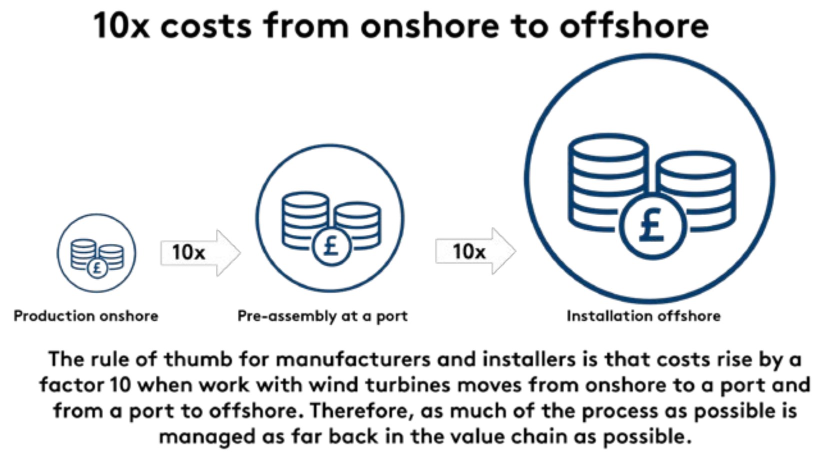
Source: Port of Odense

INSTALLATION PORTS

Before the offshore turbines are shipped, they have to be made ready, so as to reduce the work hours required at sea and thus to reduce costs. See Figure 3.1. In this context, an installation port serves as a pre-assembly hub for wind turbine manufacturers, at which the turbine towers, blades and nacelles are assembled and made ready. After this, the components are transported by ship, a jack-up, from the port to the installation area. It usually takes around 24 hours to erect a wind turbine at sea once the installation vessel has reached the offshore area.

An installation port makes areas and quays available in the period during which an offshore wind farm is erected.

Figure 3.1: *Costs of managing turbines onshore, at a port, and offshore*



Source: The CIP Foundation

1 "Analyse af havnekapacitet i relation til udbygning af dansk havvind", KPMG for the CIP Foundation, December 2023
2 Danish Civil Aviation and Railway Authority (2024): Havneatlas, kortlægning af danske erhvervshavne, KPMG (2023)

According to the Danish Transport Authority, around 150-200,000 m² is required for one year at an installation port to construct a 1 GW offshore wind farm. Foundations are often shipped and installed separately from other ports, and these require around 100-200,000 m² for six to nine months. The geographical location of an installation port is also important, as the transport time is a significant expense for the developer. An installation port should ideally be located no further than 120 to 200 nautical miles from the installation area, corresponding to 220-370 km.[3]

Port of Esbjerg

The Port of Esbjerg is the leading port in Europe for installation of wind turbines. 80% of Europe's wind capacity has been installed from Esbjerg, and since 2001, 23.6 GW has been installed from the port.

By far the majority of this capacity has been in the form of foreign wind farms, e.g. Butendiek, Northwind, Sandbank, Dantysk, Humber Gateway and Westermost Rough. In Denmark, Horns Rev I, II and III were installed from the Port of Esbjerg.

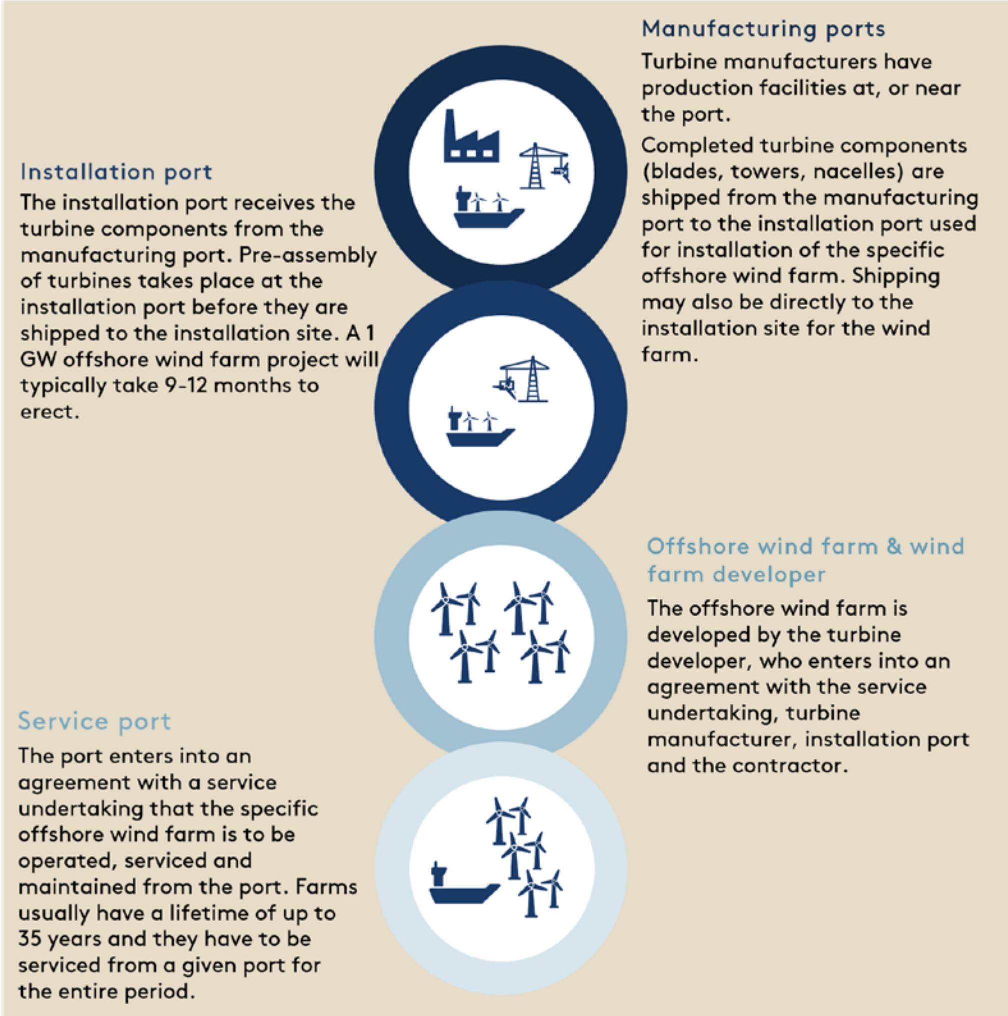
Source: Port of Esbjerg

SERVICE PORT

Ports continue to play a significant role during the operating face of a wind farm, providing regular servicing and repair of the turbines. Crews and small spare parts usually have to be transported to the offshore wind farm from a service port.

As there will be frequent voyages over the around 30-year lifetime of the offshore wind farm, the distance from the port is the most important factor in the choice of service port.

Figure 3.2: *The ports' role in the value chain for offshore wind*



Source: KPMG (2023)

Therefore, many ports, including small ports, can function as service ports, as only a small port area and quay length are required. An area for a helipad may be attractive, as developers are increasingly demanding the possibility to transport personnel and small components by helicopter when vessels are restricted by bad weather, or high waves. As offshore wind farms become larger and located further from shore, there will be requirements for larger vessels to carry larger crews and service more turbines.[4]

One possibility is to use larger flotels to accommodate crews for longer periods close to the wind farm. This can potentially change the nature of the need for port capacity for service tasks.

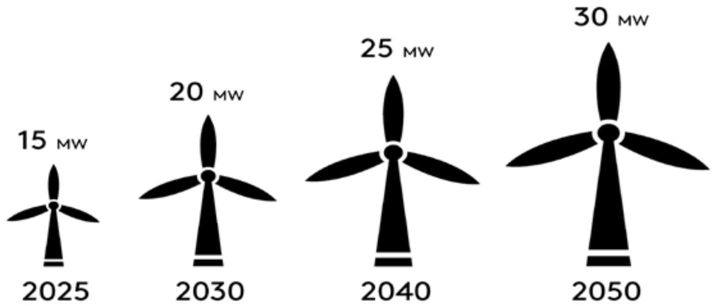
3.2 Offshore wind turbines are getting larger and heavier

Offshore wind turbines have developed over time in both size and efficiency. Whereas the Danish offshore wind farms built in the early 2000s consisted of 2 MW turbines, the industry standard today is 8-10 MW.5 Turbine manufacturers expect this development to continue also after the 15 MW turbine has become the industry standard in a few years. It is expected that offshore wind turbines will be up to 30 MW by 2050.[6]

The increasing efficiency of wind turbines has implications for their size and weight. An increase from 8 MW to 30 MW means blades will be twice a long, towers three-times as high and the weight will increase ten-fold.[7] The 15 MW turbine, which is expected to be industry standard by as early as 2025, will stand 150 m tall, have a blade length of 117 m and a weight of more than 1,700 tonnes.[8]

3 KPMG (2023)
4 Today, CTVs - Crew Transfer Vessels - are largely used for the transport of personnel from the service port to the offshore wind farm. When the offshore wind turbines become larger and are placed further from land, SOVs - Service Operation Vessels - will be used to a greater extent to handle servicing.
5 The Danish Energy Agency (2023)
6 KPMG (2023)
7 An 8 MW offshore wind turbine weighs, excluding the foundation, 878 tonnes. For comparison, a 30 MW turbine is expected to weigh 7,911 tonnes. Source: KPMG 2023.
8 Height is exclusive of wingspan. Source: KPMG 2023.

***Figure 3.3**: Expected development in wind turbine output*



Source: KPMG (2023)

Increases in the size and weight of wind turbines present new challenges for ports, as installers will be demanding more space, deeper channels and greater quay bearing capacities for handling the wind turbines. Ports must be able to meet these demands to be internationally competitive. See Table 3.1. Otherwise installers will have to adapt the installation process and ship fewer towers at a time, for example, which will raise installation costs.[9]

3.3 International goals increase the rate of offshore wind deployment around Denmark

The expected large numbers of wind turbines to be erected in future will put pressure on ports, as ever more port space will be needed to cope with the expansion. This analysis operates with three scenarios for future offshore wind deployment.[10]

***Table 3.1**: The significance of developments in turbine output for the size and weight of components*

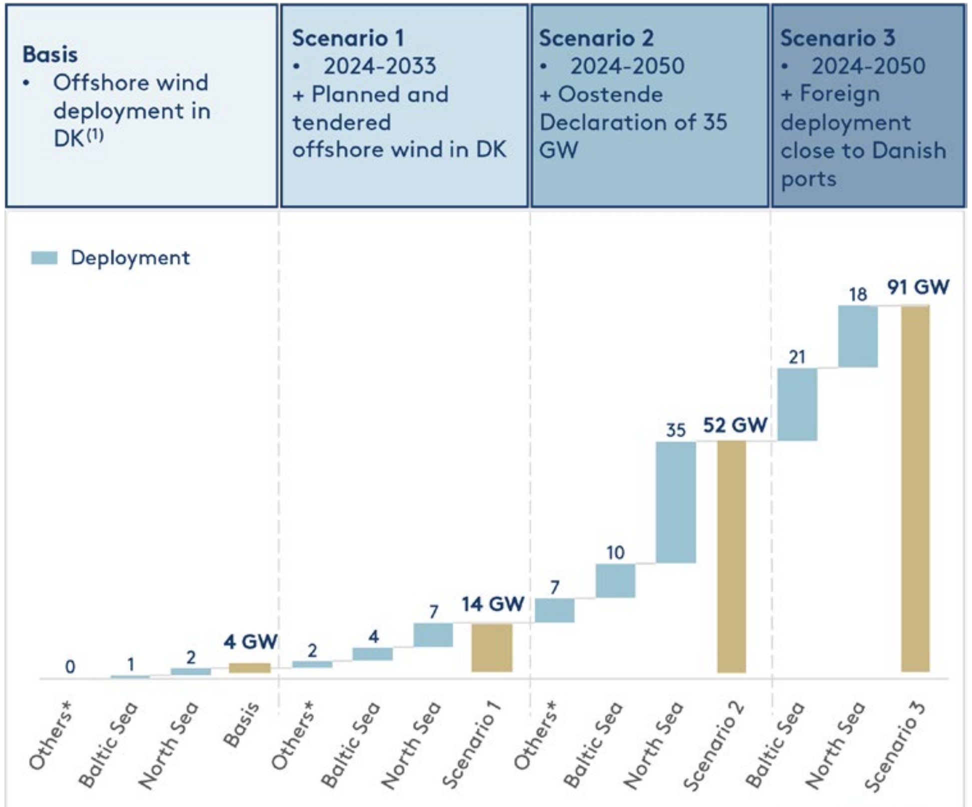
Parameter	Unit	8 MW	10 MW	15 MW	20 MW	25 MW*	30 MW*
Turbine blade							
Length	m	80	86	117	122	143	166
Weight	t	35	42	65	84	115	156
Turbine tower							
Length	m	110	119	150	200	246	303
Weight	t	558	605	860	2,070	3,391	5,555
Diameter	m	N/A	6	8	N/A	10	13
Nacelle							
Weight	t	285	446	840	945	1,442	2,200

Source: KPMG (2023)

The three scenarios illustrate different scenarios for the likely offshore wind capacity to be installed from Danish ports in the North Sea, the Baltic Sea (including Smålandshavet) and other areas (comprising the Kattegat, the Skagerrak, the Danish Straits and the Great Belt), based on existing deployment plans and political goals.

Whereas the 4 GW baseline scenario illustrates expansion already completed or underway, scenario 1 includes a further 14 GW currently under tender, Energy Island Bornholm, the North Sea Energy Island, as well as offshore wind turbine projects approved for establishment under the Open-Door scheme. Scenario 2 includes open-door projects that have not been rejected as well as the Danish part of the Oostende Declaration and the Marienborg Declaration, respectively. Scenario 3 includes a number of foreign offshore wind projects which are likely to be installed from Danish ports because the projects are closer to a Danish port than ports in the home country for the projects.[11] As foreign offshore wind projects have historically used Danish ports for installation,[12] and fulfilment of climate

***Figure 3.4**: Three scenarios for expansion of offshore wind*



Source: KPMG (2023)

9 Statement from installer interview
10 For further elaboration, see KPMG 2023
11 Date of data collection is 1.12.2023. Source: KPMG 2023.
12 For example the Port of Esbjerg in the North Sea has installed 22 GW, where Denmark itself has only about 1 GW installed. Source: DI (Danskindustri.dk) & The Danish Energy Agency (ens.dk)

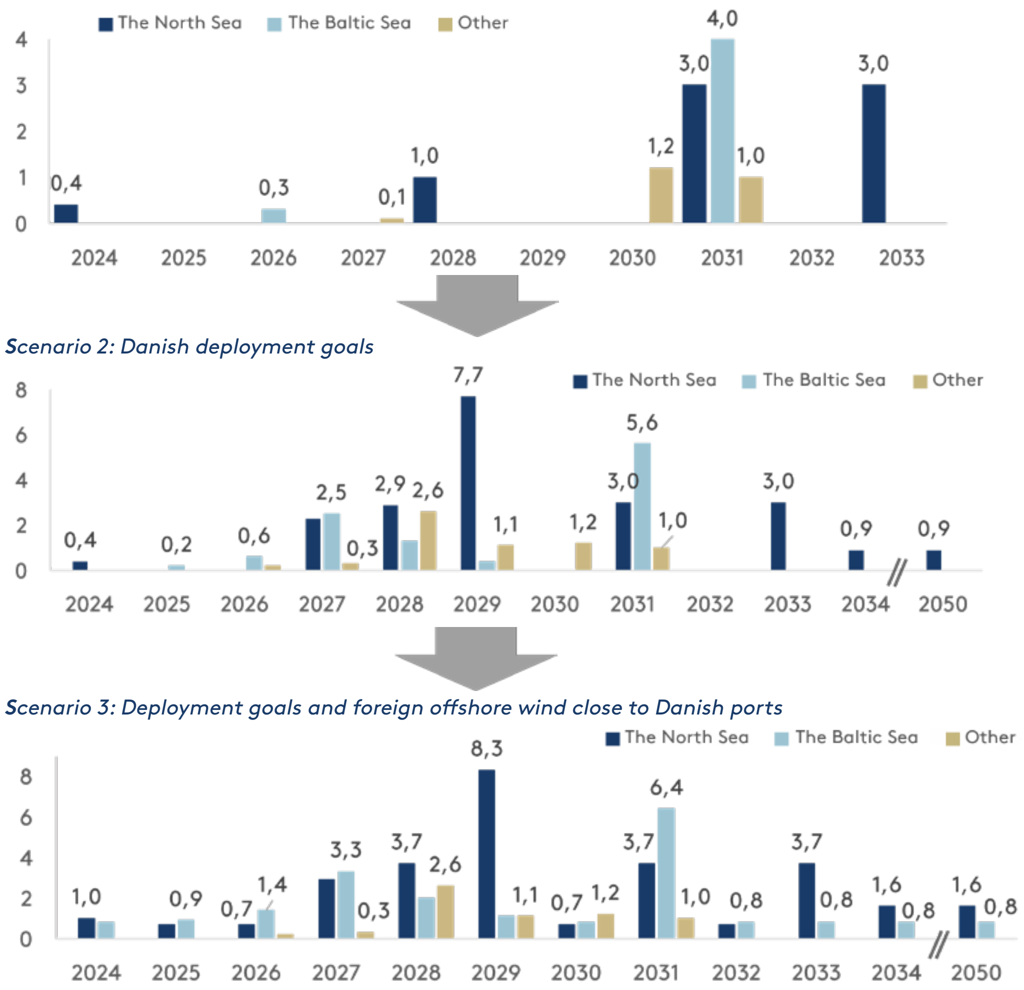
and deployment goals has high political priority, scenario 3 has been assessed as the most realistic estimate of the offshore wind deployment likely to be installed from Danish ports.

The offshore wind forming the basis for the three scenarios can be placed on a timeline of when the offshore wind farms start producing.[13] The start-up dates for the Danish offshore wind farms included in scenarios 1 and 2 are known, while it has been assumed that the foreign offshore wind and parts of the Oostende and Marienborg declarations will be deployed evenly in the period after 2030. Offshore wind expansion after 2030 is uncertain, and in practice the rate of deployment is likely to be more uneven and, depending on national tendering procedures and ambitions to move quickly, risk being bunched together during the 2030s. This issue applies for several European countries.

While the deployment profile for scenario 1 shows considerable deployment in 2031 and 2033 because of the North Sea Energy Island and Energy Island Bornholm, scenario 2 indicates larger deployment around 2029, primarily from the Thybo I and II projects in the North Sea. Expansion in the Baltic Sea in 2031 is driven by increasing deployment of around Bornholm. The deployment profile in scenario 3 shows a steady increase throughout the period, driven by foreign projects.

***Figure 3.5:** Three scenarios for offshore wind expansion (GW)*

Scenario 1: Planned and approved offshore wind in Denmark



Note: Deployment of offshore wind after 2030 is uncertain and in practice the rate of deployment is very likely to be more uneven, as seen in the years before 2030.

Source: KPMG (2023)

Mitigating initiatives

Mitigating initiatives reduce the need for channel depth and quay bearing capacity, and they are widely used today. For example, insufficient channel depth can be mitigated by transporting wind turbine components on barges or tugs to the wind farm, so that jack-up vessels do not have to sail all the way into the port. Similarly, quays with insufficient bearing capacity can be reinforced with metal plates to distribute the load, just as quays can be lengthened temporarily.

Mitigating initiatives reduce the need for structural investments in ports, but as the costs of these initiatives usually rests with the installer and developer, ports with adequate dimensioning are preferred.

3.4 Larger turbines and higher rates of deployment increase and change demand for port capacity

Greater turbine size and weight increases the need for deeper channels and stronger quays, and the expected deployment and installation of offshore wind from Danish ports will increase the need for pre-assembly areas. While the area determines the annual amount of offshore wind that can be installed, dimensioning factors – channel depth, bearing capacity, quay length and breadth – determine whether offshore wind power can be installed from a specific port and the costs of installation.[14] When an offshore wind farm is to be installed, the developer of the farm selects the port from which installation is to take place. Therefore, capacity and dimensions of the port affect whether the port is internationally competitive. A survey of installers[15] shows the capacity and dimensioning in demand by offshore wind turbine installers and manufacturers today, and their expectations for the future. See Table 3.2.

***Table 3.2:** Current and future demand for port dimensions*

	Depth (m)	Quay bearing capacity (t/m^2)	Quay length (m)	Quay breadth (m)	Area (m^2/GW/år)
2023	10	5	250	30-60	160,000
2025-	12-14	50	250	30-60	160,000-200,000

Source: KPMG (2023)

13 The commissioning year for Danish projects in scenarios 1 and 2 is known, while parts of the Ostend and Marienborg declarations as well as the foreign offshore wind from scenario 3 are assumed to be equally developed during the period.

14 Ports that do not meet the demand for dimensioning measures can make use of mitigation measures and thus avoid structural investments, KPMG (2023)

15 KPMG (2023)

Installers and manufacturers expect the demand for ports with deep channels and large quays with high bearing capacity to increase. Future demand for quay lengths and breadths will be more or less the same as today. The area needed to install offshore wind will be between 160,000 and 200,000 m²/year per GW.[16]

The two dimensioning factors that will see the greatest increase in demand (i.e. channel depth and quay bearing capacity) should be considered in relation to the port area. The port area needed for installation is significant today and will be so in future as well, and the majority of Danish ports are neither large enough now, nor have the option to expand in the future to accommodate offshore wind installation. Port area is therefore what can allow a port to be an installation port, as both channel depth and quay bearing capacity can be increased through dredging and reinforcement, respectively, although this will require considerable investment. However, in the short term, the dimensioning factors are what can allow a port to exploit a given port area for installation, unless mitigating initiatives are applied. Installation of offshore wind also requires access to a buffer area early on for storing the large components during manufacture. Buffer areas may also be necessary to deal with any delays in the value chain.

3.5 Denmark has many relevant offshore wind ports

Denmark has a large number of ports with potential to play a role in the value chain for offshore wind. The map to the right shows commercial ports in Denmark with a cargo turnover of more than 100,000 tonnes in recent years.

***Figure 3.6**: Potential ports in Denmark: Commercial ports with a cargo turnover above 100,000 tonnes*

Source: KPMG (2023)

Although most of the ports can function as service ports if offshore wind is installed close enough to the port, not all ports can function in practice as installation ports for offshore wind turbines. Many ports are too small and, in many cases, upgrading the port facilities to manage installation would be too extensive compared with the installation potential. On the other hand, many of the ports could receive service vessels, and could establish service facilities and a helipad, which are facilities that are increasingly in demand in connection with service tasks.[17]

Based on Danske Havne[18] and other sources, KPMG has identified a number of Danish commercial ports with potential to play an active role in offshore wind installation in the future. Most of these ports are already functioning as installation, production and/or service ports, while the remaining have the potential to do so based on their existing dimensioning factors.[19]

The ports have been categorised on the basis of three criteria:
The geographical location of the port is a vital strategic and economic factor for offshore wind. Short distances secure lower installation costs, more time-efficient use of technical labour and minimum production downtime.

Facilities and capacity are crucial for ports to be able to attract installation or service tasks. Ports with sufficient port area, good channel depth or high quay bearing capacity will potentially have lower investment needs.

Potentials for development are also very important for the ports. For example, a port located in a relatively unbuilt-up area will have better opportunities for expansion to create the area necessary, while ports with nearby housing will be more restricted.

***Figure 3.7**: Criteria for selection of wind ports*

Source: KPMG (2023)

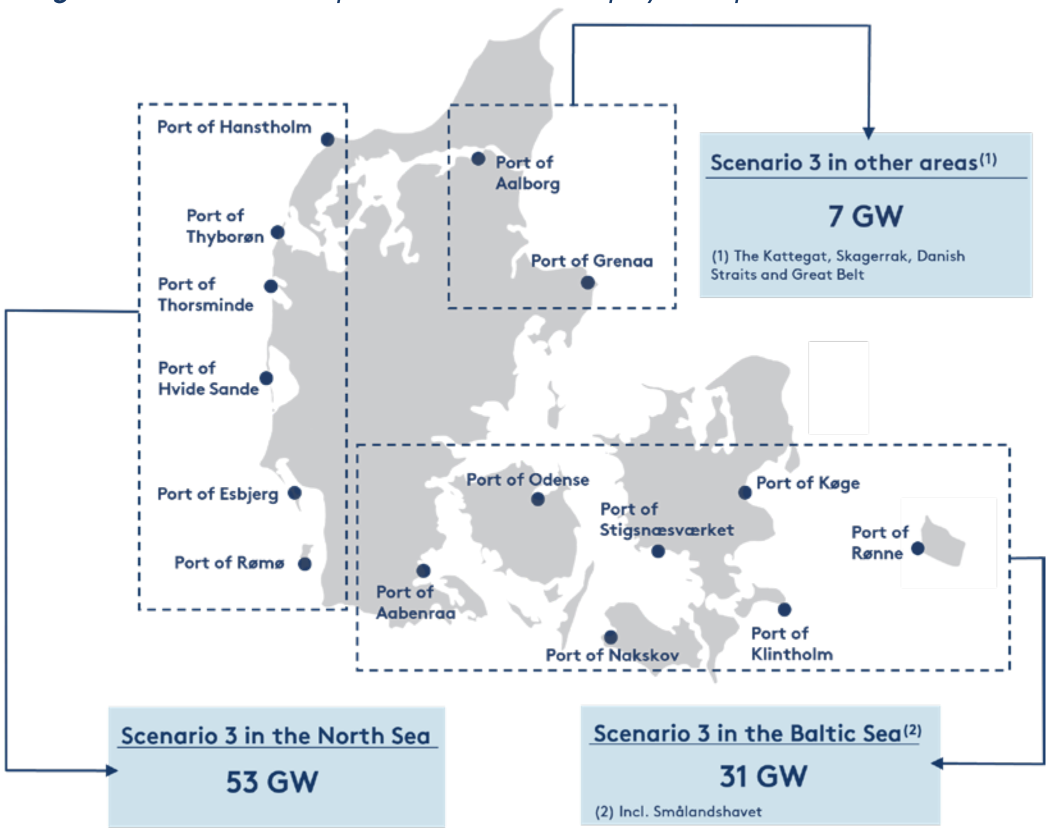
16 KPMG (2023)
17 KPMG (2023)
18 Danish Ports (danskehavne.dk)
19 Stignæs Olie Terminal has been selected by KPMG as it meets all dimensioning factors. Hanstholm Havn has been selected by KPMG as they have experience with O&M of offshore wind and have potential for expansion into an installation port.

The ports identified are marked on the map below for the expected offshore wind deployment in scenario 3, which is deemed the most realistic scenario.

Offshore wind deployment in the North Sea and the Baltic Sea accounts for 92% of total wind installation. The ports marked on the map may be strategically crucial for both installation and subsequent servicing of offshore wind turbines. As the developer covers the costs of the installation of offshore wind, the different ports can operate in other areas than those shown in the illustration.

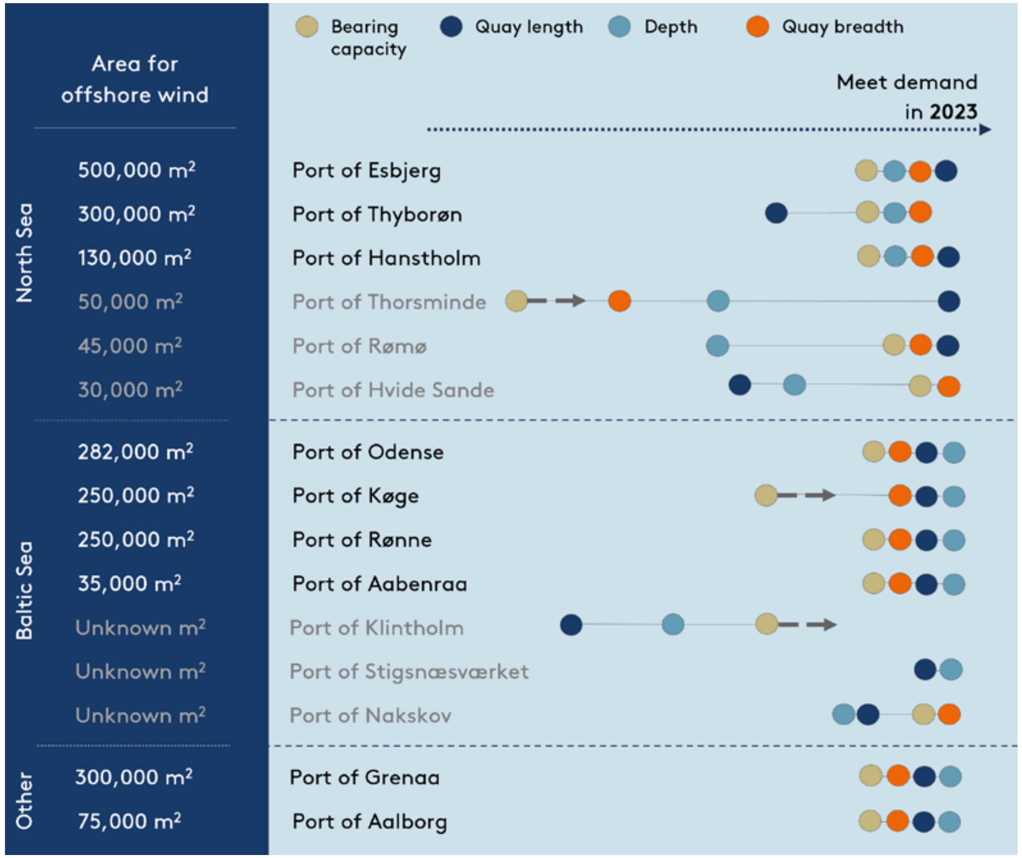
For example, the Port of Odense may be more relevant in relation to projects in the Kattegat, the Skagerrak, the Danish Straits or the Great Belt, as transport to the Baltic Sea is inhibited by having to sail under the Great Belt bridge, through Drogden in the Sound and past Copenhagen Airport.[20]

Figure 3.8: *Danish wind ports in relation to deployment plans*



Source: KPMG (2023)

Figure 3.9: *Dimensions of Danish wind ports in relation to demand from manufacturers and installers, 2023.*



Note: Dimensions demanded in 2023: Bearing capacity 5 t/m², quay length 250 m, depth 10 m, quay breadth 30-60 m. This is met by the majority of ports in 2023. Ports marked in grey are smaller ports from which installation is not expected.

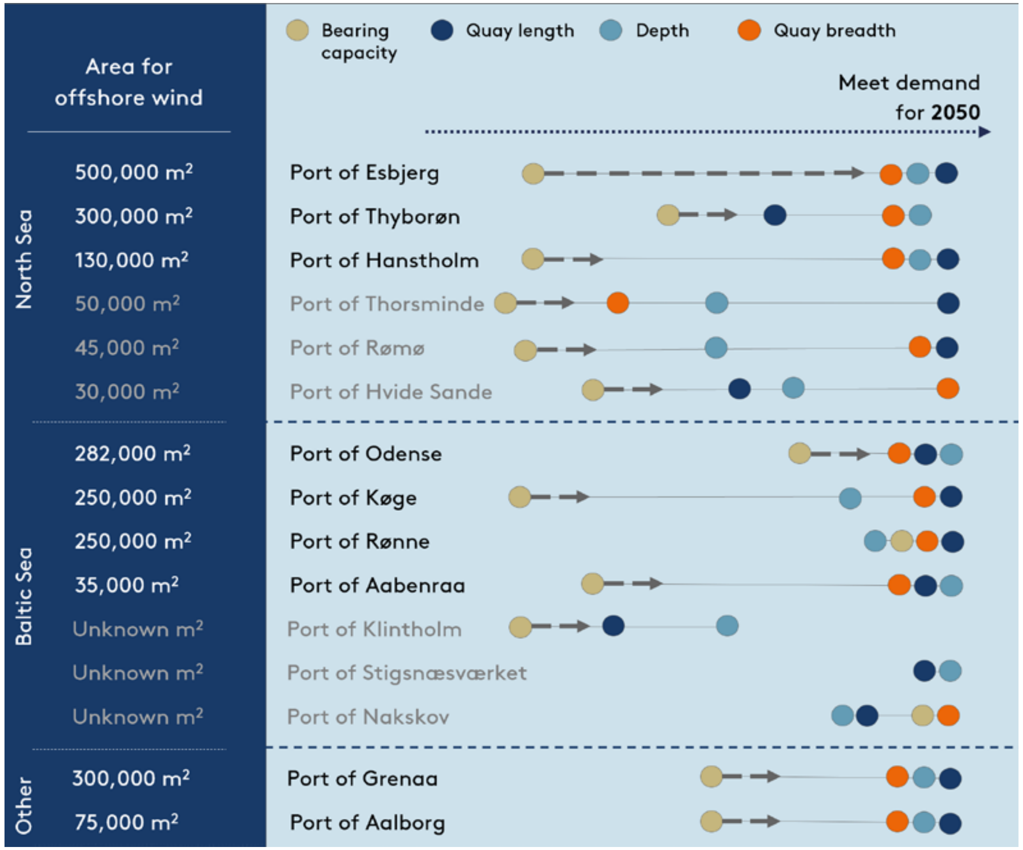
Source: KPMG (2023)

The majority of the ports identified meet the current demand related to installation of offshore wind, see Figure 3.9.

The ports at Thorsminde, Hvide Sande and Klintholm do not meet the current demand with regard to port dimensions, and Rømø is challenged by shallow channel depths. Furthermore, these four ports only have a relatively small port area, and in practice offshore wind installation from these ports will not be realistic, as investments in the port would not be viable with the limited volumes that could be installed from the ports.

20 Transport under the Storebæltsbroen may depend on the fact that turbine towers can be transported separately or horizontally, e.g. using barges.

***Figure 3.10**: Dimensions of Danish wind ports in relation to demand from manufacturers and installers, 2025 – 2050*



Note: Dimensions demand up to 2050: Bearing capacity 50 t/m², quay length 250 m, depth 12-14 m, quay breadth 30-60 m. Ports in the Baltic Sea area and other areas such as the Port of Grenaa and Port of Aalborg meet dimensions demand more consistently, while ports in the North Sea area have a large spread. Ports marked in grey are smaller ports from which installation is not expected
Source: KPMG (2023)

Comparing the current port dimensions with the expected demand resulting from larger major wind turbines, dispersion increases, and the majority of the ports are not dimensioned to be able to meet future demand for bearing capacity and/or channel depths. See Figure 3.10.

The ports are closest to meeting the future demand in the Baltic Sea and in "Other areas", while ports in the North Sea are more challenged. Most of these ports are challenged by bearing capacity, and installers will therefore have to carry out mitigating initiatives to be able to ship from these ports, unless the technical bearing capacity of the ports is increased.

CASE: Port of Esbjerg & mitigation

The Port of Esbjerg is Europe's largest offshore wind port, and over the years more than 22 GW have been installed from the port. In comparison, around 2.3 GW of offshore wind power has been installed in Danish waters and less than 1 GW in the North Sea. Esbjerg has a low technical bearing capacity of 5 tonnes/m2 but it has historically increased the bearing capacity through mitigating initiatives (temporary reinforcements), as has been required in connection with several projects. A port can therefore be competitive if it has experience with mitigating initiatives to ensure an optimal framework for offshore wind projects.

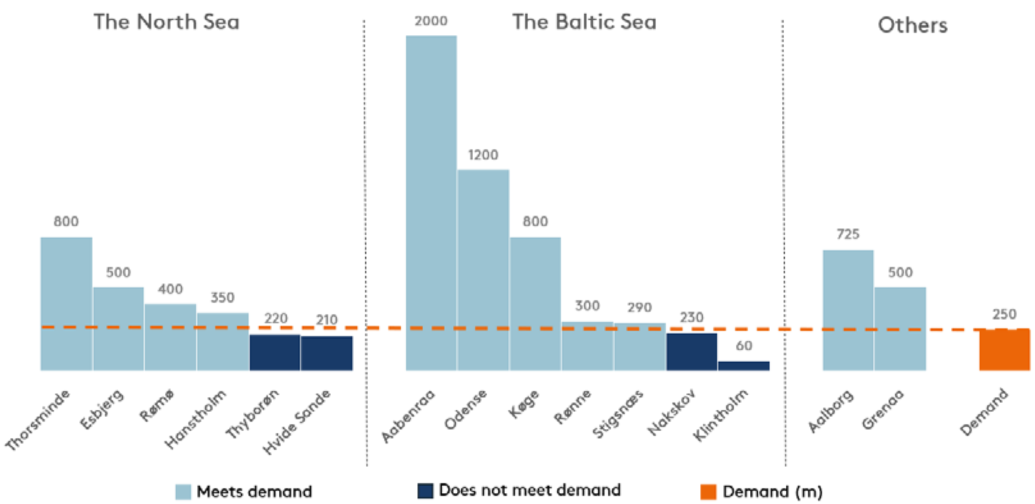
Sources: KPMG 2023, Danish Industry (Danskindustri.dk) & Danish Energy Agency (ens.dk)

3.6 Danish offshore wind ports will be under-dimensioned in the future

As future wind turbines become larger and heavier, installers' demands for port dimensions will change. The dimensions identified as particularly important for the installation of offshore wind are quay length, quay breadth, bearing capacity and channel depth.

Quay length is essential so that installation vessels can moor when turbine towers, blades and nacelles are to be shipped from the port to the wind farm. Only few ports, including Thyborøn, Hvide Sande, Nakskov and Klintholm, do not meet both current and future demands for a quay length of 250 m.

***Figure 3.11**: The ports' quay lengths comapred to demand, 2025 - (m)*



Source: KPMG (2023)

Similarly, **quay breadth** is important for installation vessels because there is a need for either shore cranes or ship cranes to move large components from port to ship. Large components include blades of more than 100 m, which have to lie across the vessel, and turbine towers with a diameter of 8-10 m. The majority of the ports identified meet the demand for quay breadth, and this demand is not expected to change significantly over time because it is more important that the area behind the quay is large enough for storage and pre-assembly.

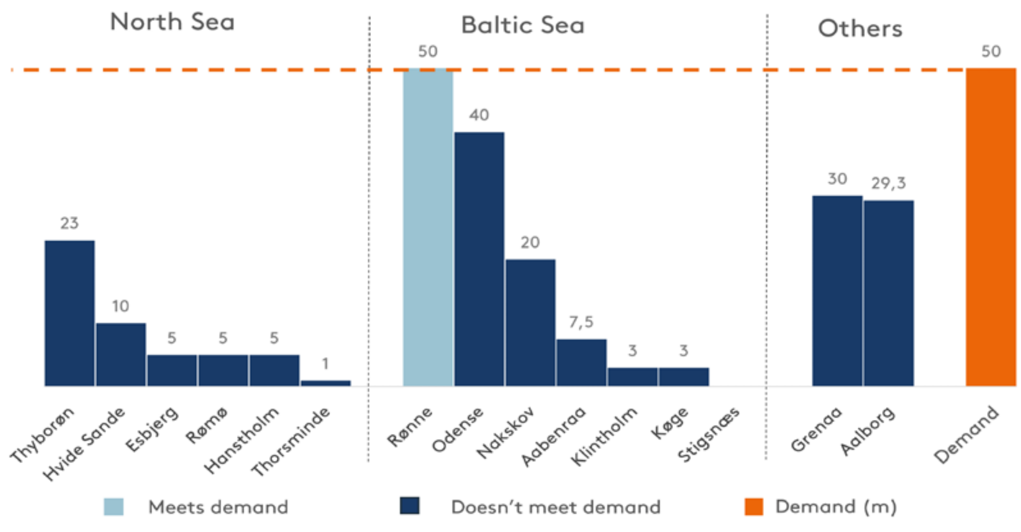
The bearing capacity of quays is a critical dimension for managing turbine components as they become larger and heavier. In just a few years, when the 15 MW turbine becomes the industry standard, weight is expected to increase from around 1,100 tonnes to 1,700 tonnes, corresponding to an increase of around 50% compared to the 10 MW turbine.

When the 15 MW turbine is introduced, probably around 2025, the demand for a high bearing capacity will therefore already exceed the technical capacity of all of the ports except for Rønne. Investment is needed to meet the demand for increased bearing capacity, unless mitigating initiatives are taken to temporarily increase the bearing capacity.

Like bearing capacity, **channel depth** is also a critical dimension to shipping offshore wind turbines. Vessels to ship turbine components from port to wind farm are likely to be larger and have a deeper draught, and therefore installers will demand a channel depth of 12 - 14 m.

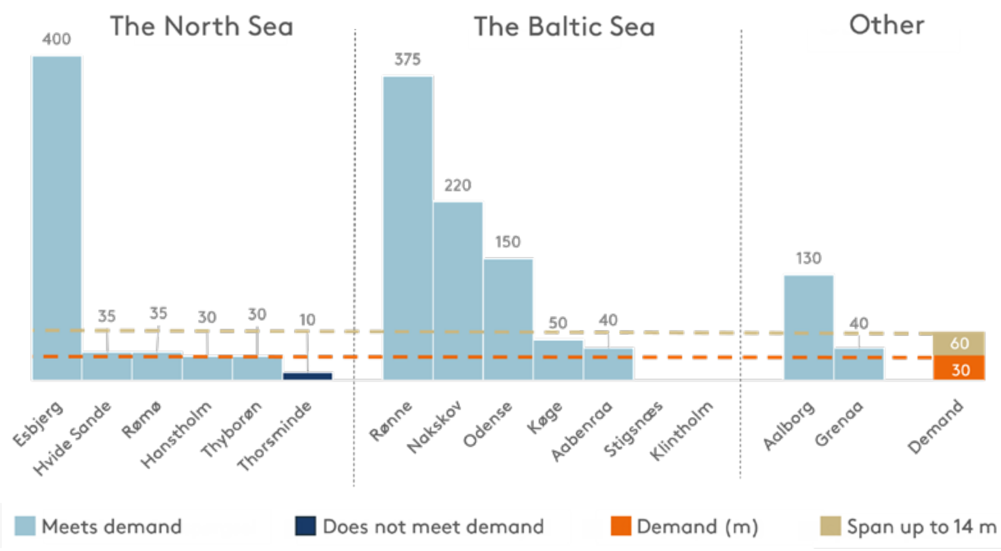
Only two ports, the Port of Aabenraa and Stignæs Oil Terminal, can currently meet this demand. However, a large number of ports come close, with channel depths of

***Figure 3.13**: Ports' bearing capacity, 2025 - (tonnes/m²)*



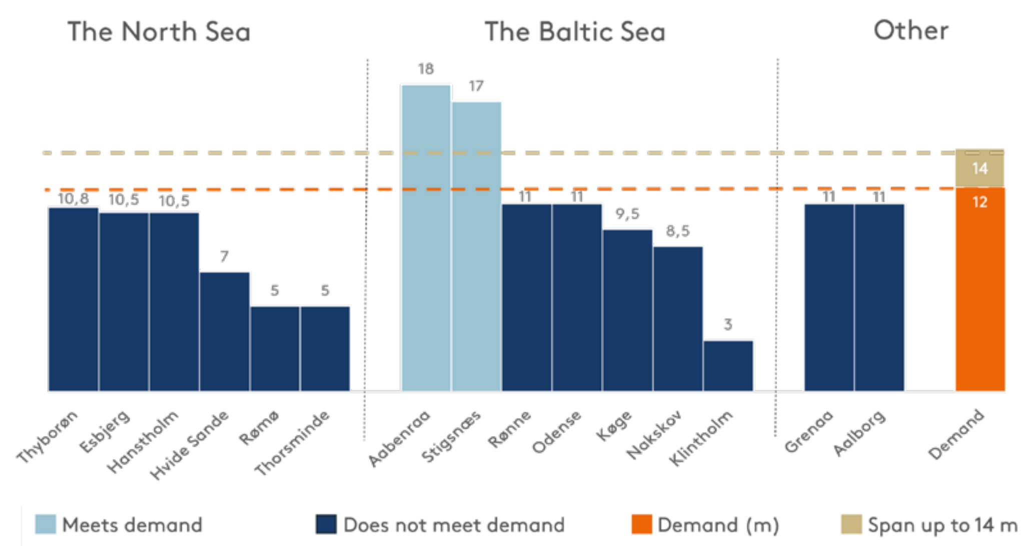
Source: KPMG (2023)

***Figure 3.12**: Ports' quay breadth in relation to demand, 2025 - (m)*



Source: KPMG (2023)

***Figure 3.14**: Ports' channel depth in relation to demand 2025 - (m)*



Source: KPMG (2023)

between 9 and 11 m. As the channel depth is already relatively good in the identified ports, investment in dredging will be more manageable. On the other hand, obtaining permits to dump dredging spoil is often a challenge and may delay or prevent a project. Also in this context, it is possible to carry out mitigating initiatives, e.g. by using barges instead of jack-ups.

The offshore wind ports identified basically meet future demands for quay breadth and quay length, but with respect to channel depth and quay bearing capacity, where demands will change, there is a significant difference between the ports' dimensions and the installers' demands. If Danish ports are to be attractive to installers and future offshore wind installation, in most places there are needs for investment in both deeper channels and stronger quays.

As mentioned earlier, the alternative is mitigating initiatives that make the installations themselves more costly. So, in principle, the question is who is to bear the costs: the ports or the installers?

3.7 Danish ports have potential to install large amounts of offshore wind

Port space is a critical but dynamic dimension for deployment of new offshore wind. Service ports require less port area (around 8,000 m^2), while considerably more space is required at ports that ship offshore wind turbines. Shipping 1 GW offshore wind over a period of one year requires between 150,000 and 200,000 m^2. However, this area requirement does not exclude smaller ports, as smaller ports will have the possibility to ship projects over a longer period of time, or ship smaller projects.

However, in practice, a relevant installation port will require port areas of a certain size.

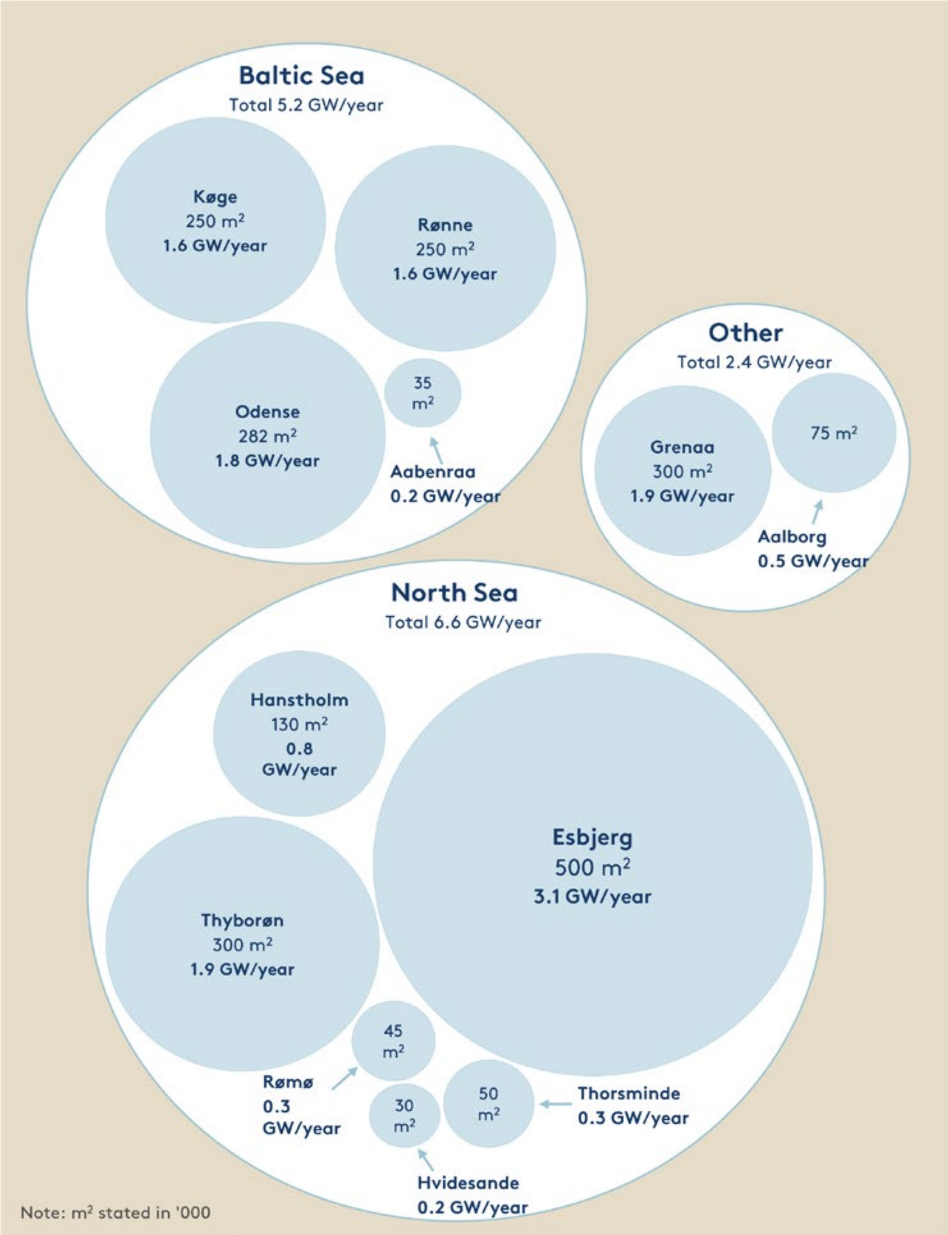
Including smaller ports although they are unlikely to be relevant as installation ports, Figure 3.15 shows the number of GW that ports could potentially install per year on the basis of the port area available for offshore wind installation. In the North Sea, Esbjerg is the largest port, with a possible annual installation of 3.1 GW, while in the Baltic Sea, the ports at Odense, Rønne and Køge can install most wind power, with a capacity of 5 GW/year. In "Other areas", Grenaa is the largest port, with a possible 1.9 GW annually.

Overall, the offshore wind ports identified can install 14.2 GW annually.

These results are based on relatively optimistic calculations of the requirement for port area, and they include the port area from the smallest ports, which are unlikely to be developed into installation ports.

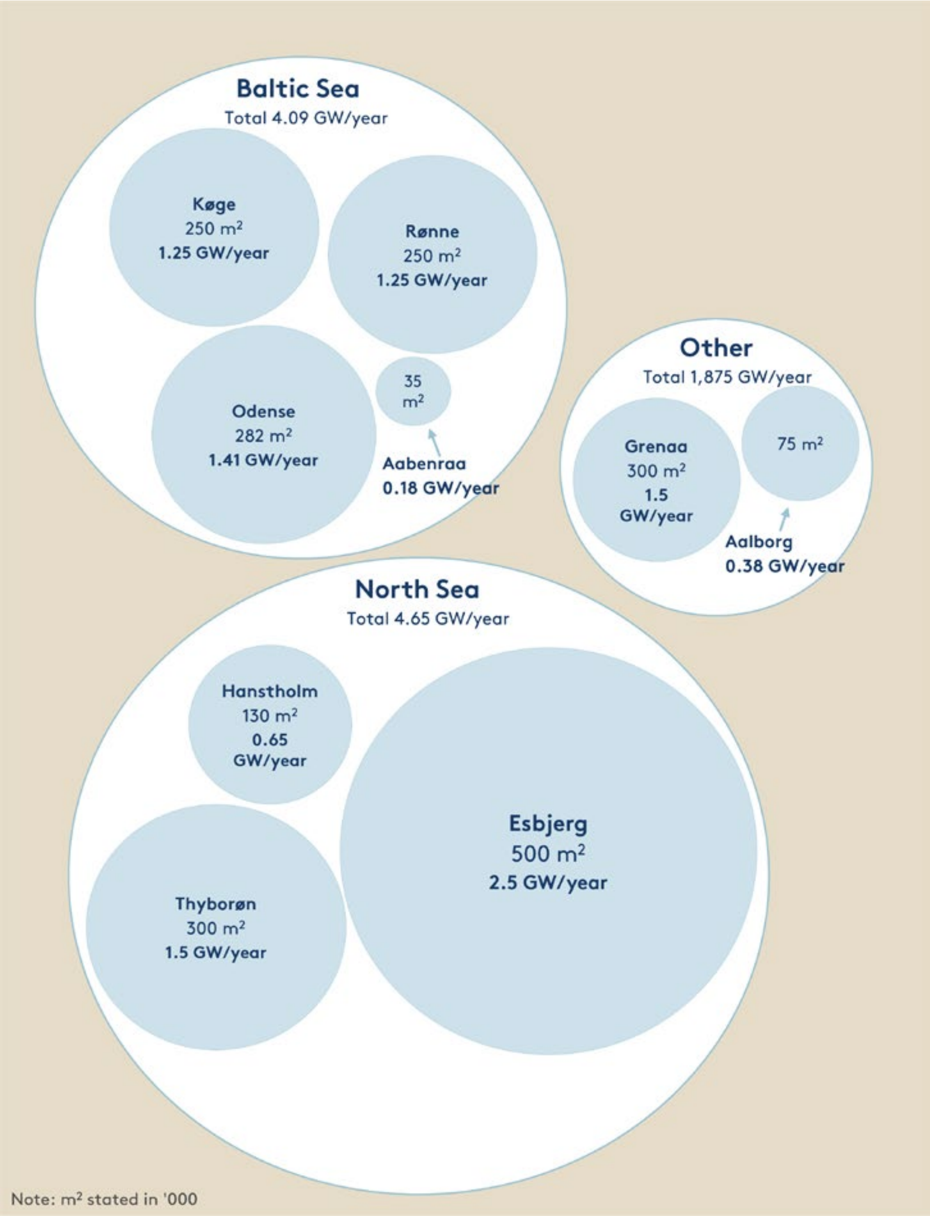
If port capacity is instead calculated on the basis of a requirement for port area of 200,000 m^2 per GW per year, and if the smallest ports at Thorsminde, Rømø and Hvidesande, which are unlikely to play a role as installation ports, are excluded, port capacity falls by 25% . See Figure 3.16 on the following page.

***Figure 3.15:** Area at Danish ports for offshore wind installation, calculations by KPMG*



Source: KPMG (2023)

***Figure 3.16**: Area at Danish ports for offshore wind installation, conservative scenario*



Source: The CIP Foundation based on KPMG (2023)

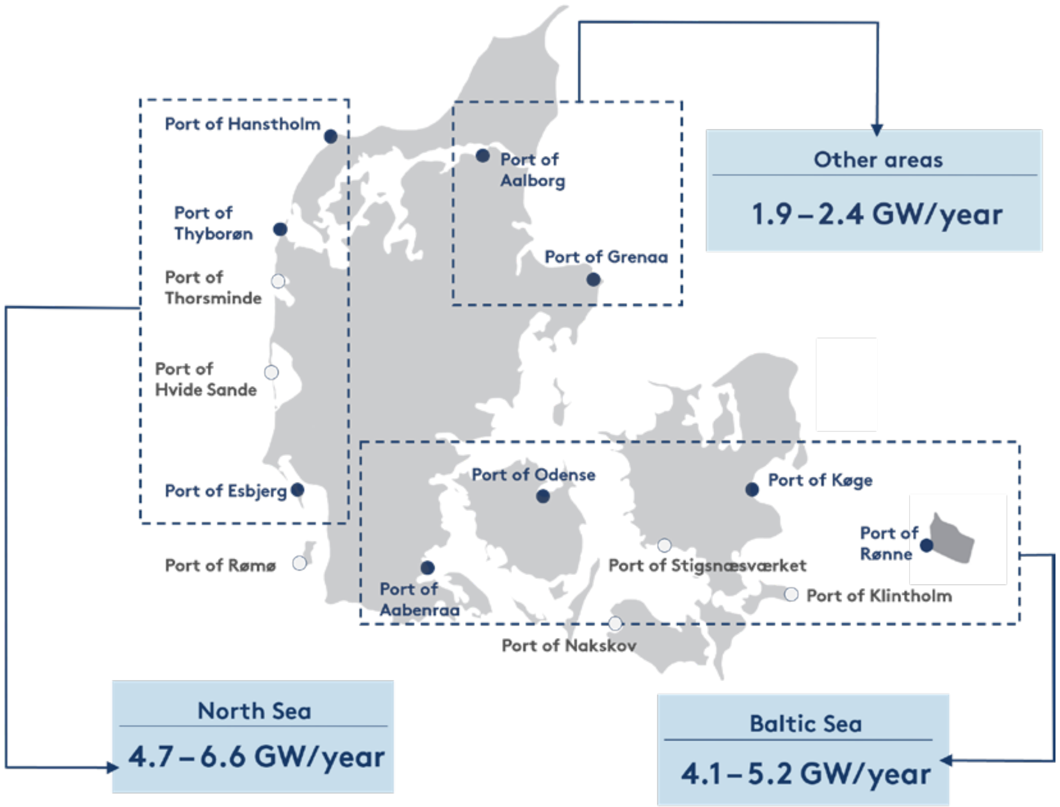
Overall, if ports' bearing capacity and channel depth are increased, Denmark will be able to ship between 10.6 GW and 14.2 GW per year, depending, in particular, on area use at and around the port. This corresponds to an accumulated capacity of between 275 GW and 370 GW up to 2050.

The figure below shows the range for the annual number of GW that could be installed in the North Sea, in the Baltic Sea and in "Other areas", respectively, on the basis of the port area available.

3.8 Deployment plans cause bottlenecks in Danish ports

Comparing Danish port area capacity with the time profiles for offshore wind deployment provides an illustration of Danish over- or under-capacity with respect to managing expected offshore wind deployment. Figures are based on scenario 3, which includes political goals and a percentage of foreign offshore wind power, because this has been assessed as the most realistic scenario.

***Figure 3.17**: Danish port capacity with regard to offshore wind installation, GW/year*



Source: The CIP Foundation based on KPMG (2023)

The comparison of Danish port capacity with the deployment profiles for offshore wind does not take account of depth and bearing capacity, as ultimately these parameters, or mitigating initiatives to make up for them, must be in place if the installation of offshore wind turbines is to be possible.

The conclusions about Danish port capacity in relation to expected offshore wind deployment are therefore based on the assumption that channel depths and bearing capacities are sufficiently increased, or, alternatively, that mitigating initiatives are applied.

With activation of all ports and optimal use of port areas, there will be a bottleneck in deployment in the North Sea in 2029, preventing deployment of 1.7 GW.

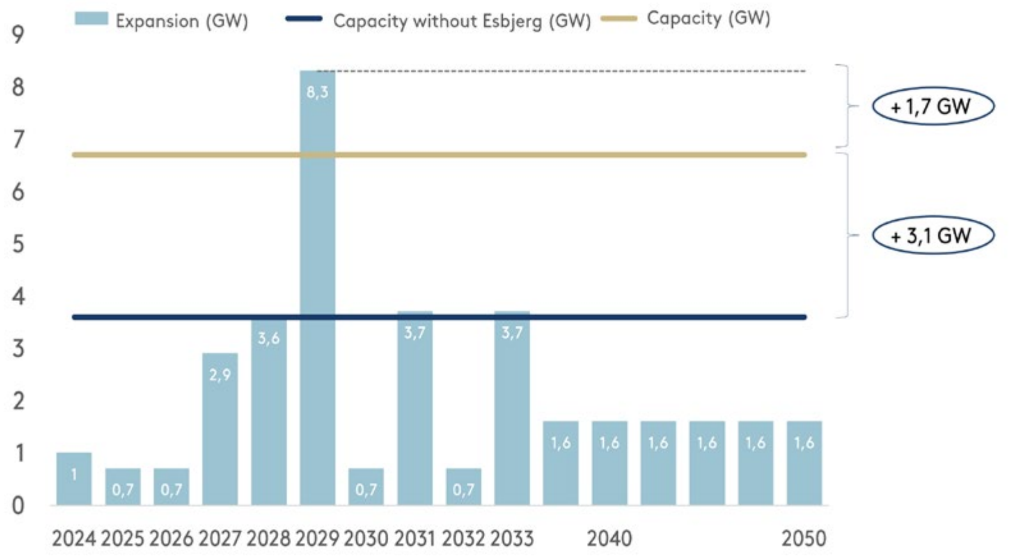
Figure 3.18 shows that Esbjerg will constitute a large part of capacity in the North Sea. The Port of Esbjerg is already booked several years ahead, and if port capacity here is deducted, the bottleneck in 2029 will be 4.8 GW and capacity will also be under pressure in 2028, 2031 and 2033.

In the Baltic Sea, there will be a bottleneck in deployment in 2031, preventing deployment of 1.2 GW.

Figure 3.19 illustrates the Port of Odense's share of capacity, which in practice could be difficult to exploit because of bookings or challenges with transport under the Great Belt bridge.

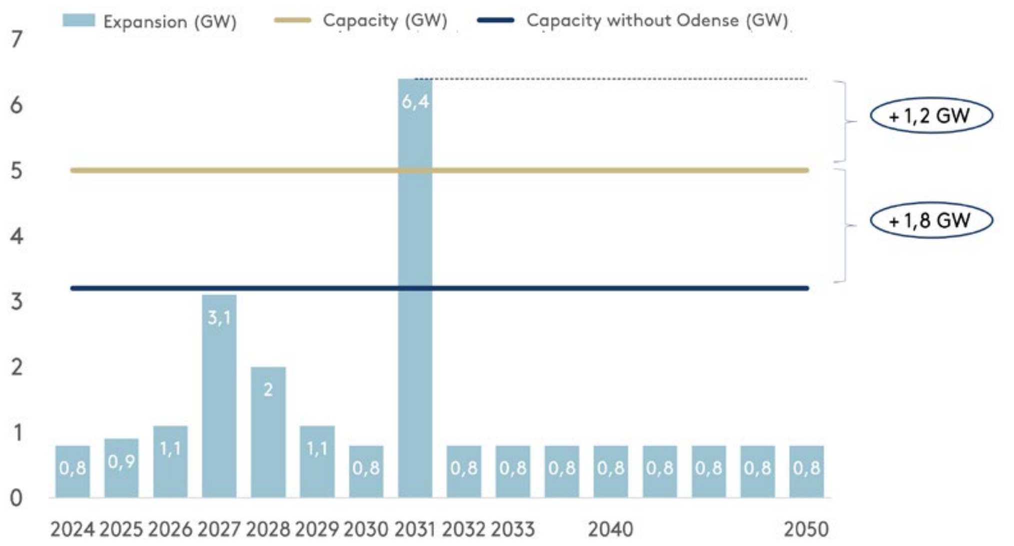
Omitting Odense from the calculations, the bottleneck will rise to 3 GW in 2031, and capacity will be under pressure in 2027, although without further bottlenecks.

***Figure 3.18**: Bottlenecks in the North Sea, 2024-2050*



Note: Figure illustrates capacity for installation of turbine towers, blades, and nacelles.
Source: KPMG (2023)

***Figure 3.19**: Bottlenecks in the Baltic Sea, 2024-2050*



Note: Figure illustrates capacity for installation of turbine towers, blades, and nacelles.
Source: KPMG (2023)

Photo: Port of Esbjerg

In "Other areas" (comprising the Kattegat, Skagerrak, the Danish Straits and the Great Belt), a bottleneck will arise in 2028, preventing deployment of 0.3 GW. The figure below illustrates that Grenaa Port accounts for the majority of the capacity in the area, and omitting this port, the bottleneck in 2028 will rise to 2.2 GW, while bottlenecks will also arise in the years up to and including 2031. As the only other shipping port, the Port of Aalborg will be fully booked in 2026 and 2027.

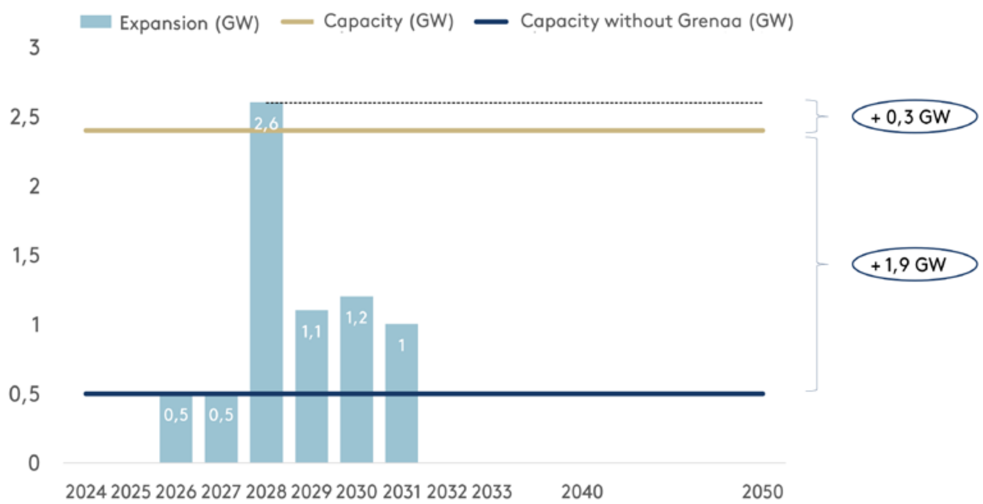
Capacity from Grenaa therefore plays a key role if deployment of offshore wind in the area is to be realised. Because of its geographical location, the Port of Odense could ship to parts of the area, and this may potentially reduce the bottleneck in 2028, when there is less of a need in the Baltic Sea.

Based on the more conservative calculations, which reduce total capacity by 25%, no new bottlenecks are caused, but the existing bottlenecks grow, as illustrated by the pale blue line in Figure 3.21 to the right.

The review of installation capacity in the North Sea, in the Baltic Sea and in "Other areas" shows that, with current deployment plans, several bottlenecks will arise that together will make it impossible to ship a total of 3.2 – 6.7 GW, depending on capacity and area use.[21] If foreign offshore wind is excluded, so that the calculations include only Danish offshore wind, the amount of offshore wind that cannot be installed because of a shortage of port area falls to between 1.9 and 5.3 GW.[22]

So, even if the necessary investments in channel depths and bearing capacity are made, Danish Ports will not be able to manage the deployment planned and the goals set. There is a need for additional port capacity or more evenly planned deployment.

***Figure 3.20:** Bottlenecks in other areas, 2024-2050*



Note: Figure illustrates capacity for installation of turbine towers, blades, and nacelles.

Source: KPMG (2023)

***Figure 3.21:** Bottlenecks in the North Sea, the Baltic Sea and other areas, after investments in upgrading quay carrying capacity and fairway depth in all Danish installation ports, 2024-2050.*

Note: The expansion of offshore wind after 2030 is characterized by uncertainty, and in practice the pace of expansion will very likely become more uneven. Figure illustrates capacity for installation of turbine towers, blades, and nacelles.

Source: The CIP Foundation based on KPMG (2023)

The review also shows that the biggest ports account for a major part of port capacity, that port capacity is high in Denmark accumulated up to the year 2050, and that there will be unexploited capacity for large parts of the period. To eliminate capacity challenges, port capacity could be expanded or the rate of deployment could be changed, e.g. by advancing current plans.

The review is based on the areas ports have available for shipping offshore wind. Pressure on capacity will be greater if the areas are used for other offshore wind than that assumed in the scenario, or if the areas are converted to another function. Similarly, pressure on capacity could increase further if areas that are currently reserved for offshore wind installation are instead used for other purposes, e.g. manufacture.

21 Calculations based on KMPG (2023), scenario 3.
22 Calculations based on KMPG (2023), scenario 2.

3.9 Conclusion: Danish Ports cannot realise Denmark's goals

Danish Ports currently do not offer the dimensions that installers will need for shipping offshore wind turbines in a few years.

Offshore wind turbines will be larger and heavier, and political goals and deployment plans will increase the rate at which turbines are to be shipped from ports. Managing larger and heavier components and aiming at a five-fold increase in installed wind capacity by early 2030 will put more pressure on ports.

From 2025, 15 MW is expected to be industry standard for offshore wind turbines, and this will lead to an increase of around 50% in turbine weight. From the perspective of installers, demand for port capacity will thus change, with focus on stronger bearing capacity and deeper channels. In terms of these dimensions, only a few Danish ports today offer what is demanded. In an international perspective, this may make Danish ports less attractive when installers or developers are to select a port from which to install offshore wind farms.

Investments in quay bearing capacity and deeper channels are required if Danish ports are to remain attractive for shipping in the future, because the mitigating initiatives used today increase the costs of installation.

The port area available at Danish ports is not sufficient to realise adopted plans and goals.

Even with further investments in Danish ports, bottlenecks will arise in the North Sea, in the Baltic Sea and in "Other areas" due to a shortage of port capacity to manage deployment plans. Bottlenecks will peak in the late 2020s/early 2030s.

In contrast, in many other years, there will be over-capacity, with possibilities to install more offshore wind than needed. Possibilities for installation from Danish ports depend, in particular, on the ports with most area designated for offshore wind: Esbjerg in the North Sea, Odense, Rønne and Køge in the Baltic Sea, and Grenaa in "Other areas".

The analysis is sensitive to available capacity, and the number and size of bottlenecks could be higher if this is changed, e.g. if ports are booked for other projects, or if port areas are instead used for other purposes such as manufacture or handling of foundations. A conservative calculation, in which capacity at the smallest ports is excluded and area needs for shipping are increased, does not lead to new bottlenecks but exacerbates the existing bottlenecks.

Therefore, the total amount of offshore wind that cannot be installed due to a lack of port area has been estimated at between 3.2 and 6.7 GW, depending on area and capacity utilisation.

If foreign offshore wind is excluded, so that the calculations include only Danish offshore wind, the amount of offshore wind that cannot be installed falls to between 1.9 and 5.3 GW.

To avoid bottlenecks in wind expansion and to realise current deployment plans, there is a need for investments in deeper channels around ports and stronger quay bearing capacity. Furthermore, there is a need to expand port areas temporarily for a few years, and to bring forward existing deployment plans to spread out the pressure on ports more evenly, or to include foreign ports in the task.

Photo: Port of Grenaa

4. International Competition

Danish ports are in international competition to be chosen as an offshore wind port by developers and installers. Where Chapter 3 described how Danish ports can meet the demands of the future and contribute to realising deployment plans, this chapter describes the competition situation facing Danish ports, including how this situation may develop in the North Sea and the Baltic Sea, respectively. The description looks at the competition situation for Danish ports with regard to installing Danish offshore wind projects, as well as the competitiveness of Danish ports with regard to installing foreign offshore wind projects.

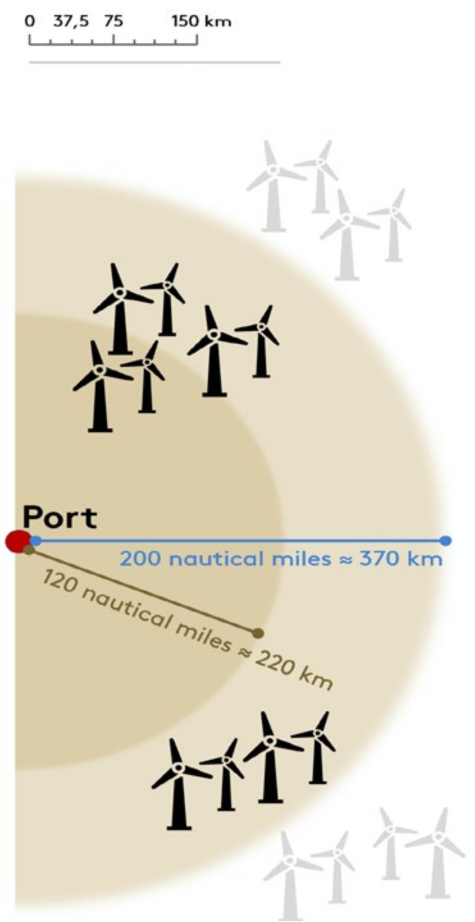
4.1 Several important competitive parameters

In order to compare the competition between different Danish and foreign ports, the CIP Foundation has identified four competitive parameters which indicate the competitiveness of a foreign installation port in relation to Danish installation ports: two port-specific parameters and two country-specific parameters.

PORT-SPECIFIC COMPETITIVE PARAMETERS
The ***transport distance*** between the port and Danish offshore wind farms is a pivotal parameter when assessing whether a foreign port can compete for Danish offshore wind areas. As considerable costs are linked with transport and derived effects such as storage of components or downtime in production, all else being equal, installers and developers will prioritise an installation port located relatively close to where the offshore wind turbines are to be installed.[23] Today, wind turbines are transported over long distances for installation. However, it is likely that, as many offshore wind farms are to be developed internationally within the same time horizon, the transport limit will become smaller, because there will be more offshore wind turbine projects in the ports' local area. The limit for transport distance between an installation port and an offshore wind farm is 120-200 nautical miles, corresponding to approx. 220-370 km².[24] Foreign ports within this distance to Danish marine areas designated for wind power could compete with Danish installation ports. On the other hand, Danish ports within this radius to foreign marine areas could compete on installation of foreign projects. The shorter the distance between the port and the wind farm, the more competitive the port will be on this parameter.

A port's ***experience and size*** are also a crucial competitive parameter. Ports with experience in the installation of offshore wind and ports with adequate technical dimensions to manage large components, or with experience in carrying out mitigating initiatives, are in a better position compared with ports without this experience. If ports have expansion plans at an advanced stage, they can also be included in assessments of whether they are attractive. For example, if a port has plans to increase channel depth, bearing capacity or quay length, it may be a competitor. The same applies if a port has plans to expand its area for installation of offshore wind. With regard to dimensioning factors, like Danish ports, most ports in Europe are not dimensioned to cope with the future, larger turbines. This parameter will therefore primarily focus on the port area available that, with investment in the port, could become an asset in international competition. In this context, the size of the available port area is important, because this can indicate the size of a potential competitor and how realistic investment in the port may be.

Figure 4.1: *Installers have an expected reach of about 120-200 nautical miles between the port and the wind farm, when multiple projects are deployed simultaneaously*



Source: The CIP Foundation based on KPMG (2023)

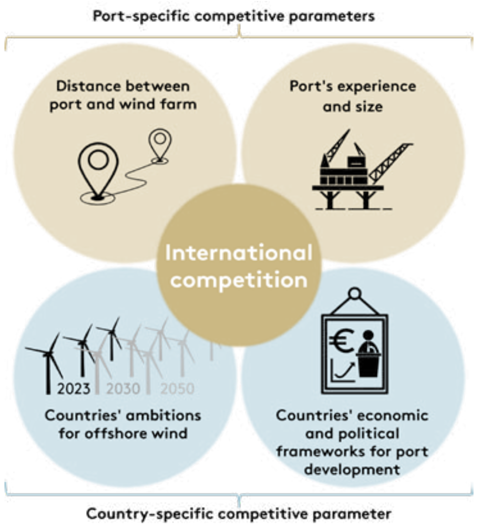
COUNTRY-SPECIFIC PARAMETERS
Countries' offshore wind energy ambitions (the ratio between their installed offshore wind and their goals for further deployment) are also important for the extent to which foreign ports can compete with Danish ports. For example, if a country has already come far in its own offshore wind expansion, or if it has relatively limited deployment plans compared with its port capacity, then the ports in this country could be better positioned to compete against Danish ports for the installation of Danish offshore wind. On the other hand, if a country still has a long way to go to reach its goals, or if it has high goals compared with its port capacity, ports in this country will be poorer positioned to compete because they will be expected to ship for their home country. The parameter is derived from the distance criteria, as a

23 Esbjerg has, for example, been involved in offshore wind turbine projects in and around Great Britain, +600 km.
24 KPMG 2023. Based on interviews with installers and developers.

country's own offshore wind areas are usually located closer to its own ports, and therefore the costs of installation from here will be less. Finally, ***countries' economic and political frameworks*** will also have an impact on the competitiveness of their ports. This competitive parameter is about political prioritisation, coordination between ports (e.g. through ownership factors) as well as the possibilities for public funding to promote port expansion and upgrades.

Political prioritisation of offshore wind expansion will typically position a country better than a country where there is less political prioritisation of ports and offshore wind installation. Danish prioritisation of public aid for port expansion and upgrades can contribute the necessary capital to finance port expansion and upgrades. This applies for municipal, regional, national and

Figure 4.2: *The international competition between installation ports is characterized by different competition parameters*



Source: The CIP Foundation (2024a)

European aid programmes. Finally, different case processing times in the various countries influence how rapidly ports can develop and adapt.

The following section describes the international competition situation for Danish ports on the basis of the four competitive parameters. First, there is a description of the competition situation in the North Sea, and then the competition situation in the Baltic Sea and "Other areas".

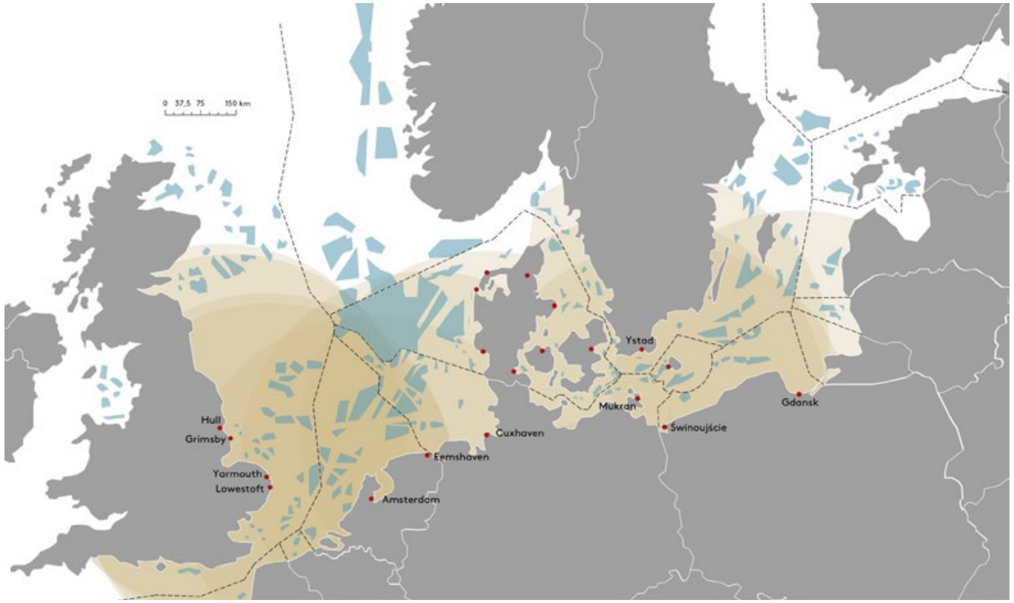
4.2 The Danish part of the North Sea is exposed to competition

In the North Sea, seven foreign installation ports can compete to various degrees with Danish ports for Danish areas. See Figure 4.3 and Table 4.1.

Cuxhaven and Eemshaven Cuxhaven can compete for the largest area of around 95% of Danish marine areas designated for offshore wind turbines in the North Sea, while Amsterdam covers about 40%. The British ports on the coast in east England, Hull, Grimsby, Lowestoft and Yarmouth, can compete for around 15%-20% of the area. Besides the competition area itself, ports can compete to varying degrees on the basis of their port area, which determines the annual number of GW that can be installed from the port. Note that, in most cases, the port areas have not been prepared for the large turbines of the future, and for this reason they will have to be upgraded with respect to bearing capacity and/or channel depth, for example, if they are to be feasible and able to join the competition.

Mitigating initiatives can reduce the need for infrastructure investments, but in a

Figure 4.3: *Ports from the Netherlands and Germany in particular can compete with Danish ports*



Note: Circles illustrate the range of foreign ports (≈370 km)
Source: The CIP Foundation (2024a)

Table 4.1: *Cuxhaven and Eemshaven can install on 95% of Denmark's sea area.*

	Competition area	Port capacity GW/year	Type port
Esbjerg	≈ 100%	2.5 GW	Production, installation and service port
Cuxhaven	≈ 95%	1.1 GW Expansion: 1.4 GW	Production and installation port
Eemshaven	≈ 95%	2.1 GW	Installation and service port
Amsterdam	≈ 40%	1.3 GW Expansion: 0.75 GW	Installation and service port
East England	≈ 15-20%	7.5 GW Expansion: 12.5 GW	Production and installation port

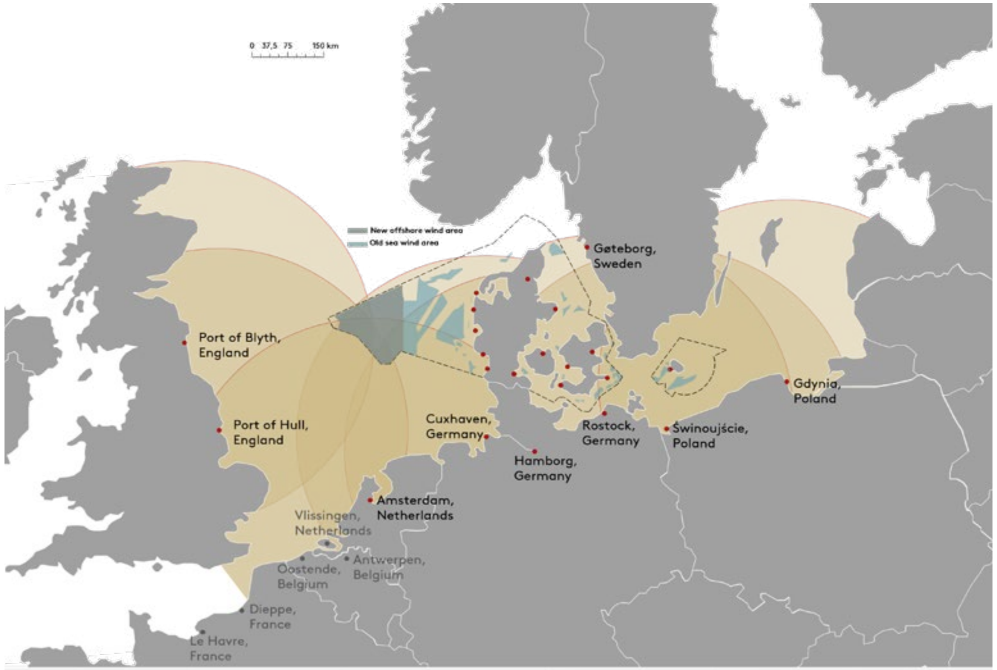
Note: GW/year is calculated on the basis of area and does not take into account the dimensioning factors of ports
Source: The CIP Foundation (2024a)

competition situation the ports with the highest capacity and best facilities will be in the best position, including those with the strongest infrastructure.

All Danish offshore wind sites in the North Sea are therefore within reach for at least one foreign port. This means there is not only competition between Danish ports to be installation ports for offshore wind turbines in the Danish part of the North Sea; foreign installation ports can also compete in the Danish market.

Over the summer of 2023, a broad group of parties in the Danish Parliament agreed on a new maritime spatial plan that significantly increases the Danish offshore wind areas. The most significant change for the Danish offshore wind potential was that the outermost parts of the Danish territorial waters in the North Sea were changed from designation for just gas extraction and carbon storage to also include designation as offshore wind sites.[25] This part of the North Sea, i.e. the outermost part around 150-300 km from the west coast of Jutland, is where most foreign ports reach into the Danish offshore wind areas in the North Sea. This means that the greatest risk from international competition from foreign ports is in these newly designated offshore wind areas.

***Figure 4.4**: There is the greatest competition in Denmark's newly laid out and most windy areas*



Note.: Circles illustrate the range of foreign ports in Danish waters (≈370 km)
Source: The CIP Foundation (2024a)

4.3 Esbjerg, Eemshaven and Cuxhaven dominate the north-eastern North Sea

The Port of Esbjerg is an important player for offshore wind turbine installation in both Germany and the Netherlands, and the port has installed more than 20 GW offshore wind outside Denmark. With its 500,000 m², the Port of Esbjerg is the largest installation port in the north-eastern part of the North Sea.[26]

Eemshaven in the Netherlands is the second-largest port with 410,000 m² designated for the installation of offshore wind. Eemshaven is a strong competitor for Danish installation ports, including the Port of Esbjerg, because the port has extensive experience with shipping offshore wind turbines to both Dutch offshore wind sites and the German part of the North Sea. Furthermore, there is a short distance to the city of Groningen, which provides access to huge amounts of qualified labour. Eemshaven has so far installed 18 offshore wind farms, primarily in Germany, but also in the UK and Holland,[27] and offshore wind farms nos. 19, 20 and 21 are currently being installed from Eemshaven. The 18 farms already installed consist of a total of 1,223 turbines, corresponding to 7.2 GW.

Cuxhaven in Germany has an ideal location with regard to competing with Danish installation ports for offshore wind. The port is state-owned but has a strong network of companies, which gives Cuxhaven a central position in the German green transition. There is plenty of space to expand the port, as there is land available around the port, but the current offshore wind areas in Cuxhaven are under pressure because the port is used by Simens Gamesa for manufacture and storage

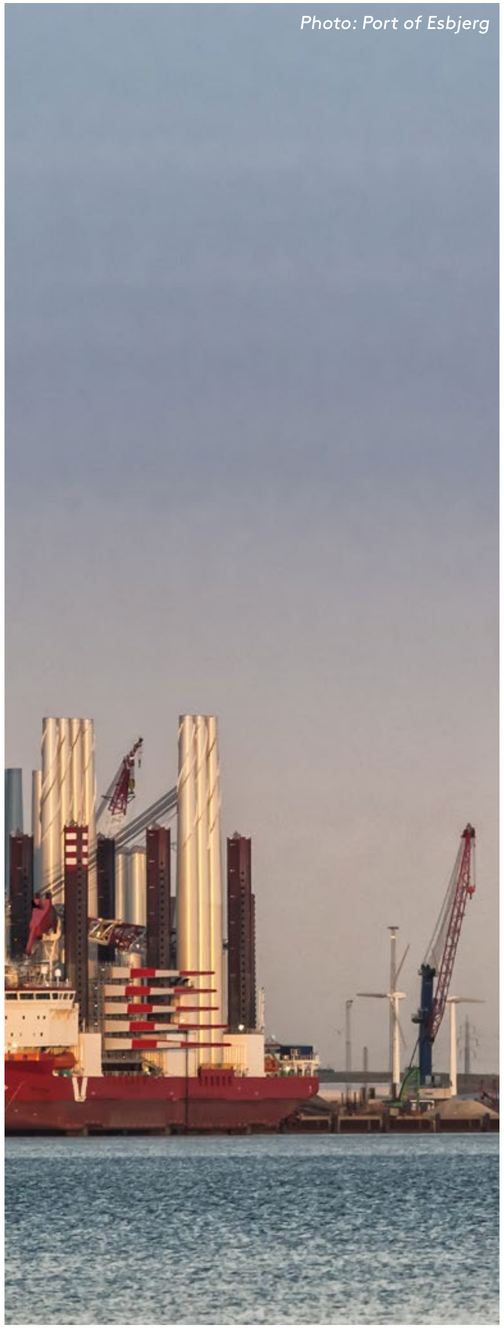


Photo: Port of Esbjerg

25 Agreement on Denmark's Marine Plan (em.dk)
26 KMPG 2023
27 Groningen Seaports: Offshore Wind (groninngen-seaports.com)
28 Menon Economics (2023): MULIGHETER FOR NORSKE SAMMENSTILLINGS- OG INSTALLASJONSHAVNER INNEN HAVVIND FREM MOT 2030

of nacelles as well as for production of onshore wind turbines.

Oostende in Belgium and the North Sea Port in the Netherlands are also two significant installation ports. However, because of their location more than 370 km away, they are unlikely to be able to compete for the Danish marine areas. Norway currently has no competitive ports for the installation of offshore wind power.[28]

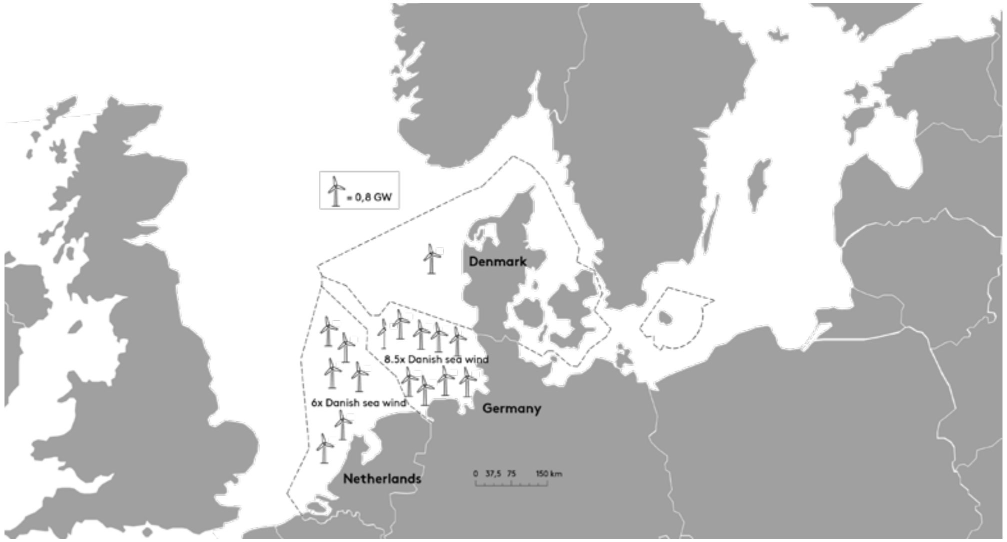
4.4 Denmark has few installed wind turbines and relatively low goals

Germany and the Netherlands do not have significantly larger areas in the North Sea than Denmark, but Denmark has considerably fewer offshore wind turbines than both these countries. At present, Denmark has 0.82 GW offshore wind power installed in the North Sea, whereas Germany has 7.1 GW installed, corresponding to around 8.5-times the Danish capacity. The Netherlands has 4.7 GW offshore wind turbines installed, which corresponds to approximately six-times as much offshore wind power as Denmark.

With regard to goals, Denmark has a 2030 target of 5.3 GW offshore wind power in the North Sea, while Germany is aiming at five-times this with 26.4 GW, and the Netherlands four-times as much at 21 GW. On the other side of the North Sea, the UK has a target of 50 GW offshore wind power across the coastline of the UK.

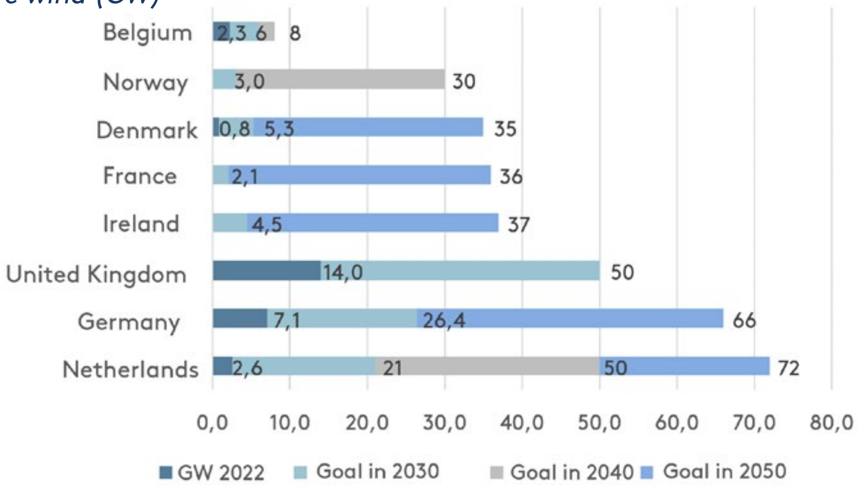
The UK, Germany and the Netherlands have the highest goals for offshore wind deployment. These three countries also have the competing ports.[29] From a Danish perspective, and all else being equal, this will reduce competition for installation in Danish

***Figure 4.5**:Denmark's installed offshore wind capacity is significantly lower than Germany and the Netherlands, 2024*



Source: The CIP Foundation (2024a)

***Figure 4.6**: There is great variation in the North Sea countries' targets for off-shore wind (GW)*



Source: The CIP Foundation (2024a)

areas, as these three countries all have to install significant quantities of offshore wind power, relative to their port capacity.

As a result of the costs of the long sailing distances, the foreign ports are likely to install offshore wind power in their home countries before they compete for the Danish areas.

4.5 Port capacity in the North Sea is under pressure – especially in 2029-2030

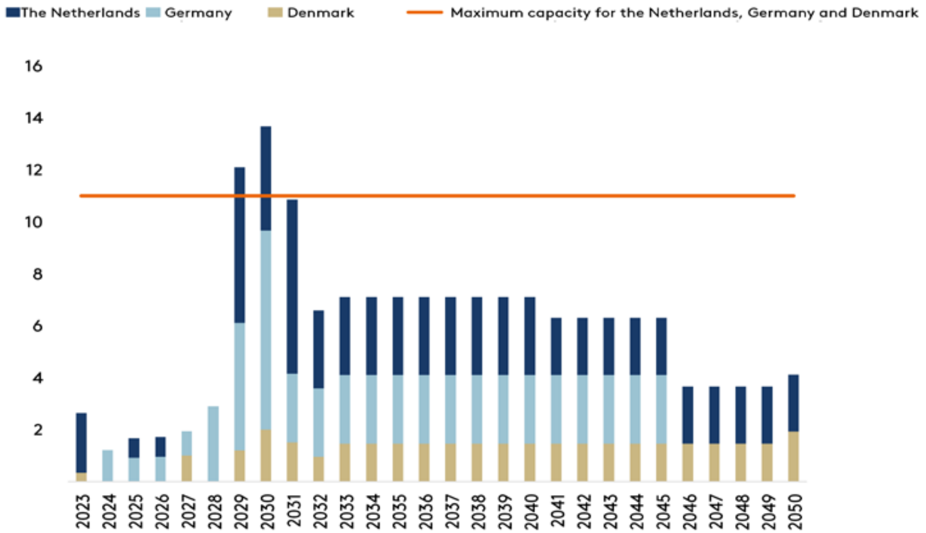
In Europe, just as in Denmark, there is a general shortage of port capacity, as a majority of the ports, and thus the port area available, have not been dimensioned to cope with the 15 GW turbines that are expected to comprise the industry standard from as early as 2025. Just as the rate of deployment in Denmark is concentrated around 2030, the Netherlands and Germany are planning the majority of their deployment between 2029 and 2031. Ports in Denmark, Germany and the Netherlands can compete for each other's offshore wind areas, and together they can ship around 11 GW annually, if all the ports are upgraded to cope with the large turbines with heavy components.[30]

With respect to the expected rate of deployment, there will be bottlenecks in 2029 and 2030, even with port investments. As demand for port capacity in these years is greater than the expected capacity, international competition between ports is likely to be limited. Furthermore, as it is most cost-effective to install offshore wind closest to the port, ports will largely install turbines in their own marine areas.

In view of the scarcity of port capacity, competition in the period 2029 to 2030 is more likely to be between countries than ports, as Denmark, Germany and the Netherlands have to achieve their politically determined deployment goals. After 2031, Denmark has a surplus of port capacity, which can be exported to neighbouring countries. The surplus capacity that can be exported has been estimated at around of 3 GW annually after 2034, as Denmark's annual port capacity in the North Sea has

29 Cuxhaven, Eemshaven, Amsterdam, Hul, Grimsby, Lowestoft and Yarmouth
30 Upgrading refers to increased quay carrying capacity and deeper fairways. The ports included in the calculation are Esbjerg, Hanstholm, Thyborøn, Eemshaven, Amsterdam and Cuxhaven.

Figure 4.7: Expected annual offshore wind expansion: Denmark, Germany and the Netherlands, 2023-2024 (GW).



Note: Maximum capacity is based on available space.
Source: North seas offshore wind port study 2030-2050

been estimated to be 4.7 GW and up to 2050 only an annual 1.6 GW will be required to install Danish offshore wind power.[31] Total expansion by Denmark, Germany and the Netherlands is expected to be 7 GW annually from 2033 to 2040, and 6.2 GW annually from 2041 to 2045, and finally just below 4 GW annually from 2046 to 2050.[32] Denmark's export potential after 2034 can be used to meet the demand generated by deployment plans in neighbouring countries.

4.6 Danish and Dutch ports must compete for the German market

Up until 2029, not only Denmark, but also the Netherlands, will have an accumulated over-capacity, if investments are made to upgrade ports. However, Germany will have an accumulated under-capacity. See Table 4.2. The same applies, although more strongly, for the years after 2031. Therefore, in the years before 2029 and after 2031, Danish and Dutch ports will be able to compete on installing German offshore wind power, as the German ports will not be able to meet German goals alone. The large surplus capacities in Table 4.2 illustrate the capacities that can be accumulated over time if investments are made to make all Danish, German and Dutch ports competitive. In practice, the ports which invest in offshore areas and facilities such as deep channels and quays with high bearing capacity will be best positioned in the competition. With the largest port capacity and the most experienced port in the North Sea, Denmark has good opportunities to compete for German offshore wind deployment after 2031. This is largely because Germany is a primary market for Danish ports, as Danish ports can reach the entire German marine area, and because 17 GW of the planned deployment in this area is situated closer to Danish ports than to German and Dutch ports.[33]

***Figure 4.8:** Danish ports can reach the entire German offshore wind area, but also parts of the British and Norwegian ones.*

Source: The CIP Foundation (2024a)

Moreover, the Dutch ports, including the largest Dutch Port, North Sea Port, can only reach parts of the German offshore marine area, and with a lower capacity. Both the Netherlands and Denmark have an opportunity to export port capacity to other markets: the Netherlands can export port capacity to the south, as Dutch ports are close to both French and Belgian wind areas, and Denmark can export port capacity to the north, as several Norwegian wind areas are within the limit of 200 km from Danish installation ports. However, a large part of the Norwegian market is likely to consist of floating turbines, and therefore Danish installation opportunities in Norwegian waters will be limited.[34]

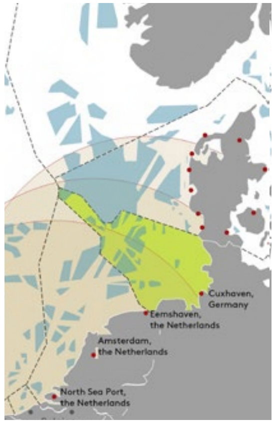


***Figure 4.9:** Dutch ports can reach parts of the German offshore wind area, but also parts of the French and Belgian ones.*

Source: The CIP Foundation (2024a)

Table 4.2: Capacity in the North Sea: offshore wind turbines and ports in Denmark, Germany and the Netherlands.

	Offshore wind turbine capacity (GW)					Port capacity (GW)				
	Current capacity put into operation	GW goal 2030	GW goal 2050	Deficiency of GW up to 2030	Deficiency of GW up to 2050	Annual port capacity	Accumulated capacity up to 2030	Accumulated capacity up to 2050	Difference in capacity up to 2030	Difference in capacity up to 2050
Denmark	0.8	5.3	35	4.5	34.2	4.7	≈ 32.9	≈ 126.9	≈ 28.4	≈ 92.7
Germany	7.1	26.4	66 (2045)	19.3	58.9 (2045)	1.1	≈ 7.7	≈ 24.2 (2045)	≈ -11.6	≈ -34.7 (2045)
Netherlands	4.7	21	72	16.3	67.3	5.2	≈ 36.4	≈ 140.4	≈ 15.4	≈ 73.1

Note: The capacity is an expression of the areas the ports have available and not whether the ports are sized to handle the large turbines of the future.
Source: The CIP Foundation (2024a)

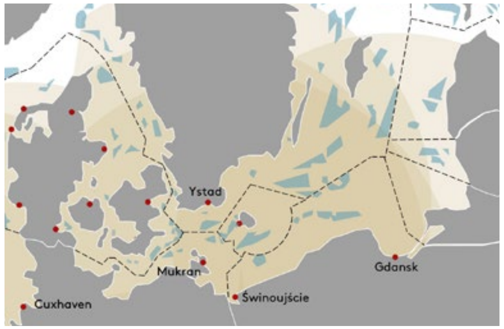
31 Cf. chapter 3 based on KPMG (2023)
32 NSEC (2023)
33 KPMG 2023
34 Floating offshore wind turbines, unlike traditional offshore wind turbines, are not attached to the seabed. The installation of floating offshore wind turbines places different demands on the ports depending on the type of turbine. Norway expects to ship floating offshore wind from domestic ports.

4.7 The Danish part of the Baltic Sea and other areas are exposed to competition

In the Baltic Sea, distances from port to offshore wind sites are shorter than in the North Sea, which reduces the relevance of the distance criterion for selection of relevant ports. Ports in Sweden, Germany and Poland cover not only the entire Danish part of the Baltic Sea, but also the coastal waters, including the Kattegat, the Skagerrak, the Danish Straits and the Great Belt.

The ports that can compete with Danish ports in the Baltic Sea and the Danish Straits are Mukran in Sassnitz, Germany and, with the right investment, Ystad in Sweden as well as Świnoujście and Gdansk in Poland. Both the Oresund bridge and the Great Belt bridge will constitute a barrier for shipping offshore wind power, as they make transport of turbines through the Great Belt and the Sound more difficult. Transporting turbines under bridges and through the tunnel therefore requires initiatives such as transporting the turbines in parts and fewer at a time, and this will increase the costs of installation.

***Figure 4.10:** Polish, German and Swedish ports can install in the Danish part of the Baltic Sea*



Note: Circles illustrate the range of foreign ports(≈370 km). Source: The CIP Foundation (2024a)

4.8 The Port of Rønne dominates the Baltic Sea

Despite the short distances between ports and the Danish offshore wind sites, competition is low. Today, only Mukran in Sassnitz, Germany, can compete with the Danish ports, although this applies for the whole Danish area and with an annual capacity to install 1.3 GW. The ports of Ystad in Sweden and Świnoujście and Gdansk in Poland are expected to be able to compete within a short period. Rønne currently dominates the Baltic region.

The Port of Rønne has been used as an installation port for the large offshore wind farms in the Baltic Sea in both Danish and foreign areas. The Port of Rønne was the installation port for Denmark's largest offshore wind farm, the 604 MW Kriegers Flak. In 2021 the Port of Rønne was selected as the installation port for the 476 MW German offshore wind farm Baltic Eagle, which was built by the German Iberdrola.[35] In 2016, the owners of the Port of Rønne adopted their Master Plan 2050, which sketched out development plans for the Port of Rønne in four phases up to 2050. Since adoption of the plan, investment decisions for the four phases have been advanced significantly. Phases one and two have been completed, whereas phase three, which, according to the plan, should be completed by 2040, has been processed and is under construction.

There will soon be applications for approval for phase four, which is expected to be finished 20-25 years before the date in the original plan. Needs for more port capacity to install offshore wind power are driving much of port development. Within a few years, it is likely that up to 45% of the revenues of the Port of Rønne will come from offshore wind.

At the moment, no ports on the Polish coast can install offshore wind turbines.[36] The Port of Rønne has been selected as the installation port for the Polish MFW Bałtyk I wind farm project. This project comprises 1.7 GW and will be built by the private Polish company Polenergia in collaboration with Norwegian Equinor.[37] The Polish port in Gdansk was originally planned for completion in 2025 and it will function as an installation port for the Polish offshore wind farm, but in mid-2023, the contractor who is to build the offshore wind turbine terminal had not yet been elected, and therefore expansion of the port is unlikely to be completed in 2025. Polenergia and Equinor have therefore entered into a contract for the Port of Rønne to be the installation port for the offshore wind farm in Polish waters.

***Table 4.3**: Foreign ports that can compete for installation in the Danish part of the Baltic Sea*

	Competition area	Port capacity GW/year	Type Port
Rønne	≈ 100%	1.3 GW	Production- and installation
Mukran (Sassnitz)	≈ 100%	1.3 GW	Installation and service port
Ystad	≈ 100%	0 GW Can be converted to installation with respect to the Triton farm	Installation port
Świnoujście	≈ 100%	0 GW Expansion: 0.85 GW planned for 2025	Installation port
Gdansk	≈ 70%	0 GW Selected by the polish authorities for installation from 2025	Installation port

Source: The CIP Foundation (2024a)

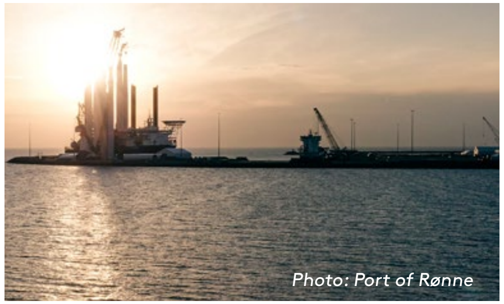


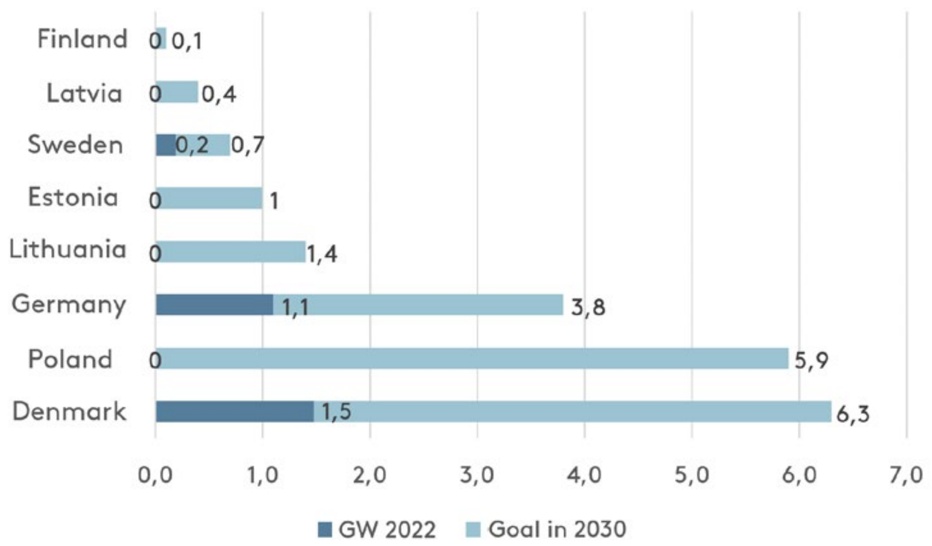
Photo: Port of Rønne

4.9 Denmark has many turbines and ambitious goals for the Baltic Sea and Danish coastal waters

Although expansion of offshore wind power has been later in the Baltic Sea than in the North Sea, there is a large, unrealised potential. Currently, 2.8 GW offshore wind turbines have been installed in the Baltic Sea region, but according to the European Commission there is an estimated potential for offshore wind turbines in the Baltic Sea of a full 93 GW.[38] Just as the North Sea countries have had the Esbjerg Declaration and later the Oostende Declaration, in 2022, the Baltic Sea countries of Denmark, Sweden, Finland, Germany, Poland, Estonia, Latvia and Lithuania signed the Marienborg Declaration

35 Port of Roenne selected as wind turbine installation port for Baltic Eagle offshore windfarm - Baltic Wind
36 Port of Rønne (2016): publiseret-masterplan-2050-d-11-16-1658-10.pdf (roennehavn.dk) visited on 26/2/24
37 Offshore wind farms - Polenergia - Corporate Website
38 Baltic Sea countries strengthen cooperation on more offshore wind and increased energy security (kefm.dk)

Figure 4.11: *Denmark has the highest goals in the Baltic Sea*



Source: The CIP Foundation (2024a)

to increase the current 2.8 GW to 19.6 GW by 2030. The Marienborg Declaration is expected to initiate a major deployment of offshore wind turbines in the Baltic Sea.

Denmark is today the dominant player for offshore wind turbines in the Baltic Sea, both with regard to current Danish capacity of 1.5 GW[39] and Denmark's goal of 6.3 GW in the Baltic Sea by 2030. This is in contrast to the situation in the North Sea, where Denmark has lower capacity and significantly lower GW-goals for 2030 and 2050 than Germany, the Netherlands and the UK. Poland's goal in the Marienborg Declaration is for 5.9 GW offshore wind power by 2030, even though, as yet, Poland has no offshore wind power in its territorial waters.

4.10 Denmark and Germany can compete for areas in Poland and Sweden

Altogether, Denmark could have the highest capacity in the Baltic Sea, provided investments are made to increase the bearing capacity and channel depth in Danish ports. Overall, there is high capacity in the Baltic Sea, primarily due to the relatively limited goals of 19.6 GW by 2030. The situation would change significantly if the goals were raised to the technical potential, which the European Commission has estimated to be 93 GW. Denmark has the highest accumulated capacity at 37 GW and Germany has the second-highest at 6.6 GW, while both Sweden, and particularly Poland, have a capacity deficit to reach their deployment goals because they do not have the port areas to install offshore wind energy.

Denmark and Germany will therefore be able to compete on supplying capacity for the Polish and the Swedish markets if they invest in upgrading their ports to manage larger and heavier turbines. Denmark has a direct advantage in this competition, partly because Rønne has more extensive experience in installing offshore wind turbines compared with Mukran, and partly because, with its central location in the Baltic Sea, Rønne has shorter navigation routes to the Polish areas. In other words, Denmark can activate a high capacity located close to the Polish offshore wind areas, and, with current deployment goals, these comprise the largest market in the Baltic Sea. The accumulated over-capacity is significant, but also requires large investments in the ports. In this context, the first ports to be expanded and to achieve the comparative advantages will be in the best competitive position, as it will be possible to include them in the developers' planning.

Unlike Denmark and Germany, the competitive pressure from Poland and Sweden is limited. It is unlikely that Gdansk will be completed within the short term and it takes time to develop an industry. Sweden also has a limited port capacity. The Port of Ystad will probably not come to play any important role for offshore wind power in the short and medium terms, as the port has no experience with offshore-wind installation. However, from the mid-2020s both ports could be competitors for Rønne, if resources are prioritised to expand the ports.

Looking towards the Baltic states, Rønne's position in the Baltic Sea is strengthened further. Although Estonia, Latvia and Lithuania have goals that contribute to achieving the goal in the Marienborg Declaration of 19.3 GW, they currently have yet to erect turbines in their waters, despite their relatively large potentials. This means that the Baltic countries have no installation experience at their ports.

Table 4.4: *Capacity in the Baltic Sea: offshore wind turbines and ports in Denmark, Germany, Poland and Sweden.*

	Offshore wind turbine capacity (GW)			Port capacity (GW)		
	Current capacity put into operation	GW goal 2030	Shortage of GW up to 2030	Annual port capacity	Accumulated capacity up to 2030	Difference in capacity up to 2030
Denmark	1.5	6.3	4.8	6	≈ 42	≈ 37.2
Germany	1.3	3.8	2.5	1.3	≈ 9.1	≈ 6.6
Poland	0	5.9	5.9	0	0	≈ -5.9
Sweden	0.2	0.7	0.5	0	0	≈ -0.5

Note: The capacity is an expression of the areas the ports have available and not whether the ports are sized to handle the large turbines of the future. Denmark and Germany and excess port capacity accumulated.
Source: The CIP Foundation (2024a)

39 Based on the accumulated capacity for all Danish offshore wind farms in both the Baltic Sea and inland waters.

4.11 Political and economic frameworks affect the rate of competition developments

The political and economic frameworks for ports vary from country to country, and they can impact the opportunities available to ports to develop in the future. Differences from country to country with regard to ownership, possibilities for state aid and authority processing times mean ports have different framework conditions.

In contrast to Danish ports, British ports have a high degree of coordination, despite the fact that they are privately owned. This is because the most important installation ports for offshore wind turbines on the British west coast are owned by the largest port operator in the UK, Associated British Ports (ABP), which is a holding company with 23 British ports in its portfolio. Furthermore, the British government has granted public funding to extend and upgrade the country's offshore wind ports.[40] Having most installation ports on the west coast of the UK owned by the same port operator has provided favourable coordination between the installation ports.

In Germany, Cuxhaven is a publicly owned port operated by Niedersachsen Ports, which operates 15 ports near Cuxhaven.[41] Niedersachsen Ports has selected Cuxhaven as its hub for offshore wind turbines.[42] In this way, larger ownership of several ports can focus efforts and prioritisation of resources, and thus roles for ports in an area.

With regard to authority processing times, there are large differences between how quickly projects are approved. Whereas in the Netherlands and the United Kingdom there are examples of port expansions which have been approved in 12 and 13 months, approval took three years and 10 months for the Port of Esbjerg. Expansion of the Port of Rønne was approved in 15 months, but is pending a dumping permit; at the time of writing it has taken two years.


Photo: Port of Grenaa

***Table 4.5:** Differences in ownership, state aid and official treatment between the competing countries*

	Denmark	Germany	Netherlands	UK	Poland	Sweden
Ownership	Municipal independent ports	Federal state-owned ports, public	Municipally owned ports	Private ports	Public	Limited company-owned
State aid	Subject to EU state aid regulations	Subject to EU state aid regulations	Subject to EU state aid regulations	UK Subsidy Control Regime	Subject to EU state aid regulations	Subject to EU state aid regulations
Authority-processing time	23 months (ave.)	12 months (e.g.)	-	13 months (e.g.)	-	-

Note: Ownership refers to the ownership of the port, but in practice port operators own and operate areas around the ports. The Danish case processing time is based on an average of three port extensions, while case processing times from Germany and England are based on individual port extensions.
Source: The CIP Foundation (2024a)

40 Public support for port infrastructure in Europe, Danish Ports (May 2022)
41 Niedersachsen Ports
42 Port Information Guide Cuxhaven (nports.de)

The three port expansions processed in Denmark in 2023 took an average of 23 months.[43] Odense Municipality expects an overall authority processing time of up to eight years for a future port expansion.

Among other things, the expected long processing time is because appeals against the approvals may have a delaying effect. Besides an average Danish case-processing time in the Danish Transport Authority of around 23 months, processing by the board of appeal concerning the environment, for example, can protract processing for a port expansion.

The difference in processing by authorities, including appeals leading to delays, could challenge Denmark's current lead. If Denmark is to maintain its strong competitive position, total authority processing times, in appeals boards in particular, must be reduced, or decisions on port expansions and upgrades must be taken much earlier than in neighbouring countries.

Different types of ownership also give different incentives and possibilities for ports. Most ports, except the British ports, are owned by the public sector, and their future development is therefore more driven by political objectives, e.g. for growth and employment.

The British ports also have the advantage that they can be allocated more state aid without being in conflict with the EU state aid regulations that otherwise restrict EU Member States in their subsidising of port expansions.

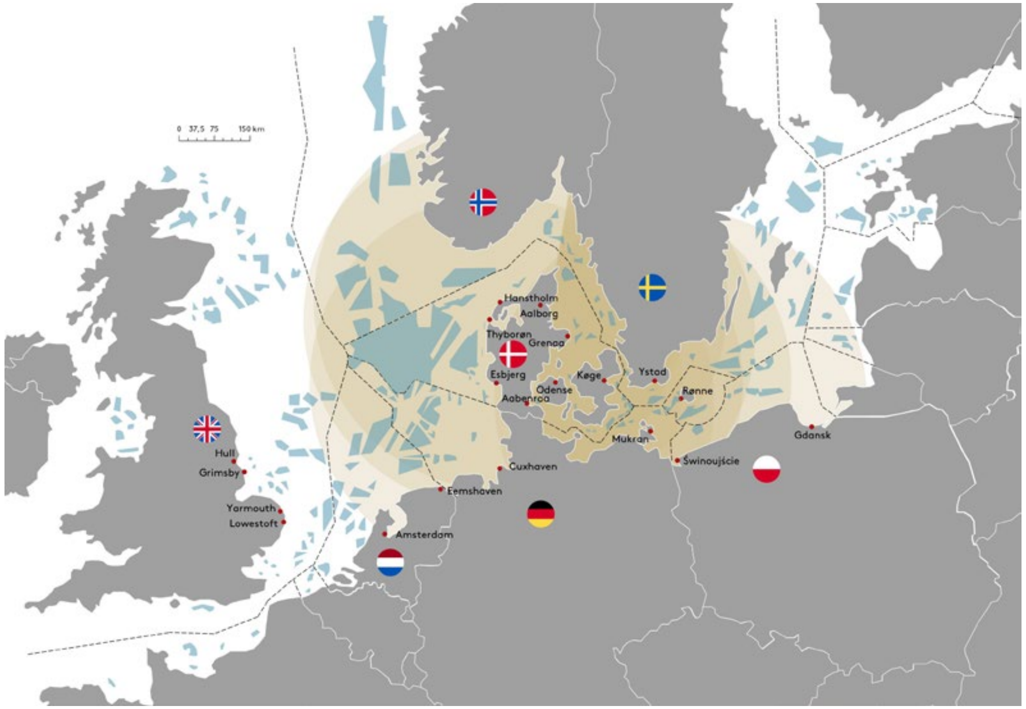
4.12 Conclusion: Denmark is at the forefront internationally, but is under threat from competition from other countries

Danish installation ports are well positioned in international competition in northern Europe, where there is a general shortage of ports which can cope with the large wind turbines expected to be the industry standard by as early as 2025. Both the capacity of Danish installation ports and their many years of experience with installing offshore wind turbines make Danish ports significant players in the North Sea and in the Baltic Sea.

Danish installation ports can reach beyond Danish borders to foreign territorial waters. In the North Sea, the Port of Esbjerg is particularly prominent with a high annual capacity of 2.5 GW. This installation capacity is today used to install offshore wind turbines in nearby German coastal waters, but Esbjerg also has experience shipping offshore wind turbines to many other European countries. In the Baltic Sea, the Port of Rønne is one of the dominant Danish ports in international waters. With an annual installation capacity of around 1.5 GW, the Port of Rønne is used to install Polish and German offshore wind farms. The strongest competitors for Danish ports are Eemshavn in the Netherlands (for the North Sea) and Mukran in Germany (for the Baltic Sea).

In the Oostende Declaration, the nine North Sea countries[44] set a goal of approx. 120 GW by 2030 and 300 GW by 2050. Furthermore, in the Marienborg Declaration, the eight Baltic countries[45] set a goal of 19.6 GW offshore wind by 2030. The competition situation therefore

***Figure 4.14:** Danish installation ports can compete on foreign land*



Note: Circles illustrate the range of Danish ports (≈370 km)
Source: The CIP Foundation (2024a)

43 Cf. The Swedish Transport Agency 2024: Årsrapport_Trafikstyrelsen som miljøvurderingsmyndighed
44 The Ostend Declaration consists of Belgium, the Netherlands, Germany, Great Britain, Luxemburg, France, Norway, Ireland and Denmark.
45 The Marienborg Declaration consists of Denmark, Sweden, Poland, Finland, Estonia, Latvia, Lithuania and Germany

differs from the North Sea to the Baltic Sea, partly because there is a greater potential for installation of offshore wind power in the North Sea than in the Baltic Sea, and partly because there are more qualified ports in the North Sea than in the Baltic Sea. Whereas the Danish GW-goal in the North Sea for 2050 is for about 12% of the total GW-goal under the Oostende Declaration, in the Baltic Sea Denmark is responsible for 33% of the total GW-goal.

Even though Denmark's GW-goal is larger in the Baltic Sea relative to its neighbouring countries', the absolute potential for Danish offshore wind is highest in the North Sea. Whereas Denmark dominates deployment ambitions in the Baltic Sea, Denmark's plans in the North Sea are more modest than those of its neighbours and more modest than its own goals in the Baltic Sea. However, Danish installation ports in both the North Sea and the Baltic Sea are some of the largest and most important installation ports for both Danish and foreign wind projects.

Like Denmark's deployment plans, international deployment plans are based on political goals for 2030 and 2045-2050. This means that, even if there were massive investments in upgrading ports in all countries, there would still be some years without enough port capacity to implement the deployment plans and thus meet the political goals. In contrast, if the necessary investments were made, there would also be longer periods, across countries, with more port capacity than is required. In this respect, note that port areas for installation of offshore wind energy cost around twice as much as other industrial areas, and this means that it will rarely be profitable to exploit port areas for the offshore industry for other purposes.[46]

***Table 4.5:** Foreign installation ports that can compete with Danish ones installation ports*

Group total	North Sea	GW/yr	Baltic Sea	GW/yr	Group total
4.7 GW/yr	Esbjerg	2.5	Odense	1.4	6 GW/yr
	Thyborøn	1.5	Rønne	1.3	
	Hanstholm	0.7	Køge	1.3	
1.1 GW/yr	Cuxhaven	1.1	Aabenraa	0.2	
3.4 GW/yr	Eemshaven	2.1	Grenaa	1.5	
	Amsterdam	1.3	Aalborg	0.4	
7.5 GW/yr	East England: Hull, Grimsby, Lowestoft, Yarmouth	7.5	Mukran (Sassnitz)	1.3	1.3 GW/yr
			Ystad	0	0 GW/yr
			Świnoujście	0	0 GW/yr
			Gdansk	0	

Source: The CIP Foundation (2024a)

Whereas, in years with under-capacity, competition will primarily be between countries that have to secure port capacity to realise their national goals, in years with over-capacity, competition will be between ports, which will have to attract activity from developers and installers. In years with over capacity, competition in the North Sea will largely be between Esbjerg in Denmark and Eemshaven in the Netherlands, both of which can compete to fill the gap in German capacity to install offshore wind turbines. In the Baltic Sea, competition is expected to be between Rønne in Denmark and Mukran in Germany, which can compete to install Polish offshore wind farms so that Poland can realise its part of the Marienborg Declaration.

In general, it is likely that all port capacity will be utilised in years with under-capacity, because there will be competition between countries for a share of the port capacity needed to achieve the politically determined goals in the Oostende and Marienborg declarations. In this context, the first countries to designate marine areas and put them out to tender, as well as ensure the necessary investments in ports, will be in the best position when developers and installers are planning and drawing up the necessary contracts. In years with over-capacity, it is expected that the best dimensioned installation ports will be selected rather than under-dimensioned installation ports, where developers' costs are pushed up by mitigating initiatives.

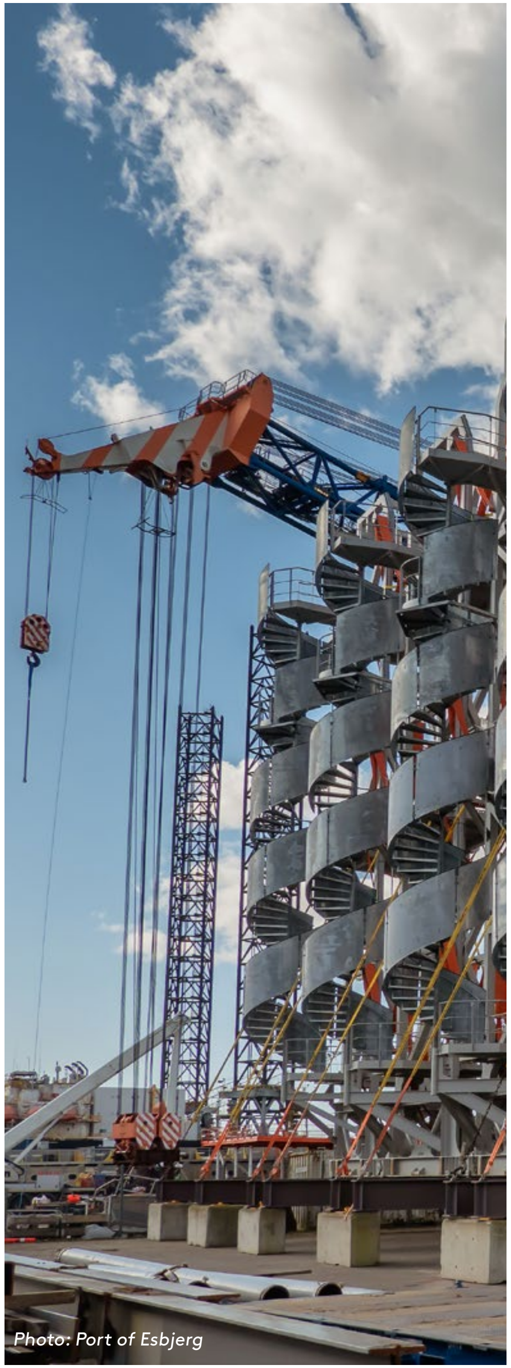


Photo: Port of Esbjerg

46 Interview with port director

5. Socio-economic impacts of offshore wind installation

If Danish ports are to compete internationally on installing future offshore wind turbines, they will have to be attractive for developers, which among other things call for greater bearing capacity and deeper channels. This will require significant investments in ports, which, on the other hand, can attract jobs and create growth locally, regionally and nationally. This chapter will analyse the socio-economic benefits from designating Danish ports as installation ports and service ports, respectively, in relation to the expected offshore wind deployment around Danish waters that forms the basis for the capacity analysis in Chapter 3.

5.1 Offshore wind generates growth and jobs

Denmark has more than 30 years of experience with offshore wind turbines and therefore has the most complete supply chain in the world. Existing analyses[47] estimate that Danish companies have 35-40% of the European market share for offshore wind turbines, and 57% of the Danish. Offshore wind power has a significant impact on the Danish economy.

The value chain for offshore wind has a number of economic effects that overall can be divided into three parts:

- The direct effects arising in production itself, construction work and subsequent operation and maintenance of wind turbines.
- The indirect effects, i.e. the effects at subcontractors supplying components and services for the wind turbines.
- The derived effects resulting from higher incomes from investments, and which are realised as higher consumption, for example, which benefits other sectors.

It has been estimated that, over time, the total Danish employment effect will be 14,600 FTE (full-time equivalents) per GW offshore wind power installed in Denmark. This breaks down to about 4,900 Danish FTE per GW in direct effects, whilst the indirect effects correspond to 5,100 FTE and derived effects amount to 4,500 FTE. See Table 5.1.

Revenues and employment in the wind turbine sector

- Total revenues in the wind turbine sector were DKK 128.5 bn in 2020.
- Revenues in 2020 broke down into DKK 115 bn. in the industrial part of the wind turbine sector and DKK 13.4 bn. for energy companies with wind-power activities.
- The turbine sector employed 32,721 FTE in 2020.
- Overall, an estimated 2.3% of private-sector employees in Denmark work in the wind turbine sector. The industrial part of the wind turbine sector alone accounts for about 2.1% of private-sector employees in Denmark.

Source: Wind Denmark: Industry statistics Wind turbine industry, November 2021

Employment and GDP effects from offshore wind are spread with considerable variation over the individual phases in the value chain, and the production of turbines and subsequent service in particular account for a large part of the employment effect. The service phase is particularly significant for the long period in which the wind farms will require labour for maintenance and repair.

Danish businesses have the lowest market share in the installation phase. Installing one GW offshore wind power from a Danish port has a direct Danish employment effect of almost 170 FTE, whereas the indirect effect is about 210 Danish FTE and the derived effect 185 Danish FTE.

The largest value added by offshore wind installation from Danish ports is thus indirect and derived effects in the form of growth in other industries.[48]

The offshore wind turbine industry has not only experienced progress in terms of the size and output of wind turbines. There have also been considerable productivity advances in recent years, which have made turbines cheaper and reduced needs for labour.

Between 2010 and 2022, the labour required to install offshore wind turbines has fallen by 60%.[49] The trend is expected to continue up to 2050, although at a slower rate.[50] This means that the employment effects will probably decrease over time.

***Table 5.1:** Labour input per GW offshore wind power in Denmark*

Full-time equivalents	Phase 1 Design and development	Phase 2A Production (wind turbines)	Phase 2B Production (platforms)	Phase 3 Installation and grid connection	Phase 4 Operation and maintenance (25 years)	Phase 5 Closure	Total
Total							
Direct	574	2,655	2,820	781	1,907	713	**9,451**
Suppliers (all)							
Direct	547	2,655	2,820	741	1,585	642	**8,991**
Suppliers (DK)							
Market share	57%	56%	48%	23%	81%	50%	**57%**
Direct	314	1,486	1,345	169	1,287	321	**4,923**
Indirect	174	1,538	1,042	213	1,814	403	**5,148**
Derived	224	1,443	733	185	1,515	351	**4,451**
Total	**713**	**4,467**	**3,119**	**568**	**4,616**	**1,075**	**14,558**

Source: QBIS based on Statistics Denmark, Ørsted, Vattenfall, Siemens Gamesa, Semco and others

47 "Socio-economic impact study of offshore wind", QBIS (2020).
48 The CIP Foundation based on QBIS (2020).
49 The CIP Foundation based on QBIS, IRENA, Denmark's statistics (INPMUL1), Wind Denmark and Wind Europe.
50 QBIS (2023), Aegir (2023), NREL (2022) and U.S. Department of Energy (2021)

***Table 5.2**: Types of jobs that can arise with local suppliers*

Type	Description	Examples
Primary (direct)	Suppliers of core activities in relation to offshore wind turbines. Often highly specialised undertakings with focus on offshore wind power.	Installation vessels, service vessels, turbine inspection, etc.
Secondary (indirect)	Suppliers with core activities in other sectors than offshore wind, but whose services are required by offshore wind developers and their primary offshore wind suppliers	Local shipyards, equipment suppliers, steel manufacturers, electricians, cleaning, fuel suppliers, etc.
Tertiary (derived)	Suppliers without direct or indirect involvement in the core activities at an offshore wind farm. These suppliers can contact personnel within offshore wind development and their primary and secondary suppliers	Local catering firms, hotels, restaurants, shops, cinemas, bakeries, etc.

Source: QBIS


Photo: Port of Grenaa

5.2 Danish ports can generate huge benefits from Danish offshore wind power

Danish offshore wind deployment plans will generate great benefits if installation takes place from Danish ports.

Based on scenario 2 for the deployment of Danish offshore wind power (see Section 3.3), which only includes Danish offshore wind power, corresponding to just under 52 GW up to 2050,51 the total Danish employment effect in the installation phase has been estimated at 27,000 FTE, after adjusting for advances in productivity.[52] This corresponds to around 1,000 FTE annually in the period, of which 300 FTE are direct effects, and indirect effects are 370 FTE.

In total, installation of Danish offshore wind energy from Danish ports will generate a GDP contribution of DKK 48 bn. up to 2050, of which around DKK 32 bn. is linked to the North Sea, 10 bn. to the Baltic Sea and DKK 6 bn. to "Other areas".

***Table 5.3**:Annual work linked to the expansion of offshore wind in scenario 2*

Direct effect	8,000
Indirect effect	10,050
Derived effects	8,750
Total	26,800

Source: The CIP Foundation (2024b)

However, good conditions for the installation of offshore wind, and good conditions for the wind industry in general, could make the effects significantly larger. If it becomes lucrative to install offshore wind power from Danish ports, this will attract more parts of the value chain to obtain synergies with regard to knowledge-sharing, transport distances and labour.

For example, if the associated production of platforms and wind turbines can be attracted, the effects will be more than ten-times higher. Today, Denmark already has a well-established industry, with annual revenues of more than DKK 100 bn.

Therefore, Denmark is in a good position to take share in future growth when offshore wind ambitions are to be realised. However, the industry faces strong growth, and the future location of the value chain depends on where the required framework and the well-dimensioned ports are available.

5.3 Danish ports can generate an export boom

There are also significant potentials with regard to installation of foreign wind farms and exports of Danish port capacity. Scenario 3 contains the same deployment plans as scenario 2 but includes a further 39 GW foreign offshore wind power in the period 2024-2050 that is likely to make use of Danish ports, as the marine areas are located closer to Danish Ports than foreign ports.

***Table 5.4**: Annual work linked to the expansion of offshore wind in scenario 3*

Direct effect	13,750
Indirect effect	17,350
Derived effects	15,050
Total	46,200

Source: The CIP Foundation (2024b)

The 39 GW foreign offshore wind power can generate an additional Danish employment effect of 19,400 FTE over the entire period. Overall, exports of port capacity will provide an additional contribution to Danish GDP of DKK 35 bn.

51 KPMG (2023b)
52 The CIP Foundation based on QBIS.

5.4 Danish ports generate sustainable growth and employment

In both scenarios, with and without foreign offshore wind power installed from Danish ports, a large part of the impact is at the beginning of the period because of the deployment profile.

However, the installation also has a large employment potential in subsequent servicing of the wind farm. This will create a more long-term employment effect, as the service period stretches over the approx. 25-year lifetime of the farms.

Deployment of offshore wind farms in scenario 2 alone will generate a total of 220,000 FTE to service the offshore wind turbines in the period from 2024-2075, and this will accumulate over the deployment. In 2050, servicing the wind farms will generate around 9,000 FTE.

Up to 2050, when the majority of the offshore wind turbines will be installed, further port capacity may be released that can be exploited to service existing wind farms. There is a substantial additional potential in this context if Danish ports can become service ports for the foreign wind farms included in scenario 3. If the Danish ports located closest on the offshore wind farm can win the service task for the offshore wind turbines, it will be possible to generate more than 5,000 more FTE by 2050.

In 2050, when deployment goals have been reached, the FTE generated through servicing the offshore wind turbines are expected to continue, as the total offshore wind capacity will not drop. The effects of the installation will also be regularly (and permanently) recreated as the turbines are replaced at the end of their lifetime of 25-35 years.

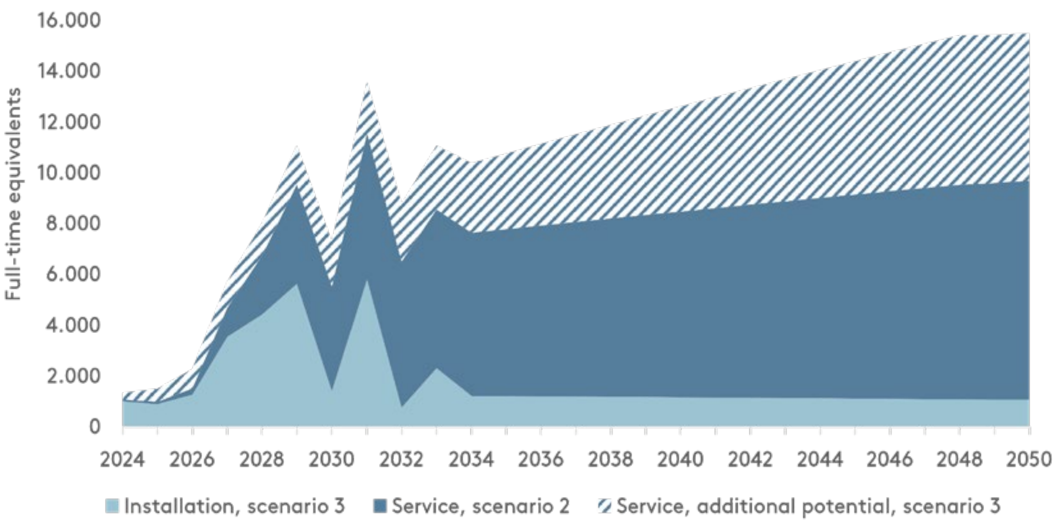
5.5 Offshore wind concentrates growth in outlying areas of Denmark

Deployment of offshore wind has great significance for the local areas where the turbines are manufactured, shipped and serviced. This applies not least to the role of ports in the deployment, and it will help create jobs and growth in local areas located on Danish coasts, usually outside traditional growth areas.

One GW of offshore wind power generates around DKK 35 mill. for the installation port, while an annual around DKK 2-4 mill. is generated for the service port. This corresponds to more than DKK 95 mill. over an expected 25-year lifetime for an offshore wind farm.[53]

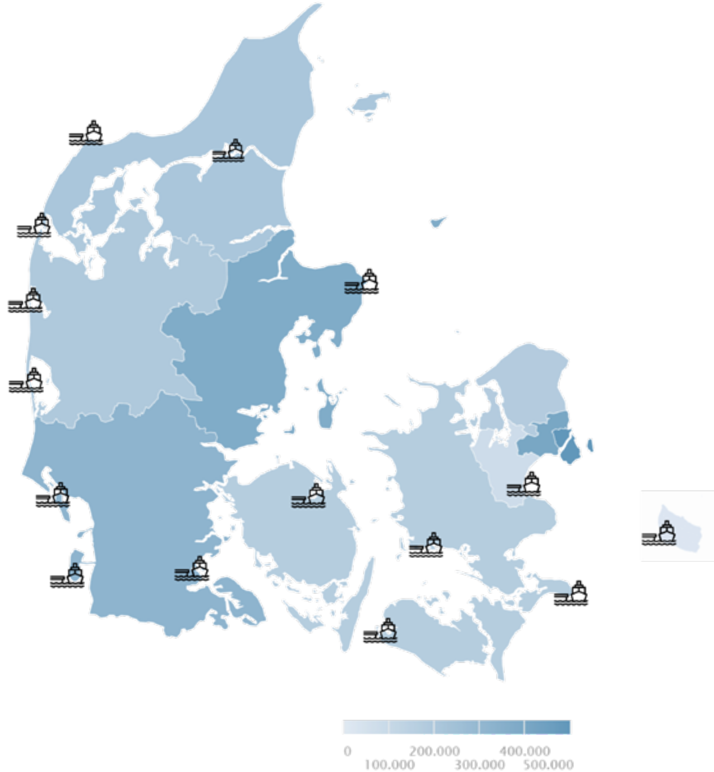
Besides the port itself, businesses and

***Figure 5.2:** Full-time equivalents linked to installation and service*



Source: The CIP Foundation (2024b) based on QBIS (2023)

***Figure 5.3:** Offshore wind concentrates growth in outlying areas of Denmark*



Note: GDP per capita broken down by regions in 2022, DKK '000 (current prices)
Source: The CIP Foundation (2024b) based on QBIS (2023)

53 QBIS (2020)

sub-suppliers at the port and in the area around the port will also benefit from the installation. This could be anything from companies delivering to the deployment itself, e.g. shipyards, storage facilities, turbine inspection and pre-assembly, to businesses that benefit from the additional activity in the area, e.g. restaurants.

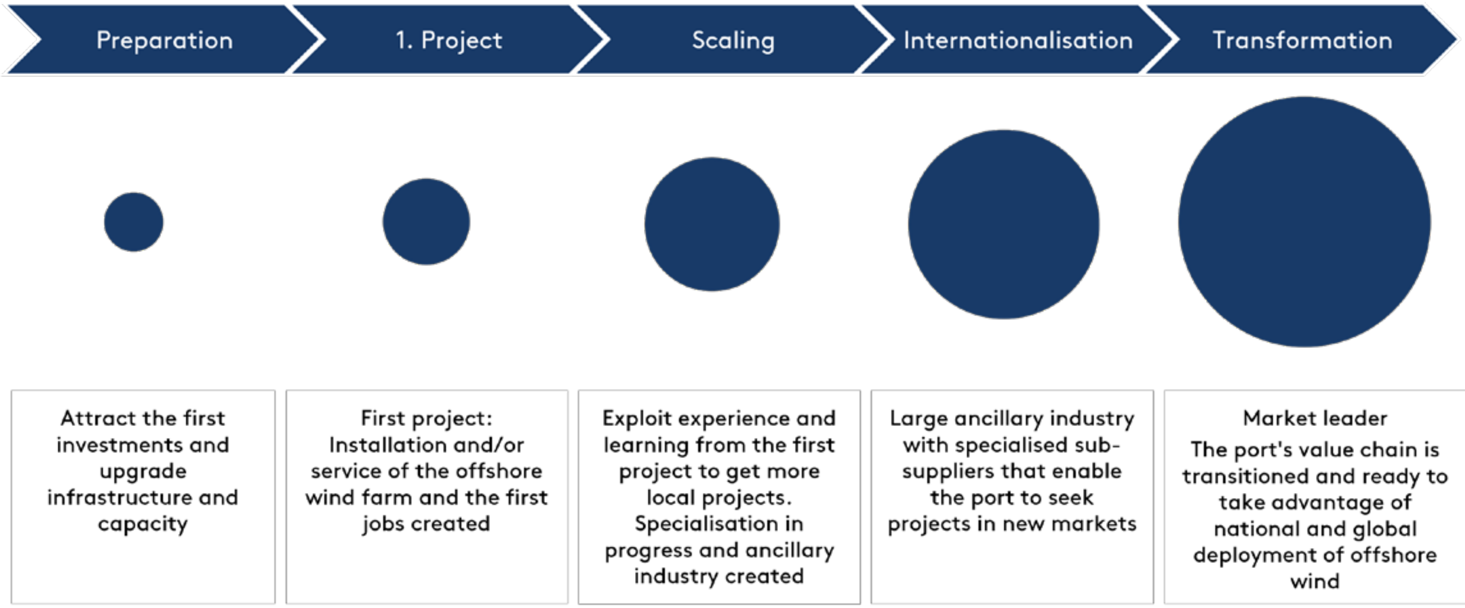
The potential for the local area ultimately depends on the area's ability to win part in the overall orders. If there is a large ancillary industry to collect orders for sub-suppliers, the effect will be significantly larger than if there is no ancillary industry.

There will usually be a snowball effect, whereby the potential increases as more projects are shipped from the port in question, as this will allow larger investments from local suppliers and thus strengthen the cluster and the opportunities for local stakeholders to specialise and win orders. In Denmark, ports at Esbjerg, Odense and Grenaa have been able to move into such a position.[54]

QBIS (2020) distinguishes between two categories of port in Denmark – the Port of Esbjerg and other ports. Depending on the other ports' ability to take part in the overall orders, QBIS estimates that 1 GW offshore wind power in the installation phase can generate DKK 80-210 mill. in revenues and create between 30-96 FTE in direct, indirect and derived effects.

For the Port of Esbjerg, which has already shipped significant amounts of offshore wind power, the local effects have been estimated significantly higher. In this context, it has been estimated that 1 GW offshore wind power will generate DKK 2.3-3.7 bn. in revenues and create between 869-1,415 FTE.

Figur 5.4: Development steps for installation port



Source: The CIP Foundation (2024b) based on QBIS (2023)

The large difference between Esbjerg and the other Danish ports is due to differences in the ability of the local community and local businesses to meet the demand for products and services relating to the installation of offshore wind turbines. Businesses in and around Esbjerg have an advantage as several years of demand have cemented a supply.

If the increased deployment of offshore wind power leads to increased specialisation and a stronger local ancillary industry, there will be a greater effect as their ability to meet demand rises. It can be assumed that the potential is greatest for the other, larger ports; a potential that can be realised as advantages in the international competition.

Besides generating jobs and growth, future deployment of offshore wind power will also help attract other investment to ports, ensure upgrades in the skills of workers in the area and enable suppliers to expand in addition to the local projects and thereby strengthen the port.

5.6 Huge potential

Deployment plans for offshore wind power are largely concentrated in the period around 2030. This means that, in the period before and particularly in the subsequent period from 2030 to 2050, there is an over-capacity of port area which could potentially be used to install foreign wind farms if the port is competitive and offshore wind installation is cost-effective despite the longer distances.

In a conservative scenario with low area use and investment in just the largest and most experienced ports[55] to become competitive, Denmark will be able to exploit a total annual offshore wind capacity of 10.6 GW. Excluding areas already identified for international deployment, there is an additional technical export potential of 195 GW divided between 76 GW in the North Sea, 82 GW in the Baltic Sea and 37 GW in "Other areas". Note that this is if it is possible to exploit the entire capacity.

Exploiting the export potential for the North Sea could create 45,600 FTE, with a direct effect of 13,600 FTE. The export potential for "Other areas" is 9,200 FTE. In the Baltic Sea, the technical export potential could generate

54 Based on interviews with port directors
55 Low area utilization refers to 200,000 m2 per GW/year. The largest and most experienced ports include Esbjerg, Thyborøn, Hanstholm, Odense, Rønne, Køge, Grenaa, Aabenraa and Aalborg. See chapter 3.7.

39,700 FTE, of which the direct effect for the period is 11,800 FTE. The export potential for "Other areas" is 18,000 FTE.

However, exploitation of the technical potential, or the added capacity, is associated with uncertainty, and it depends on future decisions and deployment profiles. For example, estimated export potential is greater than the potential deployment in the Baltic Sea, which in the same period is expected to be 73.4 GW.56 Danish port capacity can be used in the deployment of foreign offshore wind and Danish offshore wind power, just as port areas can be used for production, service or entirely different industries, if there is no need to use them to install offshore wind projects. As mentioned above, the latter is unlikely to be cost-effective, unless investments in infrastructure have already been paid for over a longer period.

5.7 Conclusion: Offshore wind installation generates growth and massive exports

Installation of offshore wind power is a vital part of the value chain, and the economic impacts from installing offshore wind power from Danish ports are considerable. Employment and GDP effects from offshore wind are spread with considerable variation over the individual phases in the value chain, and the production of turbines and subsequent service account for a particularly large part of the employment effect.

Nevertheless, it is likely that, in the installation phase alone, realising the Danish deployment goals will generate a total employment effect of 27,000 FTE up to 2050, with a GDP contribution of almost DKK 50 bn. if the installation of turbines goes through Danish ports.

If the Danish ports manage to be competitive enough for the closest foreign offshore wind also to be installed through Danish ports, the employment effect will be a further 19,400 FTE, with an added contribution to GDP of DKK 35 bn. If the ports also function as service ports for offshore wind projects, up to an annual 14,000 FTE will be generated from 2050.

Installation of offshore wind power is only a small part of a large value chain in an industry that in Denmark generates annual revenues of more than DKK 100 bn. annually. Therefore, it is also important, because installation opportunities can attract and retain the entire value chain in a large, and for Denmark very important, industry. Nevertheless, installation from Danish ports in itself entails significant added growth which, with competitive ports, could be permanent. The effects of the installation will also be regularly (and permanently) recreated as the turbines are replaced, and there will continue to be a need to service and repair the turbines.

Shipping offshore wind power will help create jobs and growth in local areas located in Danish outlying areas, usually located outside traditional growth areas. Value creation depends on the ability of a local area to take part in the activity, and if this is strong, the benefits will be greater.

6. Danish ports - challenges and opportunities

The previous chapters have described Danish port capacity in relation to offshore wind installation, the international competition faced by Danish ports, and the socio-economic gains that could be achieved if Danish ports were appointed as installers for Danish and foreign offshore wind. This chapter puts into perspective the other challenges and opportunities facing Danish ports.

6.1 Ports have several key roles for offshore wind power

The previous chapters focused on the role of ports in installing offshore wind. However, the ports' role for offshore wind is broader than just installation and this creates both opportunities for ports and challenges for the total capacity in Denmark. Because of the size of wind turbine components, production has to be carried out at the port, and servicing offshore wind farms will also become more demanding as deployment progresses and more turbines are erected offshore. Like installation, production of components and foundations in particular takes up large areas at ports and many workplaces are also required. There are already production facilities in several places in Denmark,[57] but needs will increase in line with the rate of deployment. If Denmark is to have a share in more production in the future, there is a need for further new production areas, including to manufacture and install foundations. Alternatively, installation areas will have to be converted into production areas, and this will lead to more shortages of port capacity for installation of offshore wind turbines. Offshore wind turbines must be produced before they can be installed and areas for both purposes are therefore necessary to realised deployment plans.

6.2 Defence and energy production take up new areas

Historically, ports have had many important functions for society. Besides fisheries, cargo transport, shipyards and passenger transport, ports today are undergoing changes in several areas, and this increases the need for space. Besides the presence of the offshore wind industry itself, areas for hydrogen and power-to-x production could take up further space at ports, and the current security situation could require additional areas for defence forces. For example, a plant to produce hydrogen is being constructed at the Port of Aabenraa,58 and new areas for military purposes are being taken over at the Port of Esbjerg.[59] According to the Danish Ports Act, areas at ports must be prioritised for port-related activities, i.e. for commercial activities that support the maritime transport and activities that require a close-to-port location. A combination of increased demand for traditional port activities and new, energy-producing activities aimed at marine resources will demand more space at Danish ports.

In this context, it is important to repeat the point that, it is not immediately possible to substitute one function with another. Area requirements for offshore wind power are greater, for example, and the price per unit of area is twice the price of areas for traditional port functions. This means that it will be difficult to pay returns on investments in areas for offshore wind if they are used for other purposes.

6.3 Global supply chains under pressure

Besides port capacity, other factors may also challenge deployment of offshore wind power. Global supply chains have been under pressure in recent years. This has resulted in increasing raw materials prices and steel shortages, which may also challenge the total value chain for offshore wind. A robust supply chain for wind turbines and foundations is crucial to realise growth plans.[60]

As described in Chapter 5, the green transition can generate growth, exports

Photo: Port of Grenaa

57 For example nacelles and turbine towers are produced in Esbjerg, nacelles and foundations in Odense, wings and foundations in Aalborg and turbine towers in Aabenraa
58 Linde Gas will invest up to DKK 750 million. DKK in Danish hydrogen plant (Energiwatch.dk)
59 Esbjerg Harbor faces expansion: Could become a 'military railway station' (dr.dk)
60 The future of wind energy lies beyond the horizon (group.vattenfall.com)

and jobs in Denmark. A precondition for this, however, is attracting qualified labour. Several commercial ports already report a need to import labour to manage the activities in connection with deployment of offshore wind power. In the 2020s alone, around 120,000 FTE will have to be recruited for wind power deployment already planned.[61]

The need for labour is linked to wind power deployment and therefore will be greatest during construction of the energy islands at the end of the decade. The shortage of labour can challenge both Danish wind power deployment and Denmark's possibilities to take part in international deployment.

There are also challenges with regard to maritime transport. An analysis from Spinergie in January 2024[62] maps the demand for installation vessels to manage the massive deployment plans. From as early as 2026, there will be a global shortage of installation vessels, and this will result in a maximum installation capacity of 114 GW up to 2030. This compares with specific plans for 170 GW offshore wind power and political ambitions for more than 360 GW.

Again, the problem is greatest around the end of the decade, and between 2029 and 2039 there will be a shortage of installation vessels for more than one-half of the 76 GW offshore wind power to be installed in the period. An analysis by Wind Europe and others has mapped how the global demand for various installation vessels will exceed supply as early as during 2024, and that this trend will be severe around 2030.

Expansion of the Port of Rønne

The Port of Rønne has undergone a number of expansions as part of its "Masterplan 2050". The first expansion required an investment of about DKK 500 mill. and it entailed:

- + 300 metres of new quay for cruise ships and the offshore industry with associated ro-ro ramps
- construction of 150,000 m² new port area
- 650,000 m³ dredging to deepen the port to around 11 metres

Source: Port of Bornholm and Licitationen (The Licitation)

Investments in channels

In 2024, the Port of Esbjerg is dredging the channel from 9.3 to 12.8 metres. DKK 211 mill. is being invested with funding from the European Commission.
The 2020 Finance Act included remediation, and the ports at Hanstholm and Thyborøn were granted DKK 5 mill. and 4 mill. annually over a 25-year period. The funds have been earmarked for the regular remediation of the seabed, and they were allocated in connection with an agreement on establishing test sites for wind turbines in Østerild and Høvsøre.

Source: Port of Esbjerg, TVmidtvest (TVmidtwest)

6.4 Lack of investment signals

Both 2030 and from 2045-2050 are crucial years for many countries' climate targets. The fact that many countries have centred their targets on these years creates a problem in itself, as it generates massive, but relatively short-term, demand for products and services throughout the entire value chain for offshore wind: raw materials, turbines, foundations, ships, labour and not least port areas. It may challenge willingness to invest in port infrastructure, for example, if there is only a short-term need for the infrastructure. There are other port-specific challenges, e.g. there are unequal financing possibilities for ports, depending on their organisation and ownership, and Danish ports do not own, but only administer, the seabed, and therefore dredging channels to be able to receive installation vessels is more a cost rather than an investment.

Although there are several examples in Denmark of investments in ports for offshore wind installation, the lack of investment signals is a challenge for ports and thus also to realising the deployment goals. It takes several years to expand the port, and there should be certainty in the business case before any investment is made. However, deployment of offshore wind energy depends on knowledge about possible future public tendering of offshore wind, so that ports and installers have a basis for planning.

Changed and postponed tendering procedures and cancelled open-door projects have created uncertainty among both developers and ports. If future projects are uncertain, ports will accept other tasks such as installation of foreign offshore wind. Several Danish ports are already fully booked by foreign projects for the next years, and this may mean that Danish projects have to be installed from less well-located ports. This increases costs for both developers and the green transition in general.

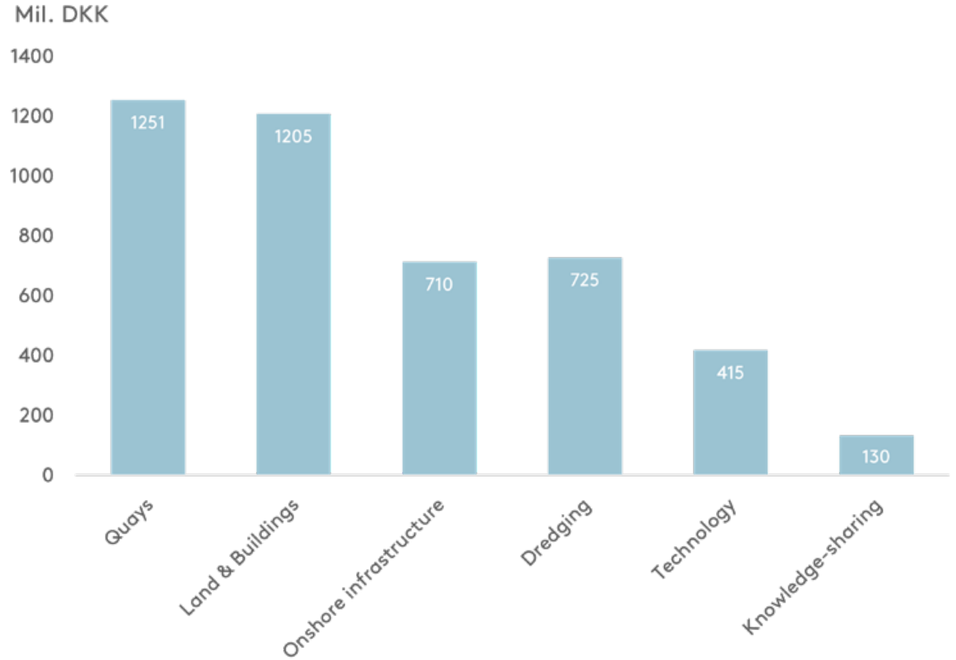
61 Center for logistics and cooperation (2020) Udfordringer og muligheder for offshore vind i Danmark. - Background for a national action plan.
62 More than 50 GW of offshore wind risks getting stuck in a bottleneck (Energiwatch.dk)

6.5 Danish ports can deliver competition and synergies

Investments in Danish ports differ significantly in terms of investment strategy and, thus, in terms of what is invested in. Over a 10-year period, ports at Odense, Esbjerg, Aalborg and Aabenraa have together invested DKK 4.4 bn. Investments in quays and land and buildings together account for more than one-half of the total investment sum, while investments in onshore infrastructure, dredging, technology and knowledge-sharing account for the remaining part. Investments are unevenly spread between the ports, and one port always accounts for one-half or more of the investment within a specific category. For example, one port accounts for more than half of investments in quay construction and one accounts for more than 75% of investments in dredging.

The different investment strategies can simultaneously exacerbate internal competition and generate synergy effects: Investments that specialise a port, e.g. a deeper channel, can increase the port's specialisation profile in the competition to attract large vessels, but such investments can also be seen as complementary and generate synergies, so that specialised ports can cooperate in the value chain, and thereby ease the investment burden for other ports. Specialisation that both encourages competition and synergies is particularly apparent on the production side, e.g. Esbjerg today produces nacelles and towers, Odense nacelles and foundations, Aalborg blades and foundations and Aabenraa towers. Ports compete on some parameters and collaborate on others. In this context, scaling effects can also reduce the costs and make the overall green transition cheaper.

***Figure 6.1:** Investments by category*



Source: Centre for logistics and cooperation (2020)

6.6 From deployment goals to deployment plan

Ports are currently facing a serious challenge: A large amount of offshore wind has to be installed in a short period of time. Driven by political goals, the majority of offshore wind turbines have to be erected in only a few years' time in 2030 and 2050. But when and where specific projects are to be completed, and who is to be responsible for development, is uncertain for by far the majority of projects. Therefore, investments in port capacity are not automatically following, as they are large, irreversible and uncertain. Neither society nor the ports benefit from unnecessary over-investment, and long-term planning and formal collaboration are therefore needed if the deployment of offshore wind is to be successful and cost-effective.

If the specific deployment up to and including 2031 is determined now through calls for tenders, this will increase transparency and establish certainty for decisions on investments in ports. This will make it possible to send investment signals through the entire value chain, and deployment can be at the lowest possible cost. Specific determination of future offshore wind projects up to and including 2031 can thus:

Help ports to make final investment decisions on port expansion on the basis of specific agreements with developers
Help secure port expansion in good time to realise Danish deployment goals
On the basis of a complete overview of projects over the long term, help ensure that ports are reserved for local projects, thus contributing to a cost-effective green transition

However, the signals will also have a positive impact on the remaining parts of the value chain, because there will be investment in production facilities for wind turbines and vessels, and more labour can be trained and mobilised. A long-term, specific deployment plan will help to ensure that Denmark can achieve its deployment goals for offshore wind energy, and reduce the costs of installation.

Photo: Port of Esbjerg

7. Conclusion

The previous chapters have mapped Danish port capacity in light of deployment plans for offshore wind in relation to international competition and socio-economic benefits. Below are the key conclusions and the CIP Foundation's recommendations.

7.1 Deployment plans and technological development are putting pressure on Danish ports

Technological advances mean that offshore wind turbines are getting larger and heavier. The political goals and deployment plans will increase the rate at which turbines are to be shipped from ports. Managing larger and heavier components and aiming at a five-fold increase in installed wind capacity by early 2030 will put more pressure on ports.

From 2025, the 15 MW offshore turbine is expected to be industry standard. This will lead to an increase of around 50% in turbine weight. From the perspective of installers, demand for port capacity will thus change, with focus on space, stronger bearing capacity and deeper channels to manage the turbines of the future and the vessels that are to transport the heavier components.

7.2 Danish ports are not geared for the deployment

Only very few Danish ports currently have the dimensions required to manage 15 MW turbines. Investments in quay bearing capacity and deeper channels are required if Danish ports are to remain attractive for installation in the future, as the mitigating initiatives extensively used today increase the costs of installation. If Denmark is to realise the deployment goals adopted in the Oostende Declaration and the Marienborg Declaration, investment is needed to upgrade Danish installation ports so that they can continue to serve as installation ports for Danish offshore wind farms, and so that Denmark can maintain its important value chain in the wind industry.

7.3 Denmark cannot realise deployment goals

Even with massive investment in Danish offshore wind ports, small bottlenecks will arise in the North Sea, in the Baltic Sea and in Danish coastal waters, because port areas are not large enough to manage deployment plans. Bottlenecks will peak in the late 2020s/early 2030s. The Danish deployment goals concentrate deployment around 2030, and this means that there will be periods with over-capacity after this date, with possibilities to install more offshore

Photo: Port of Esbjerg

wind power than is needed in Denmark. Possibilities for installation from Danish ports concentrate on ports with most port area for offshore wind installation: Esbjerg in the North Sea, Odense, Rønne and Køge in the Baltic Sea and Grenaa in "Other areas". If there is investment in upgrading of the facilities at these and a number of other ports, overall Denmark can achieve a total annual installation capacity of around 10 GW. Denmark is currently in a strong position in the international competition, and part of the capacity could be used to install foreign offshore wind farms.

7.4 The challenges repeat in Europe

The challenges of under-dimensioned ports and limited port area are the same throughout northern Europe. Like Denmark, international deployment plans are based on political goals for the years around 2030 and 2045-2050. This means that, even if there were massive investments in upgrading ports in all countries, there would still be some years without enough port capacity to implement the deployment plans and meet the goals. In contrast, if the necessary investments were made, there would also be longer periods, across countries, with more port capacity than is required.

7.5 Danish ports have a strong position in the North Sea and in the Baltic Sea

Danish installation ports are well positioned in the international competition in northern Europe. Both the capacity of Danish installation ports and their many years of experience with installing offshore wind turbines make Danish ports significant players in the North Sea and the Baltic Sea. Danish installation ports can reach beyond Danish borders to foreign territorial waters. In the North Sea, the Port of Esbjerg is particularly prominent with a high annual capacity of 2.5 GW. In the Baltic Sea, the Port of Rønne is one of the dominant Danish ports in international waters. With an annual installation capacity of around 1.5 GW, the Port of Rønne is used to install Polish and German offshore wind farms.

The strongest competitors for Danish ports are Eemshavn in the Netherlands (for the North Sea) and Mukran in Germany (for the Baltic Sea). The Danish edge provides good opportunities for Danish ports to continue to have a role in installing foreign wind farms. However, this requires investment in strengthening quays and dredging channels, so that the port can manage the larger and heavier turbine components.

Photo: Port of Grenaa

7.6 Political and economic frameworks impact development

Even though ports in the countries around Denmark are today in a weaker position in international competition than Danish ports, it is likely that competition will intensify in the future. In the UK and Germany, there is more coordination between ports, and most of the countries around Denmark have more rapid case processing by authorities for port expansion compared with Denmark. The political and economic framework, and priorities in the countries around Denmark, will create a framework enabling foreign ports to develop faster than the Danish ports.

A major challenge, however, is the lack of investment signals. Deployment plans must be known before investments in upgrading port capacity can be initiated.

7.7 Investments can generate jobs and growth

Investment in Danish installation ports so that together they have an annual capacity of 10 GW will generate growth and employment while the plans are realised. Installation of Danish wind projects alone has been estimated to have a total Danish employment effect of 27,000 FTE up to 2050. This corresponds to around 1,000 FTE per year in the period. In total, installation of Danish offshore wind energy from Danish ports will generate a GDP contribution of DKK 48 bn. up to 2050, of which around DKK 32 bn. is linked to the North Sea, 10 bn. to the Baltic Sea and DKK 6 bn. to "Other areas".
The effects are only linked to the installation phase, which in itself accounts for a small

part of total activity in the value chain for offshore wind. There is also significant production and service potential, which can account for the majority of the socio-economic benefits in the value chain.

Note that growth and workplaces will primarily be concentrated in outlying areas in Denmark, in which growth and employment are typically lower.

7.8 Danish ports can generate an export boom

There are also significant potentials with regard to installation of foreign wind farms and exports of Danish port capacity. If Danish ports have a share in foreign offshore wind deployment located close to Danish ports, there is an extra potential of 39 GW. The 39 GW foreign offshore wind power can generate an additional Danish employment effect of 19,400 FTE over the entire period. Overall, exports of port capacity can provide an additional contribution to Danish GDP of DKK 35 bn.

7.9 Ports can generate sustainable growth

Installation of offshore wind power also has a large employment potential in subsequent servicing of the wind farm. This will create a more long-term employment effect, as the service period stretches over the approx. 25-year lifetime of the farms.

Deployment of Danish offshore wind power alone will generate a total of 220,000 FTE to service the offshore wind turbines in the period from 2024-2075, and this will accumulate over the deployment. In 2050, servicing the wind farms will generate around 9,000 FTE. If Danish ports can win the service task for nearby foreign offshore wind power, it will be possible to generate more than 5,000 more FTE by 2050.

In 2050, when deployment goals have been reached, the FTE generated through servicing the offshore wind turbines are expected to continue, as the total offshore wind capacity will not drop. The effects of the installation will also be regularly (and permanently) recreated as the turbines are replaced at the end of their lifetime of 25-35 years.

7.10 Need for long-term planning

Ports are currently facing a serious development challenge: Driven by political objectives, large amounts of offshore wind are to be deployed and installed, but only few projects are known. This creates uncertainty throughout the entire value chain, as there is uncertainty about where the specific projects are to be completed.

This creates uncertainty and makes it difficult to make decisions about irreversible infrastructure investments. There is also no full overview of projects, and this can make overall expansion more costly because the total port capacity cannot be exploited efficiently.

If the market is to be able to manage the major development plans, long-term planning and allocation of roles are needed, so that investment decisions can be made on an informed basis.

The CIP Foundation recommends:

1. **Investing in an upgrade of Danish wind-power ports, so that port capacity allows for installation of up to 10 GW offshore wind power annually.**
Investment should secure adequate and future-proofed channels and quay bearing capacity, and the geographical orientation should be based on areas available and wind expansion planned. The upgrade could be anchored through investments in:
    a. North Sea: Esbjerg, Thyborøn and Hanstholm (≈4.6 GW/year)
    b. Baltic Sea: Rønne, Odense, Køge and Aabenraa (≈4.1 GW/year)
    c. Coastal waters: Grenaa and Aalborg (≈1.9 GW/year)

2. **Convert expansion goals to expansion plans** by conducting tendering procedures up to and including 2031 in order to cement investment signals in the value chain. The expansion plan can be adapted and any projects can be brought forward so that Denmark can meet its expansion goals with the port capacity available.

3. **Reduce time spent on processing by the authorities,** so that Danish ports can have permits, licences and appeals determined more rapidly, with consequential contributions to meeting Denmark's expansion goals.

Sources

Aegir (2022): LCOE - Update and recent trends (offshore), https://www.nrel.gov/wind/assets/pdfs/engineering-wkshp2022-1-1-jensen.pdf

Baltic Wind (2021): Port of Roenne selected as wind turbine installation port for Baltic Eagle offshore windfarm, Port of Roenne selected as wind turbine installation port for Baltic Eagle offshore windfarm - Baltic Wind

Business Vordingborg: Klintholm Havn er servicehavn for havvindmøller,https://businessvordingborg.dk/virksomhed/klintholm-havn/, visited on 24/01/2024

Center for logistics and cooperation (2020) Udfordringer og muligheder for offshore vind i Danmark. -Background for a national action plan. https://circabc.europa.eu/ui/group/9198696f-e42c-4a88-b4f1-7a1788eb9b7c/library/04f6ffce-cf95-4778-aa4a-65d3d3d441b9/details?download=true

CIP Foundation (2024a) memorandum on international competition between Danish and foreign installation ports for offshore wind turbines, https://cipfonden.dk/wp-content/uploads/2024/04/Notat-om-International-Konkurrence-Havvindinstallation-CIP-Fonden.pdf

CIP Foundation (2024b) Background note on the socio-economic benefits of shipping offshore wind turbines from Danish ports. *https://cipfonden.dk/wp-content/uploads/2024/04/Baggrundsnotat-om-samfundsoekonomiske-gevinster-havvindinstallation-CIP-Fonden.pdf*

CIP Foundation (2023):Roadmap for a Danish hydrogen infrastructure for the future: https://cipfonden.dk/wp-content/uploads/2023/06/Roadmap-for-en-dansk-brintinfrastruktur-til-fremtiden-CIP-Fonden-maj-2023.pdf

Danish Marine Plan (2023): Aftale mellem regeringen (Socialdemokratiet, Venstre, Moderaterne), Socialistisk Folkeparti, Danmarksdemokraterne, Liberal Alliance, Det Konservative Folkeparti, Enhedslisten, Radikale Venstre, Dansk Folkeparti, Alternativet og Nye Borgerlige om Danmarks Havplan, aftaletekst-danmarks-havplan.pdf (em.dk)

Danish Ports (danskehavne.dk): Danske Havne, https://danskehavne.dk/ visited on 24/01/2024

Danish Ports (May 2022): Offentlig støtte til havneinfrastruktur i Europa

DI (Danskindustri.dk): Esbjerg Havn flyder over af opgaver, https://www.danskindustri.dk/di-business/arkiv/nyheder/2023/12/esbjerg-havn-flyder-over-af-opgaver/

DR: Esbjerg Havn står over for udbygning: Kan blive en 'militær banegård', https://www.dr.dk/nyheder/indland/esbjerg-havn-staar-over-udbygning-kan-blive-en-militaer-banegaard

Energiwatch: Linde Gas vil investere op mod 750 mio. kr. i dansk brintanlæg, https://energiwatch.dk/Energinyt/Cleantech/article12929964.ece

Energiwatch: Mere end 50 GW havvind risikerer at sidde fast i flaskehals: https://energiwatch.dk/Energinyt/Renewables/article16726830.ece, visited on 24/01/2024

Ministry of Business (em.dk) Aftale om Danmarks Havplan, https://em.dk/Media/638314155637865872/aftaletekst-danmarks-havplan.pdf, visited on 12/02/2024

The Danish Energy Agency (ens.dk): Etablerede havvindmølleparker, https://ens.dk/ansvarsomraader/vindmoeller-paa-hav/etablerede-havvindmoelleparker

Port of Esbjerg (2023): 211 millioner kroner fra EU styrker Esbjergs rolle i europæisk infrastruktur, https://portesbjerg.dk/news/211-millioner-kroner-fra-eu-styrker-esbjergs-rolle-i-europaeisk-infrastruktur

Port of Esbjerg (2024): Offshore vind, https://portesbjerg.dk/forretningsomrader/vind visited on 24/01/2024

Groningen Sea Ports: EEMSHAVEN: ONE OF THE LEADING PORTS IN OFwFSHORE WIND INDUSTRY! https://www.groningen-seaports.com/en/industries/offshore-wind/,visited on 12/02/2024

Groningen Seaports: CIRCULAR HUB AND BIOBASED LOCATION OF NORTHWEST EUROPE, Delfzijl - Groningen Seaports (groningen-seaports.com), visited on 26/2/24

Groningen Seaports: GRONINGEN SEAPORTS, Groningen Seaports - Groningen Seaports (groningen-seaports.com) visited on 26/2/24

Holstebro Municipality Thorsminde bliver servicehavn for Thor Havvindmøllepark, https://www.holstebro.dk/servicehavn-thorsminde, visited on 24/01/2024

IRENA (2018): Renewable Energy Benefits: Leveraging-Local Capacity for Offshore Wind, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_Leveraging_for_Offshore_Wind_2018.pdf

Ministry of Climate, Energy and Utilities (2022): Marienborg-erklæringen, Østersøens lande styrker samarbejde om mere havvind og øget energisikkerhed (kefm.dk)

KPMG (2023): Analyse af havnekapacitet i relation til udbygning af dansk havvind, KPMG for The CIP Foundation, December 2023, https://cipfonden.dk/wp-content/uploads/2024/04/Kapacitetsanalyse-december-2023-KPMG.pdf

Licitationen: Aarsleff vinder udvidelsen af Rønne Havn til 500 mio. kroner, https://www.licitationen.dk/article/view/561581/aarsleff_vinder_udvidelsen_af_ronne_havn_til_500_mio_ kroner

Menon Economics (2023): MULIGHETER FOR NORSKE SAMMENSTILLINGS- OG INSTALLASJONSHAVNER INNEN HAVVIND FREM MOT 2030, https://www.menon.no/wp-content/uploads/2023-122-Muligheter-for-norske-havner-innen-havvind.pdf

Niedersachsen Ports: Port Expansion in Cuxhaven Approved, https://www.nports.de/en/ visited on 26/2/24

Niedersachsen Ports (2020): Niedersachsen Ports, Port Expansion in Cuxhaven Approved (nports.de), visited on 26/2/24

Niedersachsen Ports (2021): Port Information Guide Cuxhaven, https://www.nports.de/media/Haefen/Cuxhaven/NPorts_Port-Information-Guide_Cuxhaven.pdf

NREL (2022): A Systematic Framework for Projecting the Future Cost of Offshore Wind Energy, https://www.nrel.gov/docs/fy23osti/81819.pdf

NSEC (2023): North seas offshore wind port study 2030 – 2050, https://circabc.europa.eu/ui/group/9198696f-e42c-4a88-b4f1-7a1788eb9b7c/library/04f6ffce-cf95-4778-aa4a-65d3d3d441b9/details?download=true

Port of Odense (2024): Odense Havn, https://odensehavn.dk/ ,visited on 24/01/2024

Port of Odense (2024): https://odensehavn.dk/16858/, visited on 24/01/2024

Polenergia: Offshore wind farms, Offshore wind farms - Polenergia - Corporate Website, visited on 26/2/24

QBIS (2020): Socio-economic impact study of offshore wind, https://www.qbis-consulting.com/_files/ugd/cd2390_a67f69d716794cf1a963445c252e125d.pdf

QBIS (2023): Employment impacts of 40 GW offshore wind in France by 2050, https://www.qbis-consulting.com/_files/ugd/cd2390_f99930bf775d408a93fd1468c8b8329e.pdf

Port of Rønne (2016): Rønne Havn A/S Masterplan 2050, publiseret-masterplan-2050-d-11-16-1658-10.pdf (roennehavn.dk) visited on 26/2/24

The Baltic Sea – Energy Security Summit (2022): The Marienborg Declaration, https://www.regeringen.dk/media/11544/the-marienborg-declaration-_300822.pdf

Thorsminde By & Havn: Thorsminde bliver servicehavn for Thor, https://thorsminde.dk/servicehavnen-i-thorsminde/ visited on 24/01/2023

Danish Civil Aviation and Railway Authority 2024: Årsrapport 2023 Trafikstyrelsen som miljøvurderingsmyndighed Årsrapport_Trafikstyrelsen som miljøvurderingsmyndighed

TVmidtvest: Havne får millionbevilling fra staten https://www.tvmidtvest.dk/thisted/havne-far-millionbevilling-fra-staten

U.S. Department of Energy (2021): Offshore Wind Market Report: 2021 edition, https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf

U.S. Department of Energy (2022): Offshore Wind Market Report: 2022 edition, https://www.energy.gov/eere/wind/articles/offshore-wind-market-report-2022-edition

Vattenfall 09. May 2023: Fremtiden for vindenergi ligger hinsides horisonten: https://group.vattenfall.com/dk/nyheder-og-presse/nyheder/2023/fremtiden-for-vindenergi-ligger-hinsides-horisonten

Wind Denmark (2020): Branchestatistik for vindmøllebranchen, https://greenpowerdenmark.dk/files/media/winddenmark.dk/document/Branchestatistik%202019.pdf

Wind Denmark (2021): Branchestatistik, https://greenpowerdenmark.dk/files/media/winddenmark.dk/document/Branchestatistik_2021.pdf

WindEurope (2019): Boosting offshore wind energy in the Baltic Sea, https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Boosting-offshore-wind.pdf

WindEurope (2020a): Offshore Wind in Europe - Key Trends and Statistics 2019, https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2019.pdf

WindEurope (2020b): Financing and investment trends - The European wind industry in 2019, https://windeurope.org/wp-content/uploads/files/about-wind/reports/Financing-and-Investment-Trends-2019.pdf

WindEurope (2022): Financing and investment trends - The European wind industry in 2022, https://windeurope.org/intelligence-platform/product/financing-and-investment-trends-2022/

WindEurope (2023): Wind energy in Europe, https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-2022-statistics-and-the-outlook-for-2023-2027/