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Final Technical Report

Socio-economic impact study of offshore wind

DANISH SHIPPING, WIND DENMARK AND DANISH ENERGY WITH SUPPORT FROM THE DANISH MARITIME FOUNDATION

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Disclaimer

The objective of this report is to provide a qualified assessment of the socioeconomic impacts of offshore wind investments. The report aims to fulfil the objective by applying the best possible primary and secondary data, analytic methods, knowledge and experience from previous impact studies conducted around the world as well as a range of existing studies and reports. This means that the results should be considered the best possible assessments of the impacts given the uncertainty associated with making such assessments and not accurate measurements of actual impacts. All reasonable precautions have been taken by QBIS to verify the reliability of the material in this publication. The information contained herein does not necessarily represent the views of QBIS. The mention of specific companies or certain projects or products does not imply that they are recommended by QBIS in preference to others of a similar nature that are not mentioned.

1 PREFACE

In 2018, Denmark signed a new energy agreement for three new offshore wind farms with a total capacity of at least 2.4 GW corresponding to all Danish households' total electricity consumption. In addition, in June of 2020, the Danish Government announced a new ambition to establish two energy islands in Denmark contributing with at least 5 GW offshore wind by 2030 as well as to advance the establishment of 1 GW offshore wind farm at Hesselo.[1]

While the role of offshore wind in climate change mitigation and energy security is well understood, there has been less efforts to study the socio-economic impacts from the expansion of offshore wind in terms of economic value-added and jobs, particularly locally. As governments like the Danish are planning substantial expansions of offshore wind over the coming decade, they increasingly want to know what costs and benefits to expect from such investments.

The objective of this study is to help answer this question. First, through establishment of a full-scale cradle-to-grave model of a modern offshore wind farm in Europe, the study provides a reference model for estimating the socio-economic impacts of 1 GW offshore wind farm. Using Denmark as the example, the study lays out the detailed investment costs and the likely distribution of economic value-added and jobs, both in Denmark and abroad. Secondly, by taking an ethnographic approach, the study explores how offshore wind investments resonate through local port communities and supply chains involved in the installation and O&M of an offshore wind. Here the study focuses on four Danish ports which have been - or will be - instrumental in installing and servicing Denmark's largest offshore wind farms.

The study is financed by the Danish Maritime Fund. Danish Shipping, Wind Denmark, Danish Energy, Danish Maritime, Orsted, Vattenfall, Siemens Gamesa, MHI Vestas and the ports of Esbjerg and Ronne have been on the steering committee, while the study has been conducted by QBIS.

[1] Danish Government. See: https://fm.dk/media/18082/faktaark_klimaaftale-for-energi-og-industri-2020-et-overblik.pdf

2 EXECUTIVE SUMMARY

The offshore wind industry has been characterised by significant productivity improvements that have increased the economic return measured as megawatt (MW) per Euro invested, but also reduced the labour needed per MW. The study assesses that labour measured as Full Time Equivalents (FTEs) per MW has been reduced from nearly 19.0 FTEs per MW installed in 2010 to around 7.5 FTEs per MW installed in 2022.

When seen in isolation, productivity improvements such as these could result in reduced employment in the offshore wind industry. But the offshore wind industry has expanded heavily in the last ten years, from just under 1.0 GW to almost 25 GW, and in the next twenty, it is expected to further increase its capacity 15-fold. This has resulted in a cumulative increase in employment and economic returns from offshore wind at the same time. A win-win situation.

Case in point: In 2010, total offshore wind capacity in Europe was less than 1 GW. With nearly 19 FTEs per MW installed, the associated labour was around 19,000 FTEs. In 2019, total offshore wind capacity was nearly 23 GW and with an assessed around 10 FTEs per MW installed, the associated labour input was around 230.000 FTEs. Over the next 20 years, capacity is expected to increase 15-fold. This means that labour can increase up to 3.5 million FTEs if labour input equals 7.5 FTEs per MW as assessed for 2022.

Denmark was the first country to invest in offshore wind and through consistent Danish commitment and investments combined with skilled Danish businesses, the Danish offshore wind industry today has an assessed 40% market share of the European offshore market and the most complete supply chain in the world making Denmark a one-stop-shop for global offshore wind. This means that Danish offshore wind companies stand to gain massively from the potential 3.5 million FTEs.

The Danish market share implies that Danish offshore wind companies is assessed to receive an average of around 3.1 FTEs of each MW installed and operated in other EU countries than Denmark. Labour input from Danish subcontractors adds another 3.2 FTEs per MW, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 2.8 FTEs per MW. Put differently, for every MW offshore wind farm installed and operated outside of Denmark but within Europe, total Danish labour input amounts to 9.1 FTEs per MW.

The continued expansion of Danish wind farms matters to the domestic offshore wind sector as well. When an offshore wind farm is installed and operated in Denmark, the Danish labour return is higher. Around 4.9 FTEs per MW are generated directly within the Danish offshore companies compared to 3.1 FTEs for offshore wind farms in other EU countries than Denmark. Adding labour inputs from subcontractors and spending of wages and salaries means that the labour input on a Danish offshore wind farm amounts to a total 14.6 FTEs, i.e. 60% more FTEs per MW compared to offshore wind farms installed and operated in Europe.

Offshore wind farms installed and operated in Denmark also have other important benefits. One example is within the installation and operation & maintenance (O&M) stages of an offshore wind farm, which involves extensive labour inputs and several localized opportunities, including for domestic installation and O&M ports. This is critical from a socioeconomic perspective as offshore wind ports are often located within coastal communities removed from the host nation's main economic centres. While ports often employ few people directly, they are an important part of the municipal economy, generating substantial economic activity and local jobs in the hinterland.

The model assesses that a 1 GW Danish offshore wind farm will generate around EUR 5 million (one-off) to the installation port, while an O&M port is assessed to receive around EUR 0.5 million EUR per year, which is equivalent to EUR 12.5 million over the anticipated 25-year lifetime of an offshore wind farm.

In addition, the appointment of a local installation or O&M port also creates opportunities for local suppliers and workers within the port region itself, ranging from local shipyards, steel manufacturers and electricians to local restaurants, hotels and catering companies. Depending on the share of the total work gained by these local suppliers, the study assesses that a 1 GW Danish offshore wind farm may generate a total of between EUR 11-28 million in turnover and between 30-96 FTEs to the local installation port and suppliers combined. An O&M contract is assessed to generate between EUR 3.2-9.1 million in turnover and between 59-81 FTEs each year over a period of 25 years to the local O&M port and suppliers combined.

To better understand how offshore wind investments resonate through local port communities beyond the time-bound outputs from a single offshore wind farm investment, the study reviews the experiences of four Danish installation and O&M ports given in terms of Esbjerg, Grenaa, Ronne and Hvide Sande. Based on a combination of interviews and field studies, the study presents a five-staged model for how offshore wind can impact local installation and O&M port communities over time – from preparation and implementation to conversion, internationalization and, ultimately, transformation.

The most notable example of how Danish offshore wind investments can contribute to transforming local port communities over time is the case of Esbjerg. Once Denmark's leading service hub for the oil and gas sector, the Port of Esbjerg has transformed into a global hub for offshore wind over the past two decades. This transformation was kickstarted by Denmark's first large-scale investments in offshore wind farm with Horns Rev 1 in 2001; an investment which launched a year-long port expansion project within the port and resulted in Esbjerg winning a long string of offshore wind projects in the North Sea.

Since 2001, the Port of Esbjerg has been involved in more than 50 European wind farm projects and 55% of accumulated European offshore wind capacity. One of the main spin-offs from the first Danish offshore wind farms in Esbjerg was that it enabled local companies to test and transfer their experiences from oil and gas to a new sector; pursue growth in new markets and diversify their business strategy, also well beyond Denmark's borders. As a result, Esbjerg is now home to around 250 suppliers to the global offshore wind sector such as Semco Maritime, Esvagt, NorSea Denmark, Ocean Team Group, Jutlandia and many more.

Another example highlighted in the study is Grenaa, which was appointed as installation and O&M port for Anholt wind farm. Unlike Esbjerg, Grenaa's experiences from Anholt has not yet converted into a similar transformation of the local economy. This underline both the risks and challenges involved for offshore wind ports, who often must make sizable upfront investments to meet the offshore wind sector's requirements. From the perspective of local port economies, a positive return from offshore wind farms relies heavily on the ability of the port and local suppliers to attract a continuous portfolio of projects. Following the commissioning of Anholt in 2013, the port of Grenaa had to change its strategy to pursue growth in adjacent sectors which could benefit from some of the same facilities, competences and references gained during Anholt.

This has since led to several high-profile projects, which has generated substantial turnover for both the port and local suppliers – projects that according to the port would not have been possible without the experiences from Anholt. As for the local suppliers involved in the installation of Anholt, the exposure to an international customer segment with stringent standards in terms of quality, safety and documentation has been the most important spin-off effect from Anholt.

Based on these observations, the study reverts to the initial question: What socio-economic impacts can be expected from Denmark's future offshore wind investments? Applying the model to Thor, it is assessed that the 0.8-1.0 GW planned offshore wind farm can be associated with a direct labour input of around 5,234 FTEs in the capex phase, 1,987 FTEs over the 25-year long opex phase and around 546 FTEs in the decommissioning phase, i.e. a total direct labour input of around 7,768 FTEs. The Danish share of this labour input is assessed to be around 4,127 FTEs. Labour inputs from Danish subcontractors is assessed to add another 4,472 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 3,828 FTEs. In summary, a total Danish labour input of around 12,428 FTEs.

A part of this labour input will go to the installation and O&M ports. If Esbjerg is selected as installation port, the assessed potential varies between EUR 233-379 million in direct, indirect and induced turnover from supplier contracts and around 666-1,084 FTEs in associated direct, indirect and induced labour inputs. If either Thuboron, Thorsminde or Hvide Sande is selected as O&M port, the assessed potential varies between EUR 3.3-9-5 million in direct, indirect and induced turnover and 61-84 FTEs in associated direct, indirect and induced labour input per year over a 25-years period. The high potential corresponds to around EUR 83-237 million and 1,527-2,109 FTEs over the 25-year O&M period.

Beyond number of jobs created per MW, Denmark's next generation of offshore wind farms may however also help local ports attract new inwards investments, upskill and internationalize local suppliers and lead to more diversified and resilient port economies. Learnings from the empirical case studies also suggest that this transformation will not happen automatically, rather it requires a proactive effort by both ports and local suppliers. As offshore wind can be both a challenging and risky affair for local ports and suppliers, a long-term vision for offshore wind and clear policy commitments is a conducive factor to success.

3 OFFSHORE WIND TODAY

3.1 GLOBAL OUTLOOK

The global offshore wind market grew nearly 30% per year between 2010 and 2018, benefitting from rapid technology improvements. Over the next five years, about 150 new offshore wind projects are scheduled to be completed around the world, pointing to an increasing role for offshore wind in power supplies. Europe has fostered the technology's development, led by the United Kingdom, Germany and Denmark. The United Kingdom and Germany currently have the largest offshore wind capacity in operation, while Denmark produced 15% of its electricity from offshore wind in 2018. China added more capacity than any other country in 2018.[2]

Offshore wind power capacity is set to increase by at least 15-fold worldwide by 2040 and thereby becoming a USD 1 trillion business. Under current investment plans and policies, the global offshore wind market is set to expand by 13% per year, passing 20 GW of additions per year by 2030. This will require capital spending of USD 840 billion over the next two decades, almost matching that for natural gas-fired or coal-fired capacity. Achieving global climate and sustainability goals would require even faster growth: capacity additions would need to approach 40 GW per year in the 2030s, pushing cumulative investment to over USD 1.2 trillion.[3]

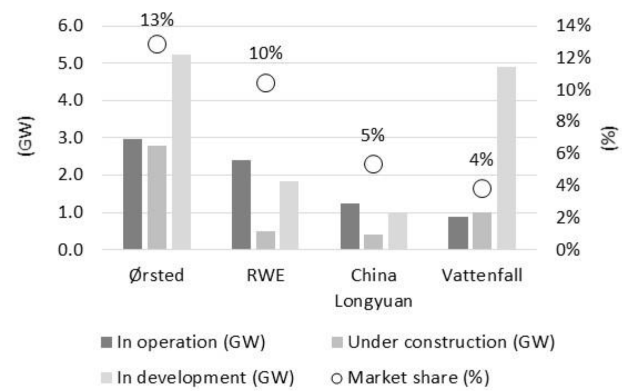
The promising outlook for offshore wind is underpinned by policy support in an increasing number of regions. Several European North Seas countries – including the United Kingdom, Germany, the Netherlands and Denmark – have policy targets supporting offshore wind. However, offshore wind faces several challenges that could slow its growth in established and emerging markets. Developing efficient supply chains is crucial for the offshore wind industry to continue to drive down costs. Doing so is likely to call for multibillion-dollar investments in ever-larger support vessels, port upgrades and construction equipment. Such investments are especially difficult in the face of uncertainty. Governments can facilitate investment of this kind by establishing a long-term vision for offshore wind and precisely defining the measures to be taken to help make that vision a reality.[4]

3.2 MAIN PLAYERS

Investment in offshore wind projects is mainly by large utilities and investment funds because the projects have relatively high upfront capital costs. European companies develop and own most offshore wind assets. Denmark-based Orsted owns the largest share (12%) and is actively expanding into other markets in the United States and Asia. Germany-based RWE consolidated its share of the offshore wind market after acquiring E.ON and Innogy renewable energy assets in the North Sea and Baltic Sea, and is now with 10% market share, the second-largest offshore wind operator in the world, cf. Figure 1.

[2] IEA (2019).
[3] Ibid.
[4] Ibid.

Figure 1: Leading market players in the offshore wind industry, 2018

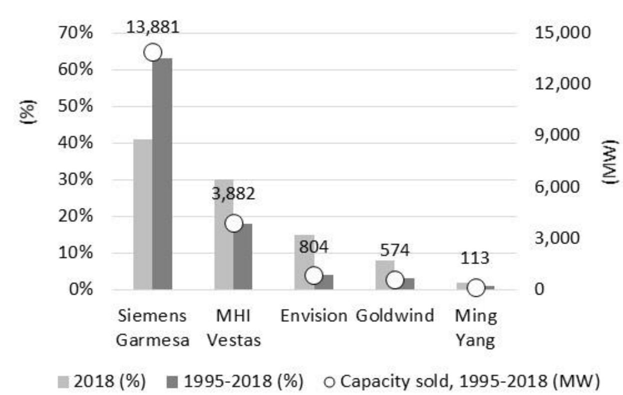


Source: IEA (2019).

Chinese companies account for a growing share of the market. With 5% markets share, China Longyuan Power Group ranks as the largest producer of wind power across Asia. Another Chinese company is China Three Gorges Corporation (CTG) – previously known for its hydroelectric projects – is one of the world's largest energy companies and has become actively involved in the offshore wind industry. With 4% market share, Vattenfall is the fourth largest player in offshore wind. As Orsted, Vattenfall has a large amount of capacity under preparation (nearly 5 GW) indicating that its market share could rise in the coming years.

Manufacturers of offshore wind turbines are mostly based in Europe, and the market is concentrated among a small number of companies. Spanish-headquartered Siemens Gamesa and MHI Vestas, a joint venture between Vestas and Mitsubishi Heavy Industries, dominates the offshore wind industry, accounting for over two-thirds of the offshore wind capacity installed in 2018, cf. Figure 2.

Figure 2: Leading manufacturers of offshore wind turbines, 2018



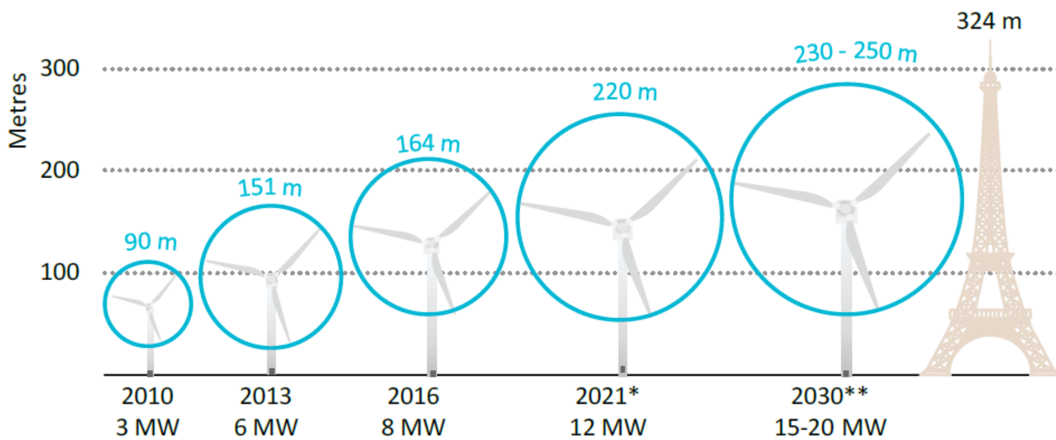
Source: IEA (2019).

Together, these two manufacturers account for over 80% of all offshore capacity commissioned from 1995 through the end of 2018. The share of turbines produced by Chinese manufacturers is expanding with its focus on the market in Asia, accounting for close to 30% of offshore wind capacity additions in 2018. Another important component in the value chain is the construction and servicing of offshore wind turbines. Between 2010 and 2018 nearly USD 4 billion per year was invested in the construction of offshore wind installations across Europe and China, while over USD 1 billion was spent annually on operations and maintenance.

3.3 Technology

Offshore wind technology has made impressive advances since the first turbines were installed near the shore in Denmark in 1991. Since then, equipment suppliers have focused research and development spending on developing bigger and better performing offshore wind turbines. The technology has grown dramatically in physical size and rated power output. Technology innovation has led to an increase in turbine size in terms of tip height and swept area, and this has raised their maximum output. The tip height of commercially available turbines increased from just over 100 metres (m) in 2010to more than 200 m in 2016, while the swept area increased by 230%. The larger swept area allows for more wind to be captured per turbine. A 12 MW turbine now under development is expected to reach 260 m, or 80% of the height of the Eiffel Tower, cf. Figure 3.

Figure 3: Evolution of the largest commercially available wind turbines



Source: IEA (2019).

The industry is targeting even larger 15-20 MW turbines for 2030. This increase in turbine size and rating has put upward pressure on capital costs as larger turbines pose construction challenges and require larger foundations, but it has also reduced operation and maintenance costs, ultimately leading to lower levelized costs of electricity.

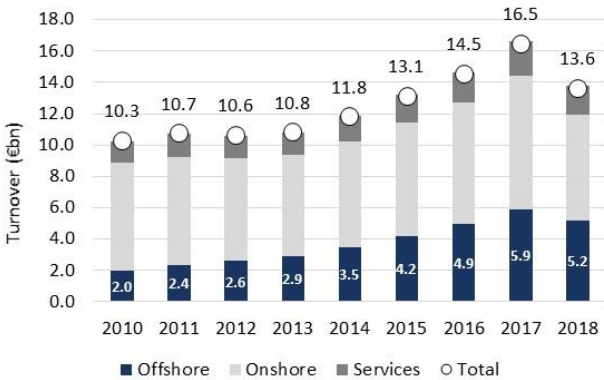
3.4 Denmark

In April 2020, Wind Denmark asked its members to assess the share of their turnover accruing from offshore, onshore and services in 2020, 2015 and 2010. The results indicate a doubling in the share of turnover from offshore from around 20% in 2010 to around 40% in 2020. Applying these survey results to Wind Denmark's annual industry statistics suggests that turnover from offshore has increased from around EUR 2.0 billion in 2010 to around EUR 5.2 billion in 2020 corresponding to an increase of EUR 3.2 billion, cf. Figure 4. As total turnover has increased from around EUR 10.3 million in 2010 to EUR 13.6 million corresponding to an increase of around EUR 3.3 billion, this means that offshore wind solely has driven the increase in turnover for Danish wind companies.

European countries spent around EUR 85 billion on new offshore investments from 2010 to 2018.[5] As a rough indicator of Danish market share, it is assessed based on Wind Denmark's member survey that Danish wind companies' offshore turnover constituted an average of 40% of these investments, cf. Figure 5. Market players state that Denmark is considered to have the biggest and most comprehensive offshore wind supply chain in the world and the key sourcing hub for offshore wind farms. The rough indicator of Danish market share of around 40% supports these perceptions.

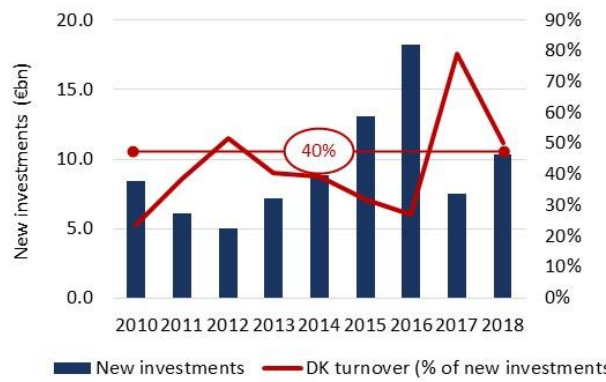
[5] WindEurope (2020a and 2020b).

Figure 4: Turnover of Danish wind companies, 2010-2018



Source: Wind Denmark member survey, April 2020, and Wind Denmark (2020b).

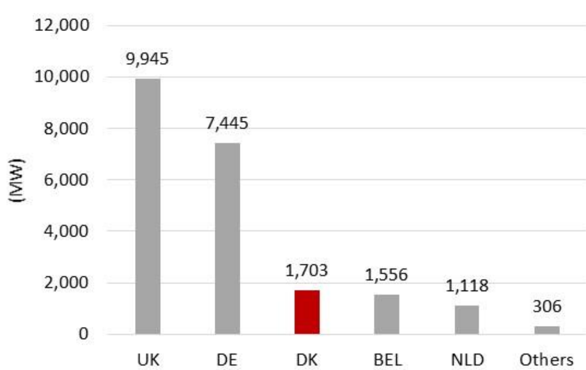
Figure 5: New investments compared to offshore turnover of Wind Denmark members, 2010-2018



Source: WindEurope (2020a and 2020b) and Wind Denmark member survey, April 2020.

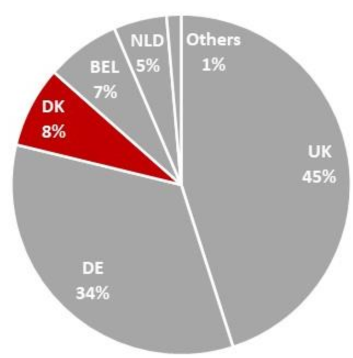
Today, there are 22,072 MW of installed capacity across Europe. This is a total of 5,047 turbines connected to the grid across 12 countries. Five countries – the UK, Germany (DE), Denmark (DK), Belgium (BEL) and the Netherlands (NLD) – represent 99% of this capacity, cf. Figure 6. As Denmark's share of total cumulative European installed capacity in 2019 only was around 8%, cf. Figure 7, it follows that Danish offshore wind turnover primarily must come from foreign offshore investments making Danish offshore wind a strong export sector.[6]

Figure 6: Cumulative installed capacity by country, 2009-2020, (MW)



Source: WindEurope (2020a).

Figure 7: Cumulative installed capacity by country, 2009-2020, (% of total)



Source: WindEurope (2020a).

[6] WindEurope (2019).

4 AN IMPACT MODEL FOR OFFSHORE WIND INVESTMENTS

4.1 INTRODUCTION

The objective of the offshore wind model is to provide new insight into the socioeconomic impacts of offshore wind. Existing estimates of economic value-add and jobs generated from offshore wind have tended to vary in methodology and scope. As an example, some studies may focus on total man hours required but not on the distribution of same within or between countries. Similarly, other studies may focus on selected parts of an offshore wind project, e.g. production, installation and O&M, while remaining stages such as planning, and decommissioning are not included.

In a Danish context, existing methods have tended to focus on total expected Danish jobs from offshore wind investments but less often where in Denmark jobs from offshore investments most likely will be located. Thus, can offshore investments help coastal and more remote areas of Denmark and if yes, how much? And what is the difference between an EU and Danish offshore investments when it comes to Danish supplier contracts and jobs? And what professions and industries will benefit from offshore investments and how much? These are some of the questions that the model aims to provide a more granular answer to.

The complexity of establishing such a model is that offshore wind farms vary considerably in their size and their distance from shore and generally, that there is no single way to build and operate an offshore wind farm, where much depends on the specific conditions at the site. Further, the pace of innovation in the wind industry has been rapid over the past decade making it difficult to set the appropriate size and technology.

Up to 2025, experts are however reasonably confident of the technologies that will be deployed.[7] An important exception and uncertainty is turbine size. Although manufacturers are working on designs that will ultimately stretch capacities to greater than 15 MW, the timing of their introduction is a complex commercial decision. For the purpose of this model and ensuring comparability with technical studies[8], the model is designed for a 1 GW offshore farm using 10 MW turbines located 60 km from shore in 30-meter water depth and commencing operation in 2022.

The 1 GW capacity and 10 MW wind turbines will ensure relevance in terms ability to simulate new rather than existing offshore wind investments, but the distance from shore and water depth are more typical for offshore wind farms in the UK, Germany and other countries in the EU than Denmark, where distance to shore and water depth typically are shorter and less deep. However, through correction of capex and opex in order to reflect differences in distance from shore and water depth, the model can provide results for Danish offshore wind investments as well as EU investment.

[7] Consultations with Orsted capex team and BVG Associates (2019).
[8] BVG Associates (2019).

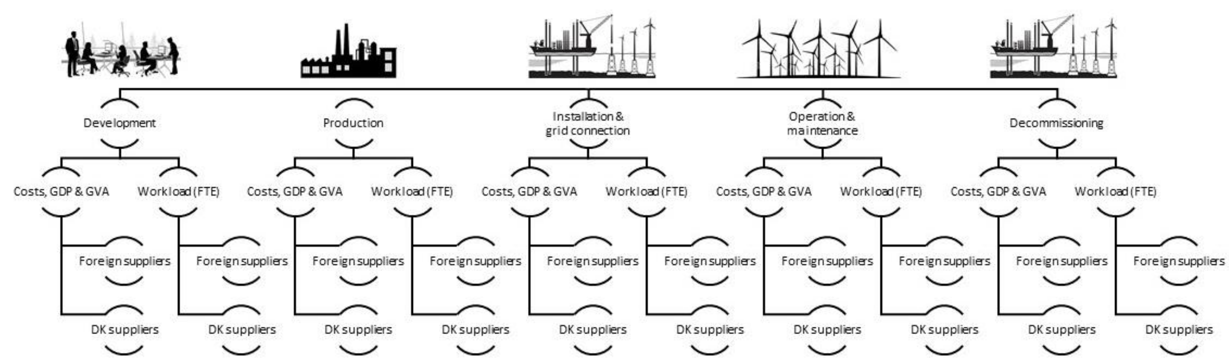
4.2 MODEL STRUCTURE

4.2.1 Model structure

The offshore wind farm model is split into five different phases. Phase 1 is design and development. Phase 2 is production of turbines and balance of plant. Phase 3 is installation and grid connection. Phase 4 is operation and maintenance (O&M). Phase 5 is decommissioning. It has been an important objective of the model to be able to provide detailed impact assessments for each of these phases.

More specifically, assessments of lifetime costs, Gross Domestic Products (GDP), supplier contracts, labour inputs and locations for each phase. For supplier contracts, further assessments of split between Danish and foreign companies, split between direct, indirect and induced turnover from these contracts, split between the industries receiving contracts as well as split between locations of activities accruing from these contracts, i.e. how many activities are located in ports areas versus other areas of the respective countries. For labour input, there are similar assessments of split between Danish and foreign labour input, split between direct, indirect and induced labour input, split between professions delivering labour inputs as well as the split between locations of labour inputs, cf. Figure 8.

Figure 8: An offshore wind farm lifetime model



Note: FTE=Full-Time Equivalent, GDP=Gross Domestic Product and GVA=Gross Value Added.
Source: QBIS based on BVG Associates (2016 and 2019) and IRENA (2018b) and consultations with Orsted capex and opex teams.

4.2.2 Core results

Phase 1-3 constitute the capex of the offshore wind farm, while phase 4 constitutes the opex and phase 5, the depex. The core results of the model consist of capex/depex and opex costs. The capex/depex and opex are typically the key indicators reported by owners, developers and operators and therefore, provide a good indication of where the model results are in comparison to existing farms, planned farms and targeted offshore wind unit costs by authorities, e.g. the Danish Energy Agency.

The core results of the model have been established using primary and secondary data. The primary data consists of opex and capex data from Orsted, Vattenfall, and Semco. The secondary data consists of data from existing reports.[9] The data structure consists of the five main phases (development, production, installation, O&M and decommissioning) and around 160 different sub-activities within the five main phases, cf. Appendix D. To the extent data is strong enough, the detailed structure enables detailed and more accurate assessments of costs, labour input, market share, location of activities.

Capex is assessed to an average of 2.646 million EUR per MW. The minimum capex is assessed to 2.496 million EUR per MW, while the maximum capex is assessed to 2.792 million EUR per MW. The variation primarily stems from the installation & grid connection phase, while the production phase, particularly the production of wind turbines shows less variation in the assessed costs. Since installation & grid connection can be subject to different contractual setups and division of work between public and private players depending on the investment country, while the production of wind turbines and balance of plant usually is subject to pure market competition, it might explain some of the differences in variation. The average capex of 2.646 million EUR per MW corresponds to 19.769 million DKK per MW, cf. Table 1.

Table 1: The core model results, capex, opex and depex.

	Phase 1 Develop-ment			**Phase 2A** Production Wind turbines			**Phase 2B** Production Balance of plant			**Phase 3** Installation & grid connection			**Phase 4** Operation & maintenance			**Phase 5** Decommis-sioning			**Total**		
	CAPEX			CAPEX			CAPEX			CAPEX			OPEX			DEPEX					
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
CAPEX (million EUR/MW)	0.145	0.145	0.145	1.250	1.260	1.270	0.771	0.813	0.855	0.330	0.429	0.523							2.496	2.646	2.792
CAPEX (million EUR/GW)	145	145	145	1,250	1,260	1,270	771	813	855	330	429	523							2,496	2,646	2,792
CAPEX (million DKK/GW)	1,080	1,080	1,080	9,338	9,412	9,486	5,760	6,073	6,387	2,465	3,204	3,906							18,643	19,769	20,859
CAPEX and DEPEX (million EUR/MW)	0.145	0.145	0.145	1.250	1.260	1.270	0.771	0.813	0.855	0.330	0.429	0.523				0.392	0.392	0.392	2.887	3.038	3.184
CAPEX and DEPEX (million EUR/GW)	145	145	145	1,250	1,260	1,270	771	813	855	330	429	523				392	392	392	2,887	3,038	3,184
CAPEX and DEPEX (million DKK/GW)	1,080	1,080	1,080	9,338	9,412	9,486	5,760	6,073	6,387	2,465	3,204	3,906				2,925	2,925	2,925	21,568	22,694	23,784
OPEX (million EUR/MW/year)													0.033	0.048	0.090				0.033	0.048	0.090
OPEX (million EUR/GW/25 years)													819	1,188	2,259				819	1,188	2,259
OPEX (million DKK/GW/25 years)													6,115	8,871	16,875				6,115	8,871	16,875
Time	12-30 months			6 months						6 months			25 years			6-36 months					

Note: 1,000 MW, 10 MW turbines, 30 m water depth, 60 km from shore, project life 25 years and commissioned in 2022.
Sources: QBIS based on Orsted, Vattenfall, Siemens Gamesa, Semco and BVG Associates (2016 and 2019).

[9] Primarily, BVG Associates (2016 and 2019) and IRENA (2018b).

Depex is assessed to an average of 0.392 million EUR per MW. As decommissioning of a 1 GW offshore wind farm is yet to be carried out, this is subject to uncertainty. According to BVG Associates (2019), the decommissioning of 1 GW will be around EUR 392 million. The consultancy DNV GL has assessed decommissioning costs to between EUR 201-502 million.[10] Since it is unclear how DNV GL has arrived at its assessment, and BVG Associates (2019) has a thorough argumentation, the assessment by BVG Associates (2019) is used in the model.

Capex/depex are assessed to an average of 3.038 million EUR per MW. The minimum capex is assessed to 2.887 million EUR per MW, while the maximum capex is assessed to 3.184 million EUR per MW. The average capex/depex of 3.038 million EUR per MW corresponds to 22.694 million DKK per MW.

Opex is assessed to an average of 0.048 million EUR per MW. The minimum opex is assessed to 0.033 million EUR per MW, while the maximum capex is assessed to 0.090 million EUR per MW, i.e. significant difference between the minimum and the maximum assessed opex. The maximum opex is based on BVG Associates (2019) that assumes considerably higher costs than assessed necessary by Orsted and Vattenfall. Since operation and maintenance costs are expected to be subject to fierce competition in the coming years, the average opex assessment is closer to the minimum than the maximum assessments. Over 25 year, the opex is assessed to EUR 1.188 million EUR or DKK 8.871 million.

In the following sections, the assessed lifetime costs of the offshore wind model are compared to other sources.

4.3 Model check

4.3.1 Check I: Distribution of costs across phase 1-5 of an offshore wind farm

First check is the distribution of costs across the five phases of the offshore wind farm. While opex and capex are published by many sources, only BVG Associates (2016 and 2019) have been found to assess distribution of costs across the five phases.

The comparison of the model and BVG Associates (2016 and 2019) shows relatively similar cost shares as well as costs for phase 1 (design and development), production 2a+b (wind turbines and balance of plant) and phase 5 (decommissioning). For these phases, the model results are either close to or between BVG Associates (2016) or BVG Associates (2019), cf. Table 2.

The comparison shows relatively large differences in costs for phase 3 (installation & grid connection) and phase 4 (operation and maintenance). As described in section 4.2.2, installation & grid connection can be subject to different contractual setups and division of work between public and private players depending on the investment country that might explain some of the difference. For operation and maintenance, the difference is due to BVG Associates (2019) assessing much higher costs than Orsted and Vattenfall.

[10] No study found, only reference: https://ing.dk/artikel/aldrende-havmoelleparker-aabner-marked-klog-nedrivning-182308

Table 2: Check I: Distribution of costs across phase 1-5

	Phase 1 Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total**
(%)							
BVG (2016)	3%	25%	17%	11%	40%	4%	100%
BVG (2019)	3%	22%	13%	14%	41%	7%	100%
QBIS	3%	30%	19%	10%	28%	9%	100%
(billion EUR)							
BVG (2016)	0.19	1.67	1.15	0.71	2.74	0.25	6.71
BVG (2019)	0.14	1.20	0.72	0.78	2.26	0.40	5.51
QBIS	0.14	1.26	0.81	0.43	1.19	0.39	4.23

Note:
- BVG (2016): 500 MW, 8 MW turbines, 45 m water depth, 40 km from shore, 25 years project life and commissioned in 2020.
- BVG (2019): 1,000 MW, 10 MW turbines, 30 m water depth, 60 km from shore, 25 years project life and commissioned in 2022.
- QBIS: 1,000 MW, 10 MW turbines, 30 m water depth, 60 km from shore, 25 years project life and commissioned in 2022.

Sources: QBIS based on Orsted, Vattenfall, Siemens Gamesa, Semco and BVG Associates (2016 and 2019).

The higher phase 3 and 4 costs mean that BVG Associates (2016 and 2019) have significantly higher assessed total lifetime costs given in terms of EUR 6.71 billion and EUR 5.51 billion, respectively, compared to EUR 4.23 billion in the model.

In summary, check 1 shows relatively agreement between the model and BVG Associates (2016 and 2019) for phase 1,2 and 4. For phase 3 and 4, BVG Associates (2016 and 2019) assess considerably higher costs than the model, but differences in contractual setups and division of work between public and private players might play a role. In all circumstance, the assessments by Orsted and Vattenfall are given more weight.

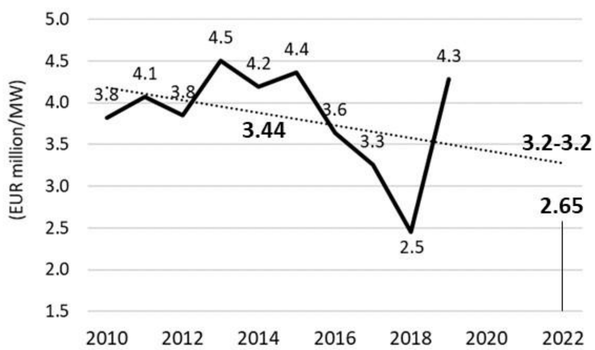
As a final comment, it is striking that the study by BVG Associates (2016) covering 0.5 GW has higher assessed total lifetime costs than the study by BVG Associates (2019) covering 1.0 GW. Despite the two studies are three years apart and despite differences in water depth (45m versus 30m) and commissioning year (2020 versus 2022), the cost differences seem excessive.

4.3.2 Check II: Comparison of CAPEX with other offshore wind in Europe

In the period 2010 to 2019, 24.6 GW of new offshore wind capacity was installed in Europe at a total cost of EUR 84.6 billion. Approximately 81% of this new capacity was installed in the UK and Germany. This correspond to an average unit cost of 3.44 million EUR per MW, cf. Figure 9.[11]

[11] WindEurope (2019b and 2020).

Figure 9: Check II: Capex, new offshore wind capacity, Europe, 2010-2019, 1:2

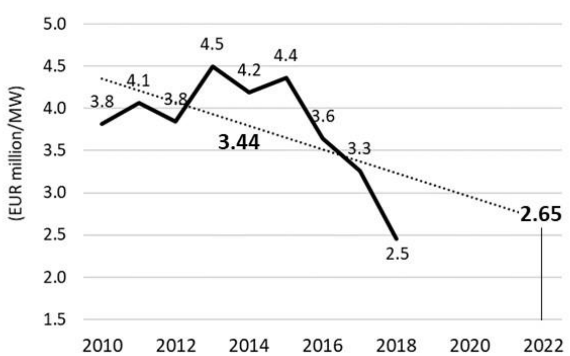


Source: WindEurope (2020a and 2020b) and QBIS based on Orsted, Vattenfall, Siemens Gamesa, Semco and BVG Associates (2016 and 2019).

Despite significant variation over the period 2010-2019, the trend in capex of new installed offshore wind capacity is downward sloping, cf. dotted trendline in Figure 9, and in this study's commissioning year of 2022, the trendline suggests a capex of around 3.2-3.3 million EUR per MW. In comparison, the model assesses an average capex of 2.65 million EUR per MW. However, the capex trendline for new installed offshore wind capacity could have had an even stronger downward sloping and in turn, been closer to the model result, if not the 2019 capex had increased to 4.3 million EUR per MW.

Each year's capex is only based on a few observations. In 2019, capex was based on four new offshore wind installations of which three had a capex equal or higher than five: 1) UK, Neart na Gaoithe, 450MW, 2023: 5.1 million EUR/MW, 2) Netherlands, Fryslan, 383MW, 2021: 2.0 million EUR/MW, 3) France, Saint-Nazaire, 480MW, 2023: 5.0 million EUR/MW and 4)Norway, Hywind Tampen, 88MW, 2022: 5.5 million EUR/MW

Figure 10: Check II: Capex, new offshore wind capacity, Europe, 2010-2018, 2:2



Source: As Figure 9

Delays and refinancing, 50 m water depth and use of floating foundation technology were the reasons for the high capex for these three new installations.[12] So, it was not the end of the downward sloped cost curve for offshore wind, but rather exceptional circumstances that increased capex. Excluding the four 2019 new offshore wind farms means that the trendline becomes more or less equal to the 2.65 million EUR per MW in 2022 assessed by the model, cf. Figure 10. In summary, the trend in the costs of new installed offshore wind capacity in the period 2010 to 2018/2019 seems to confirm the model's assessed capex for 2022.

However, high volatility in capex means that this confirmation is subject to uncertainty and should not stand alone (hence check 1-3). The high volatility reflects the fact that offshore wind farms vary considerably in size and distance from shore and generally, that there is no single way to build and operate an offshore wind farm, where much depends on the specific conditions at the site, cf. section 4.1.

[12] WindEurope (2020b).

4.3.3 Check III: Comparison of CAPEX and OPEX with Danish Energy Agency's Technology Catalogue

In the 2020 version of its technology catalogue for electricity and district heating, the Danish Energy Agency (DEA) assesses a capex of 2.130 million EUR per MW for Danish offshore wind in 2020.[13] The corresponding capex assessed by the model is 2.502 million EUR per MW in 2022, cf. Table 3.

Table 3: Comparison of CAPEX and OPEX with Danish Energy Agency's Technology Catalogue

(million EUR per MW)	**Phase 1** Develop-ment	**Phase 2A** Production Wind turbines	**Phase 2B** Production Balance of plant	**Phase 3** Installation & grid connection	**Phase 4** Operation & maintenance (25 years)	**Phase 5** Decommis-sioning	**Total**
	CAPEX	CAPEX	CAPEX	CAPEX	OPEX	DEPEX	
CAPEX and DEPEX							
QBIS	0.145	1.260	0.813	0.429		0.392	3.038
QBIS		1.260	0.813	0.429			2.502
DEA[1]		0.790		1.340			2.130
OPEX							
QBIS					0.048		0.048
DEA[1]					0.055		0.055

[1] Danish Energy Agency.
Sources: DEA (2020) and QBIS based on Orsted, Vattenfall, Siemens Gamesa, Semco and BVG Associates (2016 and 2019).

At first glance, the difference might not seem so significant considering the favourable offshore conditions in Denmark with shorter distance to shore and lower water depth keeping capex down compared to capex in other countries in Europe. A closer look does however raise some questions. Shorter distance to shore and lower water depth would primarily be reflected in lower installation and grid connection costs and lower operation & maintenance costs. However, DEA (2020) assesses phase 3 to 1.340 million EUR per MW which is much higher than the 0.429 million EUR per MW assessed in the model. Further, DEA (2020) assesses opex to 0.055 million EUR/MW which is slightly higher than the 0.048 million EUR/MW assessed in the model.

So, the costs expected to be lower due to shorter distance to shore and lower water depth in Denmark are not lower, but higher. In parallel, DEA (2020) assesses phase 2 to 0.790 million EUR per MW which is much lower than the 1.260+0.813=2.073 million EUR per MW assessed in the model. Some of these apparent discrepancies are likely to result from differences in the categorization of costs. Thus, DEAs definition of production and installation are likely to differ from this study as DEAs definitions are not designed for offshore wind, but for cross-sector comparison of different energy sources. Due to these considerations, this check should focus on the sum of production and installation and not the itemised

[13] DEA (2020).

costs, i.e. DEA's capex of 2.130 million EUR per MW versus 2.502 million EUR per MW assessed in the model, which does not seem so different considering Denmark's more favourable conditions.

4.4 MODEL RESULTS

The offshore model can produce many and detailed types of results. In this section, six of these types of results are presented in terms of lifetime costs, GDP, supplier contracts, labour inputs and salaries for 1 GW offshore wind and Denmark's assessed share of these socioeconomic impacts.

4.4.1 Results I: Lifetime costs, GDP, GVA and Danish supplier contracts

Lifetime costs are defied as the sum of all five phases of an offshore wind farm. The model assesses these lifetime costs to around EUR 4,226 million per 1 GW corresponding to around DKK 31.6 billion. Since this section focusses on Danish GDP from offshore wind farms, the currency is Danish kroner as opposed to Euro. Assessing Danish GDP from offshore investments requires two things. First, a way of assessing GDP on industry level, which is not normally done, cf. Box 1, and second, an assessment of the Danish contract share of offshore wind investments in Denmark and in other EU countries, respectively, cf. Box 2.

Box 1: GDP assessment for the offshore industry

Typically, GDP is not assessed per industry. It is however possible to make an assessment based on Statistics Denmark's multipliers. The starting point for this assessment is the fact that when a shock is given to Statistics Denmark's input-output model, the shock is exhaustively divided into three components given in terms of 1) import, 2) Gross Value Added (GVA) and 3) VAT and taxes. The sum of the multipliers for these three components equals one. As Statistics Denmark does not publish the multiplier for VAT and taxes, an alternative to multiplying the shock (investment) with the GVA multiplier is to multiply the shock (investment) with one minus the import multiplier. This produces the GVA and the VAT and taxes. However, in order to get the GDP contribution, it is necessary to add the VAT and taxes from the final consumption that include most of the VAT and taxes, most accruing from private consumption. As offshore wind investments are considered constructions for which there is no VAT and taxes, only 5% VAT and taxes corresponding to around a couple of billions DKK is added as a lump sum. This produces a close approximation to the GDP contribution. However, since this study has a more accurate import share for offshore wind than included in the Statistics Denmark's "280010 Manufacture of engines, windmills and pumps"[14], where the import multiplier is 0.300, the GDP assessment is carried out with phase 1-5 specific import shares to produce a more accurate GDP assessment on the opex and capex phases, cf. Box 2.

Source: QBIS based on consultations with Statistics Denmark.

Based on this, GDP is assessed to around DKK 9.8 billion corresponding to around 31% of lifetime costs for 1 GW offshore wind farms in other EU countries than Denmark and around DKK 20.3 billion corresponding to around 64% of lifetime costs for Danish offshore wind farms. The total share of supplier contracts out of the total lifetime costs is assessed to around DKK 29.6 billion for offshore wind farms in both Denmark and other EU countries. Out of the around DKK 29.6 billion, Danish supplier contracts are assessed to constitute around DKK 10.3 billion corresponding to around 35% of lifetime costs for 1 GW offshore wind farm in other EU countries than Denmark and around DKK 16.8 billion corresponding to around 57% of lifetime costs for 1 GW offshore wind farms in Denmark, cf. Table 4.

[14] Statistics Denmark's multipliers, INPMUL1, see: https://www.statistikbanken.dk/statbank5a/default.asp?w=1920

Table 4: Lifetime costs, Danish market shares & supplier contracts and GDP

(DKK million/%)	**Phase 1** Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total/ weighted average**
Lifetime costs							
EU/DK wind farm	1,080	9,412	6,073	3,204	8,871	2,925	31,565
Supplier contracts							
EU/DK wind farm	1,029	9,412	6,073	3,040	7,374	2,633	29,561
DK market share of supplier contracts[1]							
EU wind farm	33%	47%	31%	23%	32%	25%	35%[3]
DK wind farm	57%	56%	48%	23%	81%	50%	57%[3]
Danish supplier contracts							
Wind farm in EU	336	4,409	1,890	686	2,352	658	10,331
Wind farm in DK	591	5,267	2,896	695	5,987	1,316	16,753
GDP[2]							
EU wind farm	440	4,802	1,865	235	1,399	1,097	9,837
DK wind farm	696	5,738	3,199	1,020	7,927	1,755	20,335

[1]: See Box 2. [2]: See Box 1. [3] Weighted average.
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019), WindEurope (2020a and 2020b) and member survey data from Wind Denmark.

Box 2: Danish market shares of offshore wind investments in Denmark and other EU countries

The Danish market shares of offshore wind investments in Denmark and other EU countries are assessed based on two independent approaches. First, the assessment based on Wind Denmark survey data and WindEurope investment data suggesting an average Danish offshore market share of around 40% in the period 2010 to 2018, cf. section 3.4. Second, mapping of suppliers for each of the around 160 different sub-activities/components within the five main phases of the offshore wind farm, cf. Appendix D. For each sub-activity/component, a non-exhaustive list including what is assessed to be the biggest and most reputable suppliers, have been identified using BVG associates (2019), input from Orsted and Siemens Gamesa as well as literature studies and web searches. Based on this list, Danish suppliers' market shares in other EU countries than Denmark have been assessed as the share of Danish suppliers out of total suppliers identifies per sub-activity/component. i.e. Danish suppliers' competitiveness in other EU countries equals their share of the identified pool of suppliers. This suggests a Danish market share of around 35%, i.e. relatively close to the 40% market share in the first approach. But since the 40% include both offshore wind farms in Denmark (with higher market share, cf. below), and other EU countries, the 35% seems reasonable. In addition, also based on the list, Danish suppliers' market shares in Denmark are assessed either by expert assessments by Orsted or Siemens Gamesa or as the average between the Danish market share in other EU countries than Denmark, i.e. 35%, and a theoretical maximum market share, where Danish suppliers are selected if just they are represented as one of the identified suppliers on the list of suppliers for each of the around 160 different sub-activities/components. This suggests a Danish market share of around 57%.

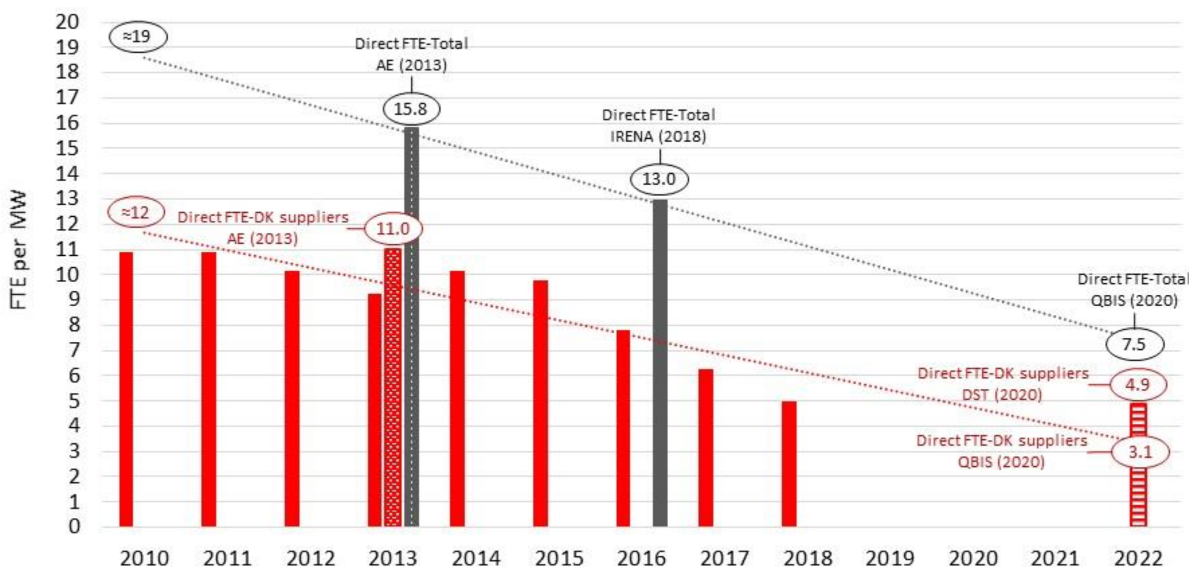
Source: QBIS based on input from Orsted and Siemens Gamesa and Danish market share assessment in section 3.4.

4.4.2 Results II: **Labour inputs** needed for 1 GW

The labour input associated with offshore wind is often debated. Renewable energy investment decisions and prioritization among renewable energy investments opportunities, particularly public, often put high emphasis on the associated labour input potential. Consequently, estimating the potential labour input in connection with renewable energy investments is important for leveraging investments, also for offshore wind.

Despite the importance, only relatively few studies have assessed the potential labour impact of offshore wind. These studies have been used in an effort to try to "calibrate the compass" for the FTE per MW to be expected from offshore wind investments when taking into consideration the significant technological development that has characterized the industry the last decade. Using two existing studies[15], the result of this "calibration" shows a downward trend starting from nearly 19 Full Time Equivalents (FTEs)[16] per MW in 2010 and 7.5 FTEs per MW in 2022 for the total FTEs per MW. Using Wind Denmark member survey and WindEurope[17] investment data on EUR and MW, the results shows an almost similar downward trend from around 12 FTEs per MW in 2010 and 3.1 FTEs per MW in 2022 for Danish FTEs per MW for offshore wind farms in other EU countries than Denmark, cf. Figure 11.

Figure 11: "Calibrating the compass" for FTE per MW, direct FTE total/DK suppliers, 2010-2022



Source: QBIS based on AE (2013), IRENA (2018b), Statistics Denmark's FTE multipliers, Wind Denmark's member survey, WindEurope (2019 and 2020) and Wind Denmark (2020).

[15] AE (2013) and IRENA (2018B).

[16] FTE measures the equivalent number of full-time employees from total working hours. It useful for converting part-time labour input to full-time employee numbers.
Read more: http://www.businessdictionary.com/definition/full-time-equivalent-FTE.html

[17] WindEurope (2020a and 2020b).

The downward trend nicely reflects the technological development that has characterised the offshore industry in the last decade. However, the question is not so much whether the trend is downward, but rather, how strong the downward trend has been and will be in the coming years. The “calibration” is this study’s contribution to an answer to that question. In the following, the applied studies, data and assessments used for the “calibration” is described in order to better explain the results.

11.0/15.8 FTE per MW: In 2013, the Danish thinktank AE[18] estimated that the Anholt 400 MW offshore wind farm would generate around 7,500 FTEs during the development, production, and installation phases (capex) corresponding to around 19 FTEs per MW.[19] The 19 FTEs per MW covered both direct and indirect work, where the direct FTEs constituted around 11 FTEs per MW and the indirect FTEs constituted around 8 FTEs per MW. Since the study uses the Statistics Denmark’s FTE multipliers[20], the assessed FTEs are pure Danish, i.e. FTEs for foreign suppliers are not included.

For the development and production phases, the study uses the FTE multiplier for “280010 Manufacture of engines, windmills and pumps”, while it uses “420000 construction” for the installation phase.

As the FTE multiplier for “280010 Manufacture of engines, windmills and pumps” is the closest FTE approximation for offshore wind available, the use of this multiplier makes sense. However, since the study was published, the value of the multiplier has decreased from 0.440 to 0.215 indicating significant productivity changes resulting in a lower labour-capital ratio. Consequently, the FTEs would be lower for development and production today.

The use of the FTE multiplier for “420000 Construction” is probably overestimating the FTEs required for installing an offshore wind farm. The multiplier covers all construction in Denmark including metro and bridges and these last two types of work are expected to have a higher labour-capital ratio than offshore wind farms that highly depend on special vessels and cranes for installation and relatively less labour input.

AE (2013) assesses that the import share is around 30% for the Anholt offshore wind farm. Based on this information, the total direct FTEs, i.e. including FTEs for foreign and Danish suppliers as well as developers, is assessed by this study to around 15.8 FTEs per MW. This assessment assumes that the labour-capital ratio is the same for Danish and foreign suppliers. An assumption justified by high degree of competition in the industry and very few local content requirements for the Danish offshore wind farms.

13.0 FTE per MW: In 2018, IRENA (2018B) estimated that the development of a typical 500 MW offshore wind farm required around 7.000 FTEs during the development, production, and installation phases corresponding to around 13s FTE per MW. This is the total FTEs including all suppliers, developers, operators, etc. Since the study is based on 2016 lifetime costs data

[18] Arbejderbevaegelsens Erhvervsrad.
[19] AE (2013).
[20] Statistics Denmark, BESKMUL1 and BESKMUL2, see: https://www.statistikbanken.dk/statbank5a/default.asp?w=1280

from BVG Associates (2016), the assessed FTEs are assumed valid in 2016 and not 2018, the year of publication of the study. Compared to the AE (2013), the assessed 13 FTEs per MW is lower and in accordance with the significant productivity improvements in the offshore wind industry in the period between 2013 and 2016 and in turn reducing FTE per MW.[21]

7.5 FTE per MW: A trendline between the assessed total FTEs per MW by AE (2013) and IRENA (2016), shows a reduction in the FTEs per MW from around 19 FTEs per MW in 2010 to around 7.5 FTE per MW in 2022. Since this assessment is based on only two data points, i.e. AE (2013) and IRENA (2018b), it is subject to uncertainty. However, a trendline based on other sources, suggests a similar downward slope (slightly less steep) for the FTEs per MW for the Danish suppliers, cf. red dotted line. So, two independent assessments indicate that FTEs per MW have been reduced and approximately with the same pace. Based on this, the 7.5 FTEs per MW is assessed to be the best available estimate on the current labour requirement for offshore wind farms considering the productivity improvements in the offshore industry.

3.1 FTE per MW: In April 2020, Wind Denmark asked its members to assess the share of their turnover accruing from offshore, onshore and services in 2020, 2015 and 2010. The results indicated a doubling in the share of turnover from offshore wind from around 20% in 2010 to around 40% in 2020 and further, adding investment data[22], a 40% market share of the offshore wind market in EU, cf. section 3.4. Applying these results to new installed offshore wind capacity in Europe[23] and the employment of Wind Denmark's members in the period 2010-2020, the Danish FTEs per MW is assessed to around 12 FTEs per MW in 2010 and 3.1 FTEs per MW in 2022. This is an average FTEs covering both offshore wind farms in Denmark and other EU countries.

Since the Danish labour input of around 3.1 FTEs per MW is around 40% of the total labour input of 7.5 FTEs per MW in 2022, it corresponds with the assessed 40% markets share above. Today, with a highly competitive and international offshore industry, a correspondence between a market share measured in turnover over investments and a market share measured in FTEs per MW is credible. However, in 2010, Wind Denmark's members share of FTEs per MW was around 60% of total FTE per MW, while their members' turnover consisted of 20% offshore wind. Thus, ten years ago, there was not necessarily correspondence between the two indicators of market share. A likely reason for this is that the early offshore wind farms, particularly the Danish, had relatively higher Danish labour input than newer offshore wind farms, simply because the EU offshore market was less developed cf. section 5.8.2.

Despite the uncertainty associated with the results of the member survey, the estimated 3.1 FTEs per MW is assessed to be the best available estimate on the current Danish labour input for offshore wind for Danish and other EU offshore wind considering the productivity improvements in the industry. Thus, the red trendline for the Danish FTEs per MW over the period 2010 to 2022 has approximately the same slope as the corresponding trendline over

[21] See section 3.3 and IEA (2019).
[22] WindEurope (2019 and 2020).
[23] Ibid.

total FTE per MW based on AE (2013) and IRENA (2018B). So, as mentioned, two independent assessments each subject to uncertainty result in the same downward slope.

4.9 FTE per MW: When assessing labour inputs of offshore wind in Denmark, Statistics Denmark's FTE multipliers, especially the FTE for "280010 Manufacture of engines, windmills and pumps", can be applied.[24] Applying this FTE multiplier to the capex for 1 GW, cf. Table 3, suggests 4.9 FTEs per MW for Danish suppliers, while this study's corresponding assessments is around 3.1 FTEs per MW.

Without more solid data it is difficult to determine with certainty whether this study assesses too low FTEs per MW or whether Statistics Denmark's FTE multiplier is generating too high FTEs per MW. It is however likely that the Statistics Denmark's FTE multiplier is generating too high labour input for the following reasons. First, the FTE multiplier not only covers wind, but also engines and pumps and last-mentioned (engines and pumps) are likely to require more labour input per produced unit than offshore wind. Compared to engines and pumps, offshore wind consists of ever-larger components and capital input is higher than labour input. Second, the import share for "280010 Manufacture of engines, windmills and pumps" is 30%, while the import share for offshore wind is assessed to around 55-60% for offshore wind farms in other EU countries than Denmark and around 35% for offshore wind farms on Denmark. I.e. simply due higher import share than used for "280010 Manufacture of engines, windmills and pumps", the Statistics Denmark's FTE multipliers can overestimate the FTEs for offshore wind. For illustration, using Statistics Denmark's FTE multiplier for "280010 Manufacture of engines, windmills and pumps" to assess direct and indirect Danish FTEs from Thor suggest around 7,900 FTEs, while this study's corresponding assessment is around 4,800 FTEs, see also section 4.5.1.

In summary, when assessing FTEs per MW for offshore wind, it is important to try to incorporate the productivity improvements of the industry reducing the labour input required per MW. Thus, due to the productivity improvements, studies just a few years old might overestimate FTEs per MW and it is therefore important to try to incorporate the dynamics of the industry when assessing the labour input required for offshore wind farms. As mentioned, the "calibration" is this study's contribution to assessing this dynamic and it suggests a total labour input of 7.5 FTEs per MW and a Danish labour input of 3.1 FTEs per MW for offshore wind farm in both Denmark and other EU countries than Denmark.

These assessed FTEs per MW are valid for the average labour input for the capex phases of the offshore wind farm, i.e. phase 1-3. However, in order to enable a more detailed analysis of the labour input required for the opex as well as the opex and depex phases, the FTE assessments need to be linked to other sources such as the IRENA (2018b) providing a detailed account of the labour needed for each phase and sub-phase over the lifetime of an offshore wind farm.

As described above, the IRENA (2018b) assesses a total 13.0 FTEs per MW in 2016, while this study assesses 7.5 FTEs per MW in 2022, but it is possible to adjust the IRENA (2018b) study to reflect 7.5 FTEs

[24] For instance, AE (2013), CRT (2014), Incentive (

per MW by assuming an unchanged labour structure in the labour input in terms of hours per work type and in terms of professions needed for the different tasks. Considering that IRENA (2018b) is analysing a 2016 commissioned 0.5 GW offshore wind farm and this study is analysing a 2022 commissioned 1 GW offshore wind farm, this assumption might seem weak.

However, IRENA (2018b) uses 8.4 MW wind turbines which is just one generation before the 10 MW wind turbines used in this study. Also, the offshore wind farm analysed in IRENA (2018b) is based on BVG Associates (2016) and BVG Associates are also the authors of a BVG Associates (2019) documenting how to build a 1 GW offshore wind farm, part by part and with detailed costs assessments per part. Comparing BVG Associates (2016) and BVG Associates (2019), the technology and components and the approach on how to install and operate and maintain the offshore wind farms are quite similar, mostly only the volumes differ. Hence, the labour/capital ratio and the associated FTEs per MW as well as the labour input across professions will be quite similar and that supports the applied assumption.

Based on these considerations and the "calibration" of the FTE per MW and IRENA (2018b), the model assesses total direct capex/depex labour input to around 7,544 FTEs per GW. Adding opex increases total direct labour input to around 9,451 FTEs per GW, while supplier contracts are assessed to require around 8,991 FTEs per GW. Table 5.

Table 5: Labour input needed per GW offshore wind farm – Europe incl. Denmark

	Phase 1 Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total**
Capex/depex – total							
Direct (FTE)	574	2,655	2,820	781		713	7,544
Direct (%)	8%	35%	37%	10%		9%	100%
Capex/opex/depex - total							
Direct (FTE)	574	2,655	2,820	781	1,907	713	9,451
Direct (%)	6%	28%	30%	8%	20%	8%	100%
Capex/opex/depex - all supplier contracts							
Direct (FTE)	547	2,655	2,820	741	1,585	642	8,991
Direct (%)	6%	30%	31%	8%	18%	7%	100%

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

It is evident that the labour-intensive phases of an offshore wind farm are the production and operation & maintenance phases, while the development, installation and decommissioning phases require relatively less amounts of labour inputs.

Based on the assessed 35% Danish market share of the EU offshore wind farms, cf. Box 2 in section 4.4.1, the Danish suppliers' labour inputs to offshore wind farms in other EU countries than Denmark are assessed to around 3,133 direct FTEs per GW. Using Statistics Denmark's FTE multipliers for indirect and induced impacts, cf. above, it is further assessed that labour input from Danish subcontractors adds another 3,190 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 2,767 FTEs per MW. This indicates a total labour input potential of around 9.090 FTEs per GW, cf. Table 6.

Table 6: Labour input for 1 GW offshore wind farm - other EU countries than Denmark

(Full Time Equivalent-FTE)	**Phase 1** Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total**
Total							
Direct[1]	574	2,655	2,820	781	1,907	713	9,451
All supplier contracts							
Direct	547	2,655	2,820	741	1,585	642	8,991
Danish supplier contracts							
Market (%)	33%	47%	31%	23%	32%	25%	35%[2]
Direct	178	1,244	878	167	506	160	3,133
Indirect	99	1,287	680	210	713	202	3,190
Induced	127	1,208	478	183	595	175	2,767
Total	404	3,739	2,036	560	1,813	377	9,090

[1] Statistics Denmark multipliers. [2] Weighted average.
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

Based on the assessed 57% Danish market share of Danish offshore wind farms, cf. Box 2 in section 4.4.1, Danish suppliers' labour inputs for Danish offshore wind farms are assessed to 4,923 direct FTEs per GW. Following same approach as above, adding labour input from Danish subcontractors adds another 5,184 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 4,451 FTEs per MW. This indicates a total labour input potential of around 14,558 FTEs per GW, cf. Table 7.

Table 7: Labour input for 1 GW offshore wind farm - Denmark

(Full Time Equivalent-FTE)	**Phase 1** Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total**
Total							
Direct[1]	574	2,655	2,820	781	1,907	713	9,451
All supplier contracts							
Direct	547	2,655	2,820	741	1,585	642	8,991
Danish supplier contracts							
Market (%)	57%	56%	48%	23%	81%	50%	57%[2]
Direct	314	1,486	1,345	169	1,287	321	4,923
Indirect	174	1,538	1,042	213	1,814	403	5,184
Induced	224	1,443	733	185	1,515	351	4,451
Total	713	4,467	3,119	568	4,616	1,075	14,558

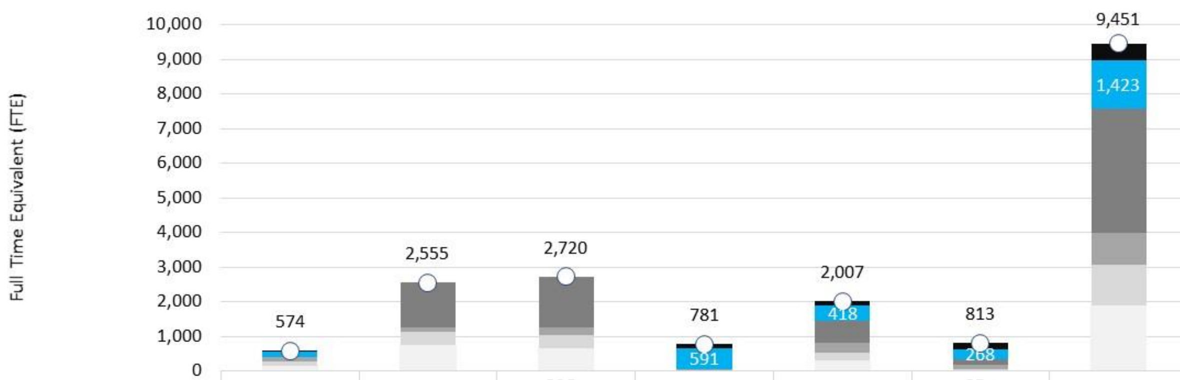
[1] Statistics Denmark multipliers. [2] Weighted average.

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

4.4.3 Results III: Labour input according to profession

As mentioned in section 4.4.2, the IRENA (2018b) study includes a detailed mapping of the labour input needed for each phase and sub-phase of an 0.5 GW offshore wind farm. In addition, the study includes an assessment of the professions needed for carrying out the different tasks under each phase and sub-phase. Adjusting the FTEs per MW of the IRENA (2018b) to level of this study's offshore model means that it is possible to incorporate the IRENA (2018b) mapping of labour input according to professions for the FTEs assessed for a 1 GW offshore wind farm with commissioning in 2022, cf. Figure 12.

Figure 12: Labour input according to profession



	P1 - Development	P2A - Wind turbines	P2B - Balance of plant	P3 - Installation	P4 - O&M	P5 - Decommis-sioning	Total
Operators	12	0	0	126	127	202	467
Ship crews	146	0	0	591	418	268	1,423
Workers + technicians	10	1,293	1,459	2	636	176	3,575
Engineers	136	126	222	30	297	106	917
Outdoor experts	113	379	378	16	239	61	1,186
Indoor experts	157	757	662	16	291	0	1,882
Total	574	2,555	2,720	781	2,007	813	9,451

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

The IRENA study (2018) split labour input according to 42 different professions. However, for simplicity, these professions have been grouped into six broader categories:

1. **Operators** include drilling, crane, cable ploug, trenching ROV and jetting system operators. Operators have a total assessed labour input of around 467 FTEs per GW with highest input intensity in phase 3-5.
2. **Ship crews** only includes ship crews. Ship crews have a total assessed labour input of around 1,423 FTEs with highest input intensity in phase 3-5.
3. **Workers and technicians** include factory and civil workers and different types of technicians. They have a total assessed labour input of around 3,575 FTEs with highest input intensity in phase 2 and then phase 4-5.
4. **Engineers** include electric, telecommunication, computer, material, industrial, mechanical, naval and civil engineers. Engineers have total assessed labour input of 917 FTEs and are required in all five phases of an offshore wind farm, however with relatively highest input intensity in phase 4.

5. **Outdoor experts** include logistics, geotechnical, health & quality, safety, environmental, sociological, marine, biology, fishing site security experts. Outdoor experts have a total assessed labour input of around 1,186 FTEs and are like engineers also required in most phases however relatively most during phase 2A and 4.
6. **Indoor experts** include administrative, accounting, marketing, taxation, regulation & standardisation and financial experts. Indoor experts have a total assessed labour input of around 1,882 FTEs with highest input intensity in phase 2A and then phase 2B and 4.

In summary, workers and technicians have the relatively highest labour input corresponding to around 38% of total lifetime FTEs of an offshore wind farm. Second are indoor experts such as accountants and lawyers with a labour input corresponding to around 20%. Third are ship crews with around 15%. Fourth are outdoor experts such as environmental and geotechnical experts with around 13%. Fifth are engineers with 10% and sixth are operators with 5%.

4.4.4 Results IV: Salaries for 1 GW

The associated salaries of the professions have been assessed using to independent approaches. First, the adjusted FTEs per profession from IRENA (2018b) multiplied by Statistics Denmark's salary statistics (LONS20)[25] per profession. Second, the assessed lifetime costs of the 1 GW offshore wind farm, cf. section 4.2.2, multiplied by Statistics Denmark's income multipliers (INPMUL1)[26].

Both approaches provide an assessment of the total Danish salaries. The first approach assesses total Danish salaries to around EUR 853 million, while the second approach assesses total Danish salaries to around EUR 732 million, cf. Table 8. Subject to the uncertainty underpinning such assessments, the two assessments mutually confirm each other.

Since it enables assessments of indirect and induced salaries in addition to the direct, the preferred assessment is however the second approach using Statistics Denmark's multipliers, which is also used for the assessment of labour inputs, cf. section 4.4.2. Considering this approach produce the relatively lowest assessed salaries, it might be considered conservative.

Based on the assessed 35% Danish market share of the EU offshore wind farms, cf. Box 2 in section 4.4.1, Danish suppliers' assessed salaries for offshore wind farms on other EU countries than Denmark are assessed to EUR 265 million corresponding to around 38% of total supplier salaries of around EUR 701 million. In addition, indirect and induced salaries can potentially add EUR 235 million and EUR 186 million, resulting in a potential total of EUR 686 million.

[25] Statistics Denmark, LONS20. See: https://www.statistikbanken.dk/statbank5a/default.asp?w=1920
[26] Statistics Denmark, INPMUL1. See: https://www.statistikbanken.dk/statbank5a/default.asp?w=1920

Table 8: Salaries for 1 GW

	Phase 1 Develop-ment CAPEX	**Phase 2A** Production Wind turbines CAPEX	**Phase 2B** Production Balance of plant CAPEX	**Phase 3** Installation & grid connection CAPEX	**Phase 4** Operation & maintenance (25 years) OPEX	**Phase 5** Decommis-sioning DEPEX	**Total**
Total							
Direct[1]	13	219	211	87	237	87	853
Direct[2]	45	215	228	66	111	66	732
All suppliers							
Direct[2]	43	215	228	63	92	59	701
DK suppliers on EU wind farms							
Direct[2]	14	101	71	22	43	14	265
Indirect[2]	7	96	48	16	54	15	235
Induced[2]	8	74	45	11	37	11	186
Total[2]	29	271	165	49	133	39	686
Danish suppliers on Danish wind farms							
Direct[2]	25	121	109	23	111	27	415
Indirect[2]	12	115	74	16	136	30	383
Induced[2]	14	89	69	11	93	22	298
Total[2]	50	324	252	50	340	79	1,095

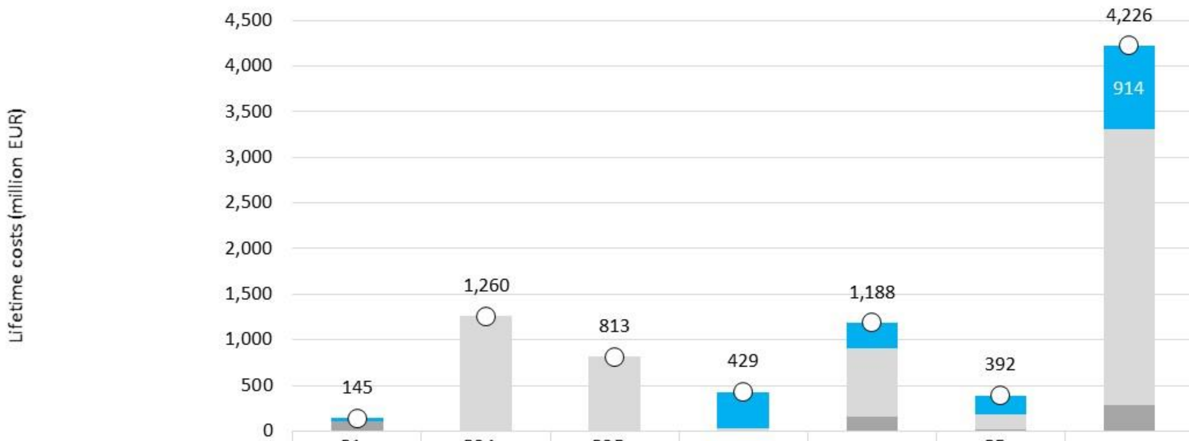
[1] Assessed based on FTE from IRENA (2018b) multiplied by Statistics Denmark's salary statistics (LONS20).
[2] Lifetime costs, cf. section 4.2.2, multiplied by Statistics Denmark's income multipliers (INPMUL1).
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

Based on the assessed 57% Danish market share of Danish offshore wind farms, cf. Box 2 in section 4.4.1, Danish suppliers' assessed salaries for Danish offshore wind farms are assessed to EUR 415 million corresponding to around 59% of total supplier salaries of around EUR 701 million. In addition, indirect and induced salaries can potentially add EUR 383 million and EUR 298 million, resulting in a potential total of EUR 1,095 million.

4.4.5 Results V: Lifetime costs according to industry

IRENA (2018b) detailed mapping of the professions needed for carrying out the different tasks under each phase and sub-phase, cf. section 4.4.3, can be applied to assess the associated industry sectors involved over the lifetime of an offshore wind farm. As professions can belong to different industries, the assessment will be subject to uncertainty. However, using broad industry categories in terms of 1) maritime suppliers 2) wind turbine suppliers/operators and 3) developers/consultants and preserving the phase of which the professions are applied, the assessment can provide useful indication, cf. Table 13.

Figure 13: Lifetime costs according to industry



	P1 - Develop-ment	P2A - Wind turbines	P2B - Balance of plant	P3 - Installation	P4 - O&M	P5 - Decommis-sioning	Total
Maritime suppliers	40	0	0	394	277	203	914
Windmill suppliers/operators	0	1,260	813	33	757	169	3,033
Developers/consultants	105	0	0	2	154	19	279
Total	145	1,260	813	429	1,188	392	4,226

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, BVG Associates (2016 and 2019) and IRENA (2018b).

Maritime suppliers include shipping companies such as operating installation vessels (e.g. Swire Blue Ocean and Boskalis) and O&M vessels (e.g Esvagt, MH-O&, Acta Marine and Northern Offshore Services). Maritime suppliers are assessed to get around EUR 914 million corresponding to around 23% of total lifetime costs.

Windmill suppliers/operators include MHI Vestas, Siemens Gamesa or other windmill producers/operators as well as all their sub-suppliers. Such suppliers are assessed to get around EUR 3,033 million corresponding to around 70% of total lifetime costs.

Developers/consultants include Orsted, Vattenfall and other developers as well as external consultants assisting with developing a farm. Developers/consultants are assessed to get around EUR 279 million corresponding to around 6% of total lifetime costs.

4.4.6 Results VI: Local impacts of 1 GW

The appointment of a local installation or O&M port creates opportunities for local suppliers and workers within the port region itself, ranging from local shipyards, steel manufacturers and electricians to local restaurants, hotels and catering companies. These opportunities as well as case studies of ports previously selected in connection with the Danish offshore wind farms are described in Chapter 5.

In terms of quantifying the potential contract sums and labour input to local suppliers and workers, the model's detailed mapping of activities and components included over the lifetime of an offshore wind farm, cf. Table 9 and Appendix D, is useful. For instance, the model shows the typical costs of a port contract in connection with the installation and the O&M phases as well as the costs of other activities and components in these phases where local suppliers might come into play, cf. Table 9. Due to confidentiality considerations, costs of most sub-components and sub-activities are not displayed.

Table 9: Activities and components under Operation and Maintenance in offshore model

(million EUR per year)		Minimum	Average	Maximum
5	**Operation, maintenance and service**	**32.2**	**47.5**	**90.4**
5.1	**Operations**	**13.4**	**15.8**	**30.1**
5.1.1	Training			
5.1.2	Onshore logistics	0.5	0.5	0.6
5.1.3	Offshore logistics			
5.1.3.1	Crew tranfer vessels (CTV)			
5.1.3.2	Service operations vessels (SOV)			
5.1.3.3	Turbine access systems			
5.1.3.4	Helicopters			
5.1.4	Health and safety inspections			
5.1.4.1	Health and safety equipment			
5.1.5	Administrative personel			
5.2	**Maintenance and service**	**19.3**	**31.7**	**60.2**
5.2.1	Turbine maintenance and service			
5.2.1.1	Blade inspection and repair			
5.2.1.1.1	Unmanned aerial vehicle			
5.2.1.2	Main component refurbishment, replacement and repair			
5.2.1.2.1	Large component repair vessel			
5.2.2	Balance of plant maintenance and service			
5.2.2.1	Foundation inspection and repair			
5.2.2.1.1	Remotely operated vehicle (ROV)			
5.2.2.1.2	Autonomous underwater vehicle			
5.2.2.2	Cable inspection and repair			
5.2.2.3	Scour monitoring and management			
5.2.2.4	Substation maintenance and service			
5.3	**Other costs**	**1.5**	**1.5**	**1.5**
5.3.1	OEM WTG monitoring and technical support			
5.3.2	Turbine Electricity consumptions			
5.3.3	Wind & Weather Monitoring			
5.3.4	Fees leases, taxes and insurance			

How much local suppliers might come into play depends on their skills and experience and since these are difficult to accurately predict and assess for most ports, the assessment of the local impacts uses low and high scenarios for local suppliers' potential share of contracts and FTEs.

For Esbjerg, offering a comprehensive offshore supply chain, the low and high scenarios ranges are set to between 35% (Danish offshore companies' assessed market share on offshore wind farms in other EU countries than Denmark) and 57% (Danish offshore companies' assessed market share on offshore wind farms in Denmark), cf. Box 2 in section 4.4.1. Due to Esbjerg's comprehensive offshore supply chain, the low and high scenarios of 35% and 57% also includes direct offshore contracts. For other ports, the low and high ranges only include subcontracts to offshore companies, not direct offshore contract as these typically go to specialised offshore companies. For the installation phase of 1 GW offshore wind farm, these scenarios suggest an assessed potential for Esbjerg varying between EUR 304-495 million in supplier contracts and 869-1,415 FTEs in associated direct, indirect and induced labour inputs. For an O&M contract, the corresponding potential vary between EUR 34-48 million and 91-130 FTEs per year corresponding to around EUR 842-1,200 million and 2,274-3,241 FTEs over the 25-year O&M period , cf. Table 10.

For other ports than Esbjerg, the scenarios are considerably lower and more arbitrary determined. As a starting point, it is assessed that being selected as installation port will as a minimum generate a contract for the port of around EUR 5.0 million corresponding to around 1.2% of total supplier contracts in the installation phase and around EUR 0.5 million per year corresponding to around 1.3% of total supplier contracts in the O&M phase. In the high scenario, it is assumed that local companies can supply products and services to the offshore companies corresponding to around another 5% of total supplier contracts in the installation phase and another 15% in the O&M phase. Due to the 25-years duration of O&M phase, the supplier percentage for the Q&M phase is assumed higher than the supplier percentage for the installation phase because the longer period can provide better opportunities for local companies to position themselves as suppliers. These percentages can however vary according to the port in question as described in the next section 4.5.

For the installation phase of 1 GW offshore wind farm, these scenarios suggest an assessed potential for other ports varying between EUR 10.6-28.0 million in supplier contract and around 30-96 FTEs for associated direct, indirect and induced labour inputs. For an O&M contract, the corresponding potential vary between EUR 3.2-9.1 million and 59-81 FTEs for the associated direct, indirect and induced labour inputs corresponding to around EUR 80-227 million and 1,466-2,024 FTEs over the 25-year O&M period, cf. Table 10.

Table 10: Local work for suppliers, contractors, developers and operators

	Phase 3 Installation & grid connection				**Phase 4** Operation & maintenance (25 years)				**Phase 5** Decommissioning				**Total**			
	CAPEX				OPEX				DEPEX							
	EUR million		FTE		EUR million		FTE		EUR million		FTE		EUR million		FTE	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Esbjerg	35%	57%	35%	57%	35%	57%	35%	57%	35%	57%	35%	57%				
Direct	142	232	259	422	16	23	25	36	141	201	226	323	299	455	511	781
Indirect	96	156	326	531	11	15	36	51	95	135	319	455	201	306	681	1,036
Induced	66	107	284	462	7	10	30	43	65	92	266	380	138	209	580	884
Total per year	304	495	869	1,415	34	48	91	130	301	428	812	1,157	638	971	1,772	2,702
Total 25 years	304	495	869	1,415	842	1,200	2,274	3,241	301	428	812	1,157	1,447	2,123	3,955	5,813
Other ports	1.2%	5.0%	1.2%	5.0%	1.4%	15%	1.4%	15%	1.4%	5%	1.4%	5%				
Direct	5.0	5.0	9	9	0.5	0.5	46	46	5.0	5.0	8	8	10.5	10.5	63	63
Indirect	3.3	13.7	11	47	0.4	4.0	1	13	3.4	11.9	11	40	7.1	29.5	24	100
Induced	2.3	9.4	10	41	2.3	4.5	11	22	2.3	8.1	9	33	6.9	22.0	31	95
Total per year	10.6	28.0	30	96	3.2	9.1	59	81	10.7	25.0	29	81	24.4	62.1	118	258
Total 25 years	10.6	28.0	30	96	80	227	1,466	2,024	10.7	25.0	29	81	101	280	1,525	2,201

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco and BVG Associates (2016 and 2019).

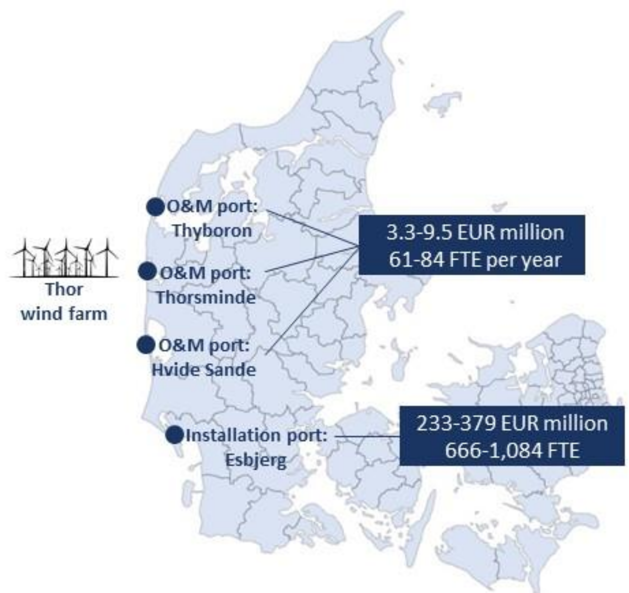
In summary, considering phase 5 is much like phase 3 just reversed, the total local lifetime impacts for phase 3-4 are assessed to around EUR 1,447-2,123 million and 3,955-5,813 FTEs for Esbjerg and around EUR 101-280 million and 1,525-2,201 FTEs for other ports. In section 4.5, the model is applied to planned and existing Danish offshore wind farms which further indicate the local impacts for installation and O&M ports.

4.5 MODEL APPLICATION

4.5.1 Thor - 800-1,000 MW

The next big offshore wind farm to be tendered out in Denmark is Thor, which is to be located in the North Sea west of Nissum Fjord, at a distance of min. 20 km from the shore. The new wind farm is named "Thor" after Thorsminde, the nearest village on the shore. The wind farm will have a capacity of min. 800 MW and max. 1.000 MW and will be connected to the grid between year 2024 and 2027. The Danish Energy Agency will conclude the tendering process with final bids in Q4 2021. Thor offshore wind farm is the first of three large offshore wind farms to be built in Denmark before 2030. This has been decided in the Energy Agreement from June 2018, which all political parties stood behind.[27]

Figure 14: Thor – 800-1,000 MW



Source: QBIS

It is not yet decided which ports that will be selected for installation and O&M ports, respectively. However, if selection criteria include proximity and in the case of Esbjerg, availability of offshore companies and supply chain logistics, Thyboron, Thorsminde or Hvide Sande could be candidates for O&M port, while Esbjerg could be candidate for both installation and O&M port, cf. Figure 14. For the purpose of using the offshore wind model for assessing the potential socioeconomic impacts of Thor, these ports are assumed to be selected as installation and O&M ports. In order to set up the offshore wind model for this assessment, the first step is to adjust capex and opex in order to reflect the Thor offshore wind farm.

Since the tendering process is still ongoing, actual capex and opex are not available for this adjustment. Alternatively, the capex and opex from the Danish Energy Agency's Technology Catalogue are used for the purpose.[28] According to this catalogue, the expected capex in 2020 is 2.13 million EUR per MW for offshore wind farms, which means that the offshore model needs to be corrected by a factor 0.91 compared to its corresponding capex of 2.50 million EUR per MW excluding development costs, cf. section 4.3.3. Opex is expected to be 0.055 million EUR per MW per year in 2020[29], which means that the offshore model needs to be corrected by a factor 1.16 compared to its corresponding opex of 0.048 million EUR per MW per year.

[27] The Danish Energy Agency (DEA). See: https://ens.dk/en/our-responsibilities/wind-power/ongoing-offshore-wind-tenders/thor-offshore-wind-farm
[28] DEA (2020), page 245.
[29] DEA (2020), page 242.

Based on this correction, the offshore model assesses that the total direct labour input will be around 5,234 FTEs in the capex phase, around 1,987 FTEs over the 25-year long opex phase and finally, around 546 FTEs in the depex phase. This result in a total direct labour input of around 7,768 FTEs over the lifetime of the Thor wind farm, cf. Table 11.[30]

Table 11: Thor 800-1,000 MW offshore wind farm – lifetime costs, contracts, and total/local FTEs

Offshore wind farm	**CAPEX**	**OPEX**	**DEPEX**	**TOTAL**
Correction	(0.85)	(1.16)	(0.85)	
Costs (EUR million)	2,028	1,238	300	3,565
Costs (EUR million per MW)	2.25[1]	1.38	0.33	3.96
Labour - direct all (FTEs)	5,234	1,987	546	7,768
Labour - direct DK (FTEs)	2,540	1,341	246	4,127
Labour - indirect DK (FTEs)	2,273	1,890	309	4,472
Labour - induced DK (FTEs)	1,981	1,579	269	3,828
Labour - total DK (FTEs)	6,794	4,810	824	12,428

Local ports	**Installation port:** Esbjerg				**O&M port:** Thuboron, Thorsminde or Hvide Sande			
	EUR million		FTE		EUR million		FTE	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Share of contracts	35.0%	57%	35.0%	57%	1.4%	15%	1.4%	15%
Direct	109	178	199	324	0.6	0.6	48	48
Indirect	73	120	250	407	0.4	4.2	1	14
Induced	50	82	217	354	2.4	4.7	12	23
Total per year	233	379	666	1,084	3.3	9.5	61	84
Total 25 years	233	379	666	1,084	83	237	1,527	2,109

[1] Expected capex of 2.13 million EUR per MW (DEA (2020)) plus development costs.
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, IRENA (2018b) and BVG Associates (2016 and 2019).

The Danish share of this labour input is assessed to be around 4,127 FTEs. Labour inputs from Danish subcontractors is assessed to add another 4,472 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 3,828 FTEs. In summary, a total Danish labour input of around 12,428 FTEs.

[30] In comparison, the Danish Energy Agency has assessed that Thor can create around 8,000 FTEs during development, production, and installation phases. This corresponds to minimum 10 FTEs per MW compared to the around 7.4 FTEs per MW assessed in the model. It is however not clear what the 8,000 FTEs include in terms of direct, indirect and induced labour or in terms of Danish and foreign labour. See: https://presse.ens.dk/news/danmarks-stoerste-havvindpark-skal-ligge-i-nordsoeen-360442

A part of this labour input will go to the installation and O&M ports. How much depends on the ports' ability to supply products and services to the offshore companies on a subcontracting basis and in the case of Esbjerg, also the ability to get direct offshore contracts. Since this ability is difficult to predict and assess for most ports apart from Esbjerg, low and high scenarios have been applied.

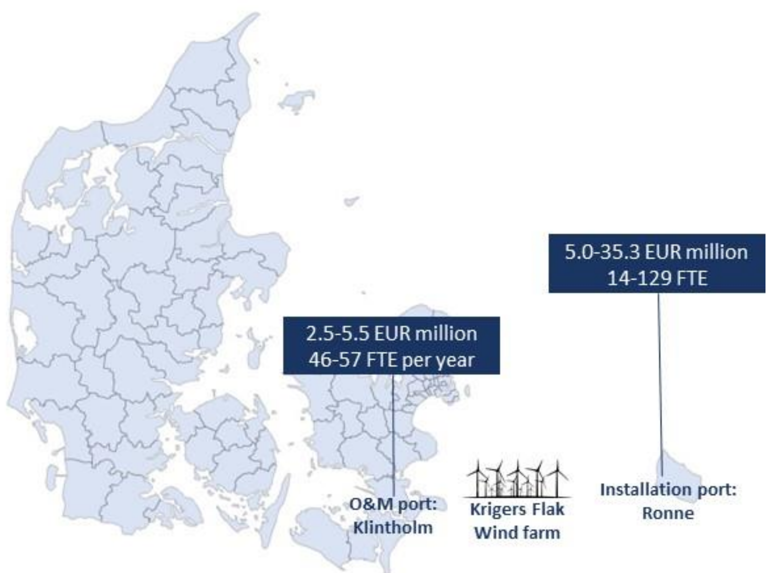
For Esbjerg, offering a comprehensive offshore supply chain, the low and high scenarios ranges between 35% and 57%, cf. section 4.4.6. This means that the assessed potential for Esbjerg vary between EUR 233-379 million in direct, indirect and induced turnover from supplier contracts and around 666-1,084 FTEs in associated direct, indirect and induced labour inputs.

For other ports, the low and high scenarios are considerably lower and more arbitrary determined. For either Thuboron, Thorsminde or Hvide Sande, being selected as O&M port can therefore generate different scales of impacts. If only the contract for port services is awarded locally, the O&M phase is assessed to generate around EUR 3.3 million in direct, indirect and induced turnover and 61 FTEs in associated direct, indirect and induced labour input per year over a 25-year period. In addition to the port contract, most of the turnover and FTEs stem from the permanents staff of the developer/operator working and living in the local area. However, if the local businesses can supply products and services to the offshore companies in an amount corresponding to around 15% of the supplier contract sum, the O&M phase is assessed to have the potential to generate around EUR 9.5 million and 84 FTEs per year. In total, there is an assessed potential of around EUR 83-237 million and 1,527-2,109 FTEs over the 25-year O&M period.

4.5.2 Kriegers Flak - 600 MW

Kriegers Flak is a 600 MW offshore wind farm currently under construction and located in the Baltic Sea about 15 km east of the island of Mon. The window for erecting Kriegers Flak is between 1st January 2019 and 31st December 2021. Kriegers Flak will form part of a new 400 MW interconnector between Denmark and Germany.

Figure 15: Krigers Flak – 600 MW



Source: QBIS

Installation port is the Port of Ronne on the island of Ronne, while the O&M port is the Port of Klintholm on the island of Mon, cf. Figure 15. The expected capex of Kriegers Flak is between 1.81-2.13 million EUR per MW corresponding to an average of around 1.97 million EUR per MW[31], which means that the offshore model needs to be corrected by a factor 0.79 compared to its corresponding capex of 2.50 million EUR per MW excluding development costs, cf. section 4.3.3. Opex is expected to be 0.062 million EUR per MW per year[32], which means that the offshore model needs to be corrected by a factor 1.31.

Based on this correction, the offshore model assesses that the total direct labour input to around 3,221 FTEs in the capex phase, 1,252 FTEs over the 25-year long opex phase and finally, 306 FTEs in the depex phase. This result in a total direct labour input of around 4,778 FTEs over the lifetime of Kriegers Flak, cf. Table 12.

The Danish share of this labour input is assessed to be around 2,747 FTEs. Labour inputs from Danish subcontractors is assessed to add another 3,037 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 2,594 FTEs. In summary, a total Danish labour input of around 8,378 FTEs, cf. Table 12.

[31] DEA (2020).
[32] Ibid.

Table 12: Kriegers Flak 600 MW offshore wind farm – lifetime costs, contracts, and total/local FTE

Offshore wind farm	**CAPEX**	**OPEX**	**DEPEX**	**TOTAL**
Correction	(0.79)	(1.31)	(0.79)	
Costs (EUR million)	1,260	937	186	2,384
Costs (EUR million per MW)	2.08[1]	1.55	0.31	3.94
Labour - direct all (FTEs)	3,221	1,252	306	4,778
Labour - direct DK (FTEs)	1,578	1,016	153	2,747
Labour - indirect DK (FTEs)	1,413	1,432	192	3,037
Labour - induced DK (FTEs)	1,231	1,196	167	2,594
Labour - total DK (FTEs)	4,222	3,644	512	8,378

Local ports	**Installation port:** Ronne				**O&M port:** Klintholm			
	EUR million		FTE		EUR million		FTE	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Share of contracts	1.2%	15%	1.2%	15%	1.4%	10%	1.4%	10%
Direct	2.4	2.4	4	4	0.4	0.4	36	36
Indirect	1.6	19.6	5	67	0.3	2.1	1	7
Induced	1.1	13.4	5	58	1.8	3.0	9	14
Total per year	5.0	35.3	14	129	2.5	5.5	46	57
Total 25 years	5.0	35.3	14	129	63	138	1,157	1,436

[1] Expected capex of 1.97 million EUR per MW (DEA (2020)) plus development costs.
Source: QBIS based on DEA (2020), Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, IRENA (2018b) and BVG Associates (2016 and 2019).

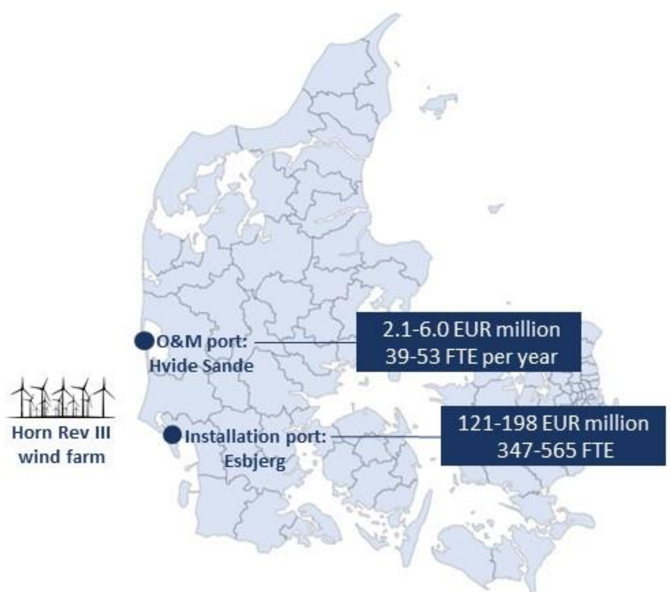
The installation port – the Port of Ronne – had prior to the contract for Kriegers Flak already built up experiences within offshore wind as base port for the Dutch Arkona offshore wind farm in 2018, cf. section 5.8.1. This means that the port and to some extent perhaps also the local businesses should be positioned to assist some of the offshore companies as subcontractors as well as potentially also direct contractors to the offshore wind farm developer/operators. This is of course relevant when trying to determine the low and high scenarios. Conservatively, the low scenario is however still defined by a situation where only the contract for port services is awarded locally and generating around EUR 5.0 million in supplier contracts and an associated direct, indirect and induced labour inputs of 14 FTEs during the installation phase. However, if the local businesses can supply products and services to the offshore companies in an amount corresponding to around 15% of the supplier contract sum (around a quarter of Esbjerg's expected share of contracts), the installation phase is assessed to generate around EUR 35.3 million and 129 FTEs.

The O&M port – the Port of Klintholm – has established the local supplier network "Kriegers Flak Service Group" for companies in cleaning, taxi, catering, hotels, marine, electrician, etc. with the aim of becoming subcontractors to the offshore companies. The local area is however not strong on industry and the high scenario is set to maximum 10% of the supplier contract sum and in turn generating around EUR 5.5 million in supplier contracts and associated direct, indirect and induced labour inputs of around 57 FTEs per year. The low scenario is defined by a situation where only the contract for port services is awarded locally and generating around EUR 2.5 million and 46 FTEs per year. In total, there is an assessed potential of around EUR 63-138 million and 1,157-1,436 FTEs over the 25-year O&M period.

4.5.3 Horns Rev III - 406 MW

Horns Rev III is a 406 MW offshore wind farm in the North Sea, 25-40 km off the Danish Jutland coast. Vattenfall won the right to construct Horns Rev 3 in 2015. The first foundation was placed in the seabed in October 2017 and the first turbines began delivering electricity to consumers in December 2018. The official inauguration of Horns Rev 3 took place in August 2019.

Figure 16: Horns Rev III – 406 MW



Source: QBIS

Installation port is the Port of Esbjerg, while the O&M port is the Port of Hvide Sande, cf. Figure 16. Capex is 2.46 million EUR per MW.[33] This means that the offshore model needs to be corrected by a factor 0.98 compared to its corresponding capex of 2.65 million EUR per MW, cf. section 4.2.2. Opex is 0.077 million EUR per MW per year, which means that the offshore model needs to be corrected by a factor 1.62.[34] Based on these corrections, the offshore model assesses that the total direct labour input will be around 2,727 FTEs in the capex phase, 1,255 FTEs over the 25-year long opex phase and finally, 285 FTEs in the depex phase. This result in a total direct labour input of around 4,269 FTEs over the lifetime of Horn Rev III, cf. Table 13.

The Danish share of this labour input is assessed to be around 2,300 FTEs. Labour inputs from Danish subcontractors is assessed to add another 2,540 FTEs, while labour input from spending of wages and salaries on food, housing, transportation, etc. adds yet another 2,540 FTEs. In summary, a total Danish labour input of around 7,010 FTEs, cf. Table 13.

[33] DEA (2020).
[34] DEA (2020).

Table 13: Horns Rev III 406 MW offshore wind farm – lifetime costs, contracts, and total/local FTE

Offshore wind farm	CAPEX		OPEX		DEPEX		TOTAL	
CAPEX correction	(0.98)		(1.62)		(0.98)			
Costs (EUR million)	1,056		782		156		1.994	
Costs (EUR million/MW)	2.60[1]		1.93		0.39		4.91	
Labour - direct all (FTEs)	2,729		1,255		285		4,269	
Labour - direct DK (FTEs)	1,329		847		128		2,300	
Labour - indirect DK (FTEs)	1,185		1,194		161		2,540	
Labour - induced DK (FTEs)	1,033		997		140		2,170	
Labour - total DK (FTEs)	3,543		3,038		430		7,010	
Local ports	**Installation port:** Esbjerg				**O&M port:** Hvide Sande			
	EUR million		FTEs		EUR million		FTEs	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Share of contracts	35%	57%	35%	57%	1.4%	15%	1.4%	15%
Direct	57	93	104	169	0.4	0.4	30	30
Indirect	38	62	130	212	0.2	2.6	1	9
Induced	26	43	113	185	1.5	3.0	8	14
Total per year	121	198	347	565	2.1	6.0	39	53
Total 25 years	121	198	347	565	53	149	965	1,332

[1] Expected capex of 2.46 million EUR per MW (DEA (2020)) plus development costs.

Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, IRENA (2018b) and BVG Associates (2016 and 2019).

For Esbjerg, the installation port, the low and high scenarios are identical to Thor, cf. section 4.5.1, and vary between 35% and 57%. These scenarios suggest an assessed potential for Esbjerg varying between EUR 121-198 million in supplier contracts and 347-565 FTEs in associated direct, indirect and induced labour inputs. For Hvide Sande, the O&M port, the low and high scenarios are identical to the basic scenarios, cf. section 4.4.6, and vary between 1.2% and 15%. The corresponding potential vary between EUR 2.1-6.0 million and 39-53 FTEs per year corresponding to around EUR 53-149 million and 965-1,332 FTEs over the 25-year O&M period , cf. Table 13.

4.5.4 Energy islands – 5 GW

The government and a broad majority in the Danish parliament have signed a climate agreement that guarantees a green energy sector, and together with the climate agreement for waste, results in CO2 reductions of 3.4 million tonnes by 2030. As a part of the climate agreement, Denmark must now have the world's first two energy islands by 2030 totalling 5 GW. One at Bornholm (close to Kriegers Flak) at 2 GW and one in the North Sea at 3 GW.

In order to set up the offshore wind model for this assessment, the first step is to adjust capex and opex in order to reflect the energy islands. Since the climate agreement has only just been passed and since commissioning date is 2030, actual capex and opex are not available for this exercise.

Alternatively, the capex and opex from the Danish Energy Agency's Technology Catalogue are used for the adjustment.[35] According to this catalogue, the expected capex in 2030 is 1.93 million EUR per MW for offshore wind farms. However, according to a recent study commissioned by the Danish Energy Agency[36], the expected average capex of wind farms located in the North Sea and Kriegers Flak (and Hesselo), i.e. the locations of the energy islands, is around 2.22 million EUR per MW, i.e. closer to the 2020 capex of 2.13 million EUR per MW of the technology catalogue. Consequently, the 2020 capex of 2.13 million EUR per MW is applied. Like Thor, this means that the offshore model needs to be corrected by a factor 0.91 compared to its corresponding capex of 2.50 million EUR per MW excluding development costs, cf. section 4.3.3.

According to the technology catalogue, opex is around 0.055 million EUR per MW in 2020[37], which means that the offshore model needs to be corrected by a factor 1.16 compared to its corresponding opex of 0.048 million EUR per MW per year. As energy islands might require different O&M setup, opex is however subject to significant uncertainty. Generally, the following assessments of the energy islands should only be considered as a best guess using current available information.

For Bornholm, the offshore model assesses total direct labour input to be around 11,517 FTEs in the capex phase, around 3,671 FTEs over the 25-year long opex phase and finally, around 1,093 FTEs in the depex phase. This result in a total direct labour input of around 16,281 FTEs over the lifetime of the energy island. The Danish share of lifetime FTEs is assessed to around 9,171. Adding labour inputs from subcontractors and spending of wages and salaries result in a total Danish labour input of around 27,617 FTEs, cf. Table 14.

[35] DEA (2020), page 245.
[36] COWI (2020).
[37] DEA (2020), page 242.

Table 14: Bornholm 2 GW energy island - lifetime costs, contracts, and total/local FTE

Offshore wind farm	**CAPEX**		**OPEX**		**DEPEX**		**TOTAL**	
CAPEX correction	(0.85)		(1.16)		(0.85)			
Costs (EUR million)	11,631		4,417		1,214		17,261	
Costs (EUR million/MW)	2.25[1]		1.38		0.33		3.96	
Labour - direct all (FTEs)	11,517		3,671		1,093		16,281	
Labour - direct DK (FTEs)	5,644		2,981		546		9,171	
Labour - indirect DK (FTEs)	5,051		4,201		686		9,939	
Labour - induced DK (FTEs)	4,402		3,508		598		8,508	
Labour – total DK (FTEs)	15,097		10,690		1,830		27,617	
Local ports	**Installation port:**				**O&M port:**			
	EUR million		FTEs		EUR million		FTEs	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Share of contracts	1.2%	10%	1.2%	10%	1.4%	10%	1.4%	10%
Direct	8.4	8.4	15	15	1.3	1.3	106	106
Indirect	5.7	46.6	19	159	0.9	6.2	3	21
Induced	3.9	31.9	17	138	5.3	8.8	27	41
Total per year	18.0	87.0	52	312	7.4	16.2	136	168
Total 25 years	18.0	87.0	52	312	185	405	3,394	4,211

[1] Expected capex of 2.13 million EUR per MW (DEA (2020)) plus development costs.
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, IRENA (2018b) and BVG Associates (2016 and 2019).

For North Sea, the offshore model assesses total direct labour input to be around 17,275 FTEs in the capex phase, around 5,507 FTEs over the 25-year long opex phase and finally, around 1,639 FTEs in the depex phase. This result in a total direct labour input of around 24,421 FTEs over the lifetime of the energy island. The Danish share of lifetime FTEs is assessed to around 13,756. Adding labour inputs from subcontractors and spending of wages and salaries result in total Danish labour input of around 41,426 FTEs, cf. Table 15.

Table 15: North See 3 GW energy island - lifetime costs, contracts, and total/local FTE

Offshore wind farm	**CAPEX**		**OPEX**		**DEPEX**		**TOTAL**	
CAPEX correction	(0.85)		(1.16)		(0.85)			
Costs (EUR million)	17,446		6,625		1,821		25,892	
Costs (EUR million/MW)	2.25[1]		1.38		0.33		3.96	
Labour - direct all (FTEs)	17,275		5,507		1,639		24,421	
Labour - direct DK (FTEs)	8,465		4,471		819		13,756	
Labour - indirect DK (FTEs)	7,577		6,302		1,030		14,908	
Labour - induced DK (FTEs)	6,603		5,262		896		12,762	
Labour - total DK (FTEs)	22,646		16,035		2,746		41,426	
Local ports	**Installation port:**				**O&M port:**			
	EUR million		FTEs		EUR million		FTEs	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Share of contracts	1.2%	10%	1.2%	10%	1.4%	10%	1.4%	10%
Direct	12.7	12.7	23	23	1.9	1.9	160	160
Indirect	8.5	69.9	29	238	1.3	9.2	4	31
Induced	5.8	47.8	25	207	7.9	13.2	40	62
Total per year	27.0	130.4	77	468	11.1	24.3	204	253
Total 25 years	27.0	130.4	77	468	278	608	5,091	6,317

[1] Expected capex of 2.13 million EUR per MW (DEA (2020)) plus development costs.
Source: QBIS based on Statistics Denmark, Orsted, Vattenfall, Siemens Gamesa, Semco, IRENA (2018b) and BVG Associates (2016 and 2019).

Like Thor, it is not yet decided which ports that will be selected for installation and O&M ports, respectively. However, unlike Thor, more unknowns exist concerning the selection of ports, and consequently, the assessment does not attempt to designate ports for installation and O&M contracts and simply assesses the potential and associated impacts.

For an installation port, depending on the ability of the local businesses and industry to attract subcontracts assumed to vary between 1.2% and 10%, Bornholm energy island can potentially generate between EUR 18.0-87.0 million in direct, indirect and induced turnover and 52-312 FTEs in associated direct, indirect and induced labour input. The corresponding numbers for the North Sea energy island are assessed to be between EUR 27.0-130.4 million in direct, indirect and induced turnover and 77-468 FTEs in associated direct, indirect and induced labour input.

For an O&M port, similarly depending on the ability of the local businesses and industry to attract subcontracts and assumed to vary between 1.2% and 10%, Bornholm energy island can potentially generate between EUR 7.4-16.2 million in direct, indirect and induced turnover and 136-168 FTEs in associated direct, indirect and induced labour input per year corresponding to around EUR 185-405 million and 3,394-4,211 FTEs over the 25-year O&M period. The corresponding numbers for the North Sea energy island are assessed to be between EUR 11.1-24.3 million in direct, indirect and induced turnover and 204-253 FTEs in associated direct, indirect and induced labour input per year corresponding to around EUR 278-608 million and 5,091-6,317 FTEs over the 25-year O&M period, cf. Figure 17 and Figure 18.

Figure 17: Bornholm – 2 GW

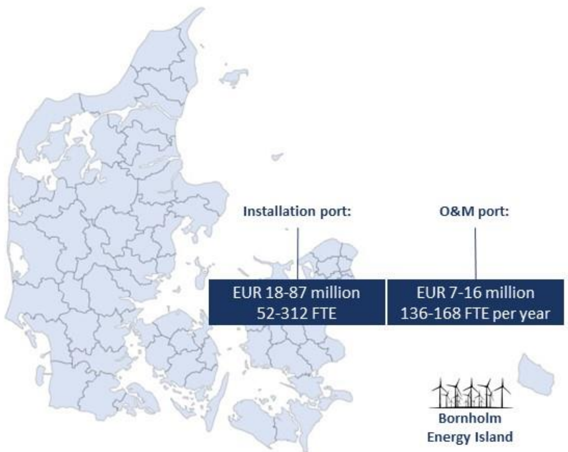
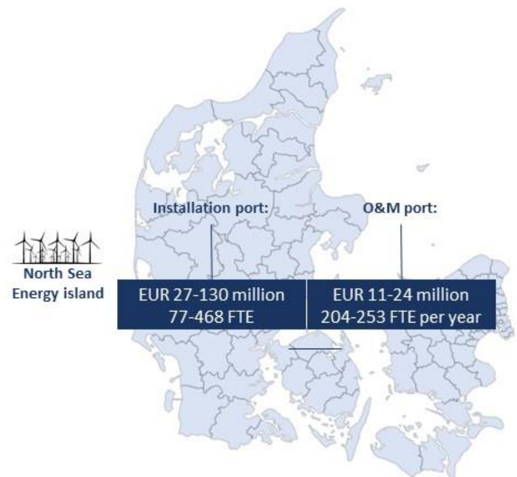


Figure 18: North Sea – 3 GW



Source: QBIS

5 The local impacts of offshore wind investments

5.1 Why "local" matters in offshore wind development

As discussed in Chapter 3, the global offshore wind energy sector has undergone a significant transformation process over the past decade. Today, the value chain for offshore wind is more "global" than "local" with manufacturing of turbines, foundations and main components produced all over the world and shipped to their final destinations.

As global energy buyers are pushing for lower prices, there is added pressure on energy companies and OWT manufacturers to reduce costs, which spills over to the sup-ply chain. At the same time, there is also a growing "counter-push" from energy buyers and host governments to link the continued expansion of green energy with (more) local jobs. This means that the demand for local content during the planning, manufacturing, installation, and operation of offshore wind farms is growing louder in many offshore wind markets.

> *"I have been around the tender process for a long time and there has been a shift as clients are now really pushing for local content. I do think we can do better as an industry, but it must be sustainable. The US for instance wants local content like anybody else, but for them it is not just at a national level but at a state level. This means that each state wants their own factories and their own supply chain set-up. That isn't sustainable because that just drives the cost model up which is not where we want to be."*
>
> Interview with Siemens Gamesa Renewable Energy (SGRE) [R2]

As an example, in the U.K., the world's largest offshore wind market, local content is an issue of high political concern. The country's new Sector Deal from 2019 sets out a non-binding proposal to gradually build up the proportion of local content going into U.K. offshore wind farms from a target of 50 percent today to 60 percent by 2030 (GTM, 2019). In other offshore wind markets such as Taiwan, local content has turned into hard law with offshore wind developers being required to use Taiwanese registered vessels for installation and service of offshore wind farms [R2]. Across the board, when tendering for new contracts, offshore wind companies increasingly must balance between buyer and policy demands for low costs vs. high local content.

5.2 Installation and O&M as a key source of local value creation

One of the main opportunities for linking the expansion of offshore wind energy with the creation of local jobs and value-added for host nations is during the installation and O&M of an offshore wind farm. For countries which unlike Denmark, cf. Box 3, do not have local manufacturing capacity in offshore wind, the installation and O&M phase, by default, becomes *the* main driver of local economic benefits.

Box 3: Denmark can provide the full value chain for an offshore wind project

The first country to install a commercial offshore wind farm over 30 years ago, Denmark remains a leading global hub for offshore wind energy, with the wind energy sector in Denmark (on- and offshore) estimated to directly employ close to 33,000 people, equivalent to 2% of the private sector employment. Of these jobs around. 80% are placed in the western, and predominantly, rural parts of the country [3]. Since the beginning of the wind energy sector on land and the subsequent emergence of offshore wind farms, Denmark has built a unique global position in on- and offshore wind, which includes a highly skilled workforce across all stages of the lifecycle, local production capabilities within on- and offshore turbines and major components, specialized maritime and logistics services, leading facilities for testing prototypes, research institutions, ports specialized in offshore wind and, not least, a comprehensive network of local suppliers. When it comes to local sourcing opportunities, the Global Head of Ports and Harbour Services from Siemens Gamesa Renewable Energy (SGRE) explains: *"The supply chain in Denmark is by far the biggest and most comprehensive supply chain to the industry across the globe, and I'm not just talking about ports but absolutely everything. Denmark is the key sourcing hub for offshore wind farms." [R2]*

Source: QBIS.

The production stage is the most labour -intensive in an offshore wind project and therefore often the main focus for local content discussions. The installation and O&M stages of an offshore windfarm combined represents more than one third of the total (direct) manhours required, cf. section 4.4.2. Further, installation and O&M also comes with several "localized" opportunities for domestic ports and the hinterland of local suppliers, incl. dock workers, seafarers, transport and logistics workers, technicians, and engineers cf. Table 16. Since many of these opportunities often accrue in coastal communities outside of a country's conventional economic centers, these jobs are often of interest to host nations and governments.

Table 16: Overview of labour required for a 500 MW offshore wind farm by stage

	Planning	**Production**	**Transport**	**Installation**	**O&M**	**Decomissioning**
% of total labour	6%	58%	0.1%	8%	20%	8%
Primary professions	Ship crew (33%), Legal, energy, real estate and tax experts (20%), engineers (10%)	Factory workers (54%)	Truck drivers (51%), Ship crew (26%)	Ship crew (87%)	Ship crew (17%), technicians (17%), engineers (15%)	Ship crew (23%), truck drivers (23%), technicians (25%), engineers (15%)
Opportunities for local suppliers	May call for international experts (e.g. seabed surveys etc.). Also, opportunities for local jobs, both within and outside ports.	Often global supply chain set-up. Some countries (e.g. DK) have strong local supply chains and can capture higher local shares.	Good opportunities for local suppliers, especially in road transport and logistics.	Good opportunities for local suppliers in and around the installation ports. Several synergies with local oil and gas supply chains.	Good opportunities for local suppliers in and around O&M ports. Several synergies with local oil and gas supply chains.	Good opportunities for local suppliers in and around Decommissioning ports, incl. local recycling sectors.

Source: IRENA (2013).

The following chapter focuses mainly on local impacts during the installation and O&M phase. As illustrated in Table 16 there are however also opportunities for local impacts during the planning and decommissioning stages of an offshore wind farm. Decommissioning offers a particularly promising growth prospect for offshore ports, cf. Box 4.

Box 4: Decommissioning – a future source of local value creation for offshore wind ports

At the end of an offshore wind farm's life there are three options: 1) extend the life of existing assets 2) repowering the site with new and larger turbines or 3) fully decommission the site [3]. Between 2020 and 2030, decisions between lifetime extension, repowering or decommissioning will be needed for over 1,800 offshore wind turbines in Europe. From 2030 to 2040, almost 20,000 offshore wind turbines will be facing end-of-life scenarios in Europe (Journal of Physics, 2019). This offers a new potential source of income for port municipalities with specialist decommissioning facilities and potentially also for local recycling industries (IRENA, 2019). So far, there is little empirical evidence on the decommissioning of offshore wind farms. In Denmark, the world's first offshore wind farm from 1991, Vindeby, was recently decommissioned by Orsted, giving a small taste of what lies ahead for the offshore supply chain. In its tender, Orsted invited engineers, advisors and contractors to come up with ideas for how offshore wind farms could be dismantled in a both cost-efficient and environmentally sound way. The experiences were later used in a research project, Odin-Wind, looking to develop a recipe for "smart decommissioning" of offshore wind farms. Based on what the industry knows so far, it is likely that decommissioning will resemble a similar cost structure as the installation phase, incl. installation vessels, service vessels, transport and logistics companies, geotechnical surveys and more. According to BVG Associates (2019), the decommissioning of 1 GW will cost around EUR 392 million, while DNV[38] estimated the corresponding decommissioning costs to between EUR 201-502 million. As the global market for decommissioning is set to grow over the coming years, there will be new opportunities for both domestic and international offshore ports and suppliers, which specialize in reuse and recycling of large steel structures and components, incl. offshore platforms, vessels and wind farms. As an example of this specialization, in 2019, US-based recycling company, M.A.R.S., decided to establish its first European recycling facility for decommissioned ships, oil rigs and, eventually, offshore wind farms in the port of Frederikshavn.

Source: QBIS.

5.3 Offshore wind ports as gateways to local economic development

Offshore wind ports play a crucial role in ensuring the cost effectiveness of an offshore wind project across the main stages of the project, from planning, production and pre-assembly, installation, O&M and decommissioning. The main types of ports involved in the offshore wind sector are listed in Table 17.

As the offshore wind industry is growing rapidly both in volume of projects and technology dimensions, ports involved in the offshore wind sector continuously need to adapt their infrastructure to service larger components, bigger vessels and increased number of activities.[39] This is especially the case for ports that want to cater to the installation of offshore wind farms, which will need to have sufficient quay, depth, load bearing capacity, land clearance for warehousing, specialized local suppliers as well as the proper supporting infrastructure in the hinterland such as access roads, hospitals, helicopter access as well as accommodation, local transport services and more.

[38] No study found, only reference: https://ing.dk/artikel/aldrende-havmoelleparker-aabner-marked-klog-nedrivning-182308
[39] Ramboll (2013).

Table 17: The main role and functions of offshore wind ports

Port type	Description
Installation and pre-assembly ports	Preassembly and/or installation of main components which are received either by road transport or, increasingly, by sea from other ports (via feeder- or base ports). Often classified as large-component ports with significant space for storage and assembly of components.
Operation and maintenance (O&M) ports	Act as local base ports for the ongoing maintenance and repair of an offshore wind farm once commissioned. Requires less space and specialized capabilities than installation or production ports.
Production ports	Due to the increased size and weight of wind turbine components, some turbine and foundation manufacturers has started to establish manufacturing facilities within suitable ports, following the example of offshore cable manufacturers where port production is well-established.
Import/export ports	Transactional ports involved in loading, unloading and storage of main components to/from the primary offshore wind manufacturing facilities.
Specialized ports	Ports which have specialized in e.g. decommissioning, re-powering, energy storage or in research and testing of offshore wind farm components.

Source: QBIS based on interviews with key Danish ports and profile of offshore wind ports by Danske Havne, cf. www.danskehavne.dk/tema-vind/

The result has been a growing orientation towards a handful of 'fixed ports' with the sufficient space, capabilities, infrastructure and hinterland support in place to allow developers to conduct their full suite of activities within, or in close proximity to, the port.[40]

> *"There are not a lot of ports that can successfully attract installation projects beyond one-offs. Why would you want to invest a lot of money and give up your daily business for a project that lasts 9 months? An installation project requires an enormous amount of space and a strong local supply chain and infrastructure."*
>
> Interview with Ziton [R6]

Box 5: What ingredients goes into choosing the right port for Siemens Gamesa Renewable Energy?

Siemens Gamesa Renewable Energy (SGRE) is closely involved in choosing which ports to use for the installation and O&M of its offshore wind farms. Depending on how the offshore wind contract is constructed, the decision is made by either Siemens Gamesa (the OWT manufacturer) or its clients (the energy companies) but always in close deliberation between the two. In the past, the choice of installation port would typically fall on the port closest to where the cables come into land – i.e. the closest domestic port. Today, this is no longer case as many offshore wind farms are moving further from shore putting them in steaming distance from bigger ports with the proper infrastructure. When deciding which port/s to use, SGRE considers three main criteria: 1) How far away is the port from the physical wind farm location, 2) What is the availability of the port, and 3) Does the port need additional investments/upgrades? Secondary and tertiary features pertain to "softer" factors e.g. the availability and quality of the hinterland such as local services and supplies. In the future, Siemens Gamesa is expecting a higher orientation towards larger, fixed ports when it comes to installation contracts as smaller ports are unlikely to be able to handle the next generation of wind turbines without significant investments. In the O&M phase, smaller domestic ports close to offshore wind farms still have an important role to play in the offshore wind sector and SGRE is continuously exploring ways to bring more local ports into the mix.

Source: Interview with Siemens Gamesa Renewable Energy (SGRE).

[40] Copenhagen Economics (2011).

The increased specialization of the offshore wind sector combined with the growing distance of wind-farms away from the shore, also means that an installation port's physical location may be superseded by its ability to provide the adequate infrastructure required to meet the industry's future demands. In effect, this means that domestic ports located closest to the offshore windfarms are no longer considered the default choice by developers when it comes to larger installation contracts, cf. Box 5. Reversely, for O&M ports, distance to shore remains the key parameter due to the frequent shipping to and from the windfarms, which may favor smaller, domestic ports.

Beyond their role as critical nodes in the offshore wind sector, offshore wind ports are however also important sources of local job and value creation in coastal communities, which are often placed far away from a country's main economic centers of activity, cf. Box 6.[41]

Box 6: Local impacts from Orsted's investments in the Humber region

In a 2015 study, Orsted looked closer at the local impacts from offshore wind farms serviced by ports in the Humber region. Like many coastal communities, the port city of Hull located in the Humber region had faced significant challenges over recent decades and the overall economic picture had been one of economic decline, the loss of manufacturing jobs, high unemployment, weak skills levels, and low population growth. Between 2013 and 2019 the study estimated that of the GBP 6 billion invested in new offshore wind farms, approximately GBP 1 billion would be captured by businesses and employees in the Humber area. The study further suggested that assuming Orsted's future windfarms continue to use Humber ports, an estimated 1,600 jobs would be created within the wider Humber region per year from 2015-2020 while up to 500 long-term local jobs could be created from O&M activities from 2020 and onwards. Beyond the creation of direct, indirect and induced local jobs from the steady inflow of new installation contracts to Humber ports, the study also found that Orsted's investments have helped secure new inward investment opportunities to the region, incl. a GBP 310 million turbine factory in the city of hull by Siemens; boosted opportunities for local suppliers; increased local skill development and improved the confidence of the private sector. It should be noted that the local impacts from Orsted's investments in the Humber region have not been further assessed or compared to the findings of this study, which indicates more modest local jobs and value-add.

Source: Regeneris (2015).

As outlined in the offshore wind model in section 4.4.4, a 1 GW offshore wind farm will generate around EUR 5 million one-off to the installation port, while an O&M port is estimated to generate around 0.5 million EUR per year. In addition to the increased turnover generated by the local ports, the appointment of a local installation or O&M port also creates opportunities for local suppliers and workers within the port region itself. Here it is useful to distinguish between opportunities for suppliers in the primary offshore wind sector (mainly direct turnover/jobs), secondary sectors (mainly indirect turnover/jobs) and tertiary sectors (mainly induced turnover/jobs), cf. Table 18.

[41] Wind Europe (2018) and Ramboll (2015).

Table 18: Types of jobs that can accrue to local suppliers

Type	Classification	Examples (Installation and O&M phase)
Primary offshore wind suppliers	Suppliers for the core activities involved in installation and O&M of an offshore wind farm. Often highly specialized businesses with a substantial part of their turnover generated from offshore wind.	Installation vessel suppliers, CTV or SOV suppliers, local turbine inspection suppliers, specialized O&M suppliers etc.
Secondary sector suppliers	Suppliers in other sectors than offshore wind whose services may be required by the offshore wind developers and/or their primary offshore suppliers.	Local shipyards, equipment companies, steel manufacturers, electricians, cleaning and inspection services, fuel suppliers, etc.
Tertiary sector suppliers	Suppliers with no direct or indirect involvement in the core activities of an offshore wind farm. These suppliers may cater to the staff of offshore wind developers and their primary and secondary suppliers.	Local catering companies servicing installation and O&M vessels or operations, taxi companies, hotels, restaurants, shops, cinemas, bakeries, etc.

Source: QBIS.

It is important to note that not all installation or O&M ports will be able to generate the same share of local turnover/jobs from a specific offshore wind investment, especially within the primary and secondary sectors. As an example, only highly specialized ports like Esbjerg with a strong local offshore wind or energy supply base will be able to generate local turnover and jobs within the primary offshore wind sector category. Reversely, for installation or O&M ports with limited primary sector involvement in the offshore wind sector, the main source of local value-add for local suppliers is likely to accrue within the tertiary and secondary sectors.

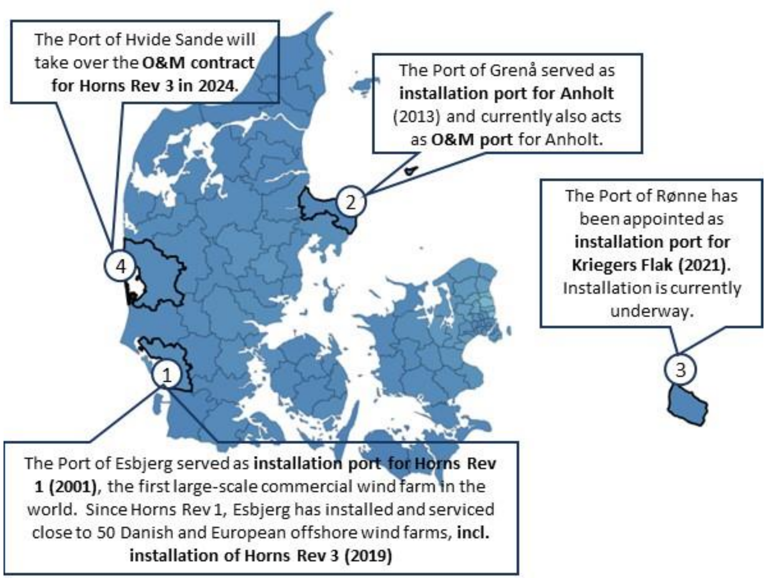
Tertiary sector impacts will accrue in any installation or O&M project but may vary depending on how much of the work takes place within the port jurisdictions. As an example, the longer an installation or O&M organization stays within a given port, the more activity with local companies in tertiary sectors. The value that accrues within a port municipality's secondary sectors is more uncertain and depends largely on the availability, competitiveness and proactiveness of local subcontractors. The experiences captured by suppliers in the secondary sector is nonetheless critical to understand some of the spin-off effects that can contribute to transforming local port economies over time. To better understand these dynamics, the following sections present case studies of four Danish installation and O&M ports.

5.4 Introduction to Danish offshore wind ports and municipalities

As a small open economy with a strong maritime sector, Denmark's ports play a critical role in facilitating economic development at both the local, regional and national level. Denmark's ports facilitate its position as EU's largest fishing nation, welcome close to one million cruise boat tourists per year and act as critical transit points for around 80% of all imports and exports.[42]

Like many other countries, Denmark's ports are undergoing significant transformations, adapting to larger vessels, changing weather, declining income from traditional port operations and increased potential in others. These changes have contributed to a wave of investments in Danish ports over the past decade, incl. in new quay areas, increased water depth and expansion of facilities in the hinterland. These investments have doubled the total assets under manage by Danish ports with 50% from 2009-2017 but have also led to increased pressure on Danish ports to generate additional port turnover.[43]

Figure 19: Overview of the four Danishinstallation- and O&M ports included in the case study



Source: QBIS

The ability of Denmark's ports to attract and sustain high turnover rates that justify their investments matter not only to the people that are directly employed by the ports[44] but also to the wider port economies. A 2017 study suggests that a middle-sized port (Port of Koege) and a large port (Port of Aalborg) play an import role in their local economies, contributing to around 7.6% and 5.7% of total employment within their municipalities, respectively. Adding indirect and induced jobs to these numbers, the share grows to 10.6% (Koege) and 11.5% (Aalborg).[45] Appendix A presents an overview of Danish ports involved in offshore wind – either presently or prospectively.

In the following section, a theory of change for local ports involved in offshore wind is presented as well as a closer look at the experiences from the installation and O&M of Danish offshore wind farms in four of Denmark's offshore wind ports, incl. Esbjerg, Grenaa, Ronne and Hvide Sande, cf. Figure 19.

[42] Danske Havne (2018).
[43] Ibid.
[44] Danske Havne reports that around 1,200 people are employed by Danish ports. See: www.danskehavne.dk
[45] Ibid.

Box 7: Collecting local experiences from offshore wind – how we did it

The insights featured in the following are based on a mix of field visits, interviews and video footage with Danish ports and local suppliers to better understand the potential value and jobs at stake for local port municipalities when a new offshore wind farm "comes to town". The case studies build on available information and consultations with 20+ people involved in installation and O&M of offshore wind in the port communities of Esbjerg, Grenaa, Ronne and Hvide Sande.

5.5 THEORY OF CHANGE

With the total lifecycle cost model for an offshore wind farm presented in Chapter 4, it is possible to estimate the economic value-add for local ports and suppliers involved in the installation and O&M stages of an offshore wind farm. The model is however not able to capture how such investments may evolve over time as local ports and suppliers build up new capabilities, investments, and know-how, which is converted into new opportunities.

Based on the experiences from the four Danish installation and O&M ports included in this study, a theory of change of the dynamic local outcomes and impacts that can accrue from a single offshore wind investment over time has been developed, cf. Table 19. Appendix B presents a more detailed characterization of local outputs, outcomes and impacts from offshore wind installation and O&M.

It is important to note that the theory of change describes the potential pathway towards a sustained economic benefit from offshore wind within a given port municipality. Notably the pathway demonstrates how some of the immediate outputs from a specific offshore wind project – e.g. number of jobs generated from installation of an offshore wind farm – may translate into longer-term outcomes and impacts which can change the fabric of the local port economy.

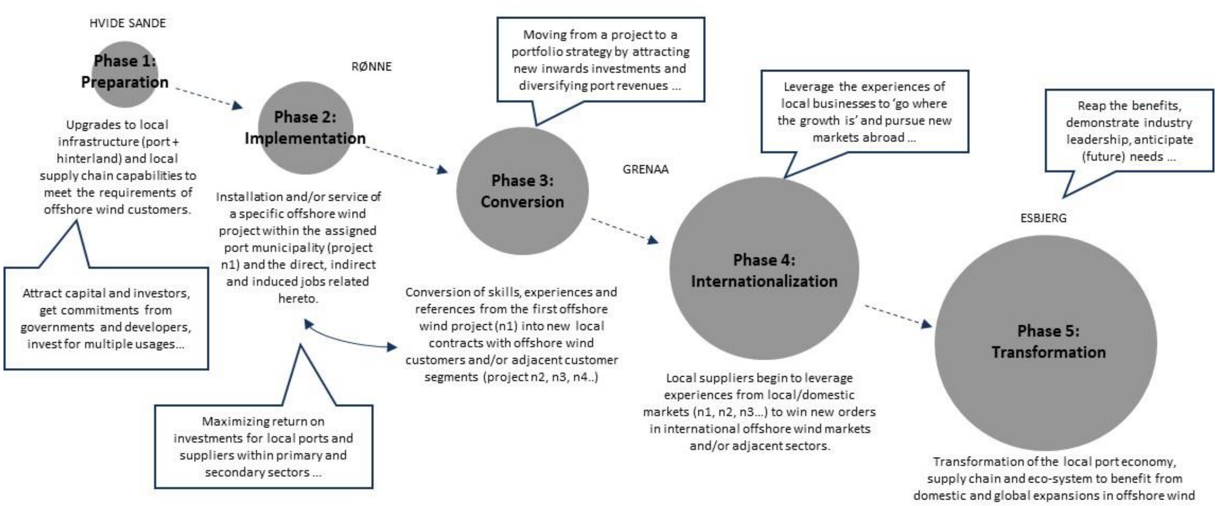
Whether the longer-term outcomes and impacts will manifest themselves from a specific offshore wind project, depend on a variety of factors, including the ability of local ports and suppliers to harvest the experiences and capabilities accumulated from their preliminary projects into a sustained future revenue stream. The positive outcomes and impacts that occur within one offshore port municipality are in other words not guaranteed to occur in another. To illustrate this, a dynamic model for local port economies involved in offshore wind is presented in Figure 20.

Table 19: Potential benefits from offshore wind investments within local port installation and O&M port municipalities

Phase	Activities	Outputs	Outcomes	Impacts
Installation phase (short duration)	1. Appointment of installation port 2. Preparation in port and hinterland 3. Setting up base for installation in port 4. Installation start 5. Installation complete	Improved port infrastructure and supporting facilities Increase in port revenue from offshore wind Increased output in primary and/or secondary sectors Increased output in tertiary sectors Hiring of local crew (O&M only) Increased local consumption (induced)	Diversification of the local port economy Improved capabilities of local suppliers Increased access to new markets abroad Greening local ports and businesses Interregional synergies and capacity building	Enhanced local activity, jobs and economic resilience
Operation & Maintenance (long duration)	6. Appointment of O&M port 7. Setting up local O&M organization 8. Operations and maintenance – ongoing (~25 years)			

Source: QBIS.

Figure 20: Potential benefits from offshore wind investments within local port installation and O&M port municipalities



Source: QBIS.

Based on the experiences from Hvide Sande, Ronne, Grenaa and Esbjerg, the “snowball model” shows how local port economies involved in offshore wind move through different stages: the bigger the snowball is, the higher degree of local value and the deeper the potential transformation of the port economy. That said, each stage presents its own unique set of challenges and opportunities. Moving the snowball from one stage to the next requires a proactive and continuous effort from the local port communities.

5.5.1 The preparation stage

The preparation stage is characterized by substantial investments and preparations by local ports who want to attract (future) offshore wind customers and contracts. This is especially the case for ports with ambitions to become part of the global installation phase, which unlike O&M require extensive handling and storage of heavy components. At the same time, during this stage significant preparations may also be required in the hinterland, incl. upgrades of local infrastructure (roads, helipads etc.) as well as with local suppliers who may have limited existing exposure to the offshore wind segment. It is worth noting, that there can be substantial risks for local ports at this stage as ports have no guarantees that their investments will pay off, and competition from both domestic and international ports for installation and O&M contracts is substantial.

5.5.2 The implementation stage

The progression from preparation to implementation begins when a port has been successful in attracting an offshore wind contract. The local value generated for the port itself during installation and O&M is relatively fixed at respectively EUR 5 million EUR (installation contract, one-off) and EUR 0.5 million (O&M contract/annual) as discussed above. In addition, the port may generate a limited amount of additional turnover during the planning phases e.g. from environmental and geological surveys. What is not fixed, is the value that can accrue to local suppliers in the hinterland during the installation and O&M of an offshore wind project. The “share of the pie” awarded to local suppliers during this stage is largely contingent on three factors: 1) The market share of existing suppliers for tasks required within primary, secondary and (to a lesser extent) tertiary sectors, 2) The availability and proactiveness of local suppliers in catering to the offshore wind project (e.g. one-stop-shop service platforms, proactive marketing efforts) and 3) The procurement policies and practices of the offshore wind developer, notably the emphasis placed on using local suppliers. Importantly, the higher degree of involvement of local suppliers during the implementation stage, the bigger the potential outcomes and impacts over time. This especially applies to suppliers in the primary and secondary sectors who are better able translate investments and experiences from a single offshore wind investment into new revenue streams and market opportunities over time.

5.5.3 The conversion stage

The progression from the implementation to the conversion stage happens when the port manages to translate a single offshore wind project to a portfolio of new inwards investments. These investments can either be in offshore wind or in adjacent sectors which require some of the same facilities and capabilities. What matters is that these new investments would not have been possible without the investments and experiences gained from the initial offshore wind investment. The arrow between stage 3 and 2 in Figure 20 illustrates the reinforcing effect that occurs when a single offshore wind project leads to the implementation of a new project which leads to yet another new project and so forth. Given the high upfront investment costs involved in servicing offshore wind projects, the conversion phase from a single project to a portfolio of projects is critical for local ports to benefit from offshore wind investments over time. The conversion stage is not without its challenges, however, and may require ports to look to other complementary business segments than offshore wind to justify the high upfront costs involved.

5.5.4 The internationalization stage

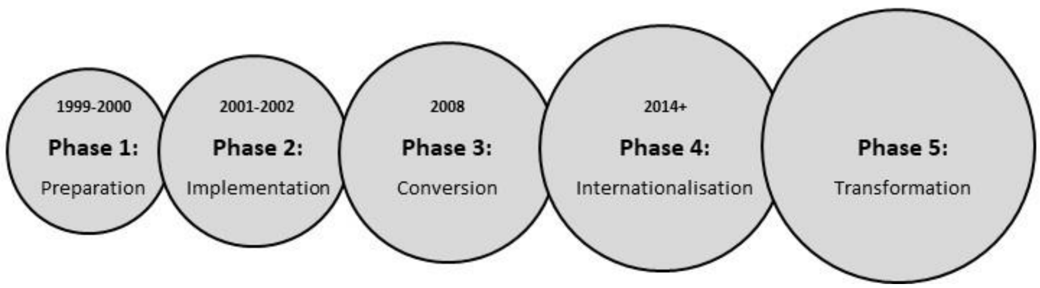
This stage happens when the local supply chain within both the primary offshore wind sector and secondary sectors become less dependent on new offshore wind investments within the port and increasingly start to pursue growth in the global offshore wind market. In the case of Esbjerg and Grenaa – the two most mature cases featured below – the internationalization stage has ridden on the back of the preliminary experiences and references gained with the first Danish offshore wind farms. The transition from the domestic to the international offshore wind market is best exemplified by Esbjerg, where local suppliers have successfully integrated into the global offshore wind supply chain over the past decade, successfully leveraging their assets, competences and global set-up from the oil and gas sector. There are also challenges to the internationalization stage: competition in the global offshore wind sector is growing and there is a downwards pressure on costs across all aspects of the installation and O&M supply chain. Further, the pressure for local content is increasing in some foreign markets, creating potential disadvantages for suppliers from other countries. Finally, not all suppliers are able to pursue growth in the global offshore wind sector. This especially applies to local suppliers with limited or no existing global set-up who depend entirely on activities within and around the port.

5.5.5 The transformation stage

The final stage is the transformation stage. In this stage, the port will have successfully converted its upfront investments into a long and continuous string of inward investments, while the local supply chain will have successfully integrated into the global offshore wind supply chain. As a result, a substantial portion of the port economy is now contingent on the continuous expansion of offshore wind, both within the port but also in international markets. Further, the port will have a strong standing with the global offshore wind sector due to a high degree of on-site expertise and a favorable eco-system within and around the local port which contributes to upholding its position as a leading local/regional offshore wind hub. For local ports who manage to enter this stage the potential impacts include a more diversified local port economy with a growing global customer segment, making both the port and businesses less resilient to external shocks in more mature sectors. As an example, in the Esbjerg case, local suppliers to the oil and gas sector reported having lost 30% of their revenues during the oil crisis in 2014, leading many companies at the time to look to other sectors (incl. offshore wind) for future growth. The challenge during this stage is thus mainly about ensuring a continued role for the port and the local supply chain in the global offshore wind sector as the sector continues to drive down costs and move to new and more distant markets.

5.6 THE CASE OF ESBJERG

Figure 21: The offshore wind evolution of Esbjerg



Source: QBIS.

Esbjerg is a municipality in the Region of Southern Denmark on the west coast of Jutland with a population of around 115,500 people. Contrary to many other port municipalities along the coast of Denmark where unemployment rates are often higher than the national average, Esbjerg is characterized by relatively high disposable income rates and low unemployment rates, cf. Appendix C.

Table 20: Profile of Port of Esbjerg

Main function	Installation- and O&M port
Total revenue (2018)	~DKK 230 million
Revenue from offshore wind	~25%
Size	4,500,000 m2 (1,000,000 m2 for offshore wind)
Quay length	14 km
Water depth	10.5 m
Offshore wind projects served to date	54 offshore wind farms in the North Sea (20.7 GW)

Source: Port of Esbjerg.

Esbjerg's favorable socio-economic status compared to the national average and other peripheral municipalities is not least due to its strong integration within the domestic and international energy sector. According to the local business association, Business Esbjerg, around one third of all jobs in the private sector in Esbjerg are "energy-related" and fall within either Oil & Gas, Wind Energy or Energy systems [R18].

As jobs within the energy sector generally tend to be higher paid, such jobs are also likely to yield higher than average income levels within municipalities with a relatively higher share of these jobs.[46] The municipality of Esbjerg is home to the Port of Esbjerg, one of Europe's leading hubs for offshore wind and a vital economic lifeline for the entire municipality, cf. Table 20. In addition to having one of the most advanced local supply chains for offshore wind, Esbjerg also has a substantial service and hospitality sector (restaurants, hotels etc.), which indirectly benefit from, and offers support to, the municipality's activities in the offshore wind sector.

The current impacts from offshore wind in Esbjerg cannot be attributed to the installation and/or service of a single offshore wind project alone. Rather, it is the result of continuous investments and efforts made by the Port of Esbjerg and the local ecosystem of offshore wind suppliers over the past two

[46] Wind Denmark (2019).

decades. Some of the most important features of this transition is discussed in the following section based on interviews with the Port of Esbjerg and selected local businesses, who have been involved in the offshore wind sector out of Esbjerg since it began in the early 2000s.

5.6.1 Transforming the Port of Esbjerg to a global hub for offshore wind

Today, a substantial part (~25%) of the Port of Esbjerg's income derives from offshore wind. However, this has not always been the case. Historically an import-export and fishing port, the Port of Esbjerg underwent its first fundamental transformation during the 1970s with the emergence of the Danish Oil & Gas sector in the North Sea. Over the past three decades, the Port of Esbjerg has played an instrumental role in servicing the Danish offshore oil and gas sector. While the oil and gas sector remains an important source of income for the port today, the share of the segment has decreased significantly over the past years and represents just 10% of port revenues today [R13].

Port of Esbjerg's first encounter with the offshore wind sector came with the first large-scale Danish offshore wind farm, Horns Rev 1, in 2001, which was since followed by Horns Rev 2 and 3, all of which were installed out of Port of Esbjerg, which also serves as the current O&M port for all three farms, cf. Table 21.

Table 21: Overview of Danish offshore wind farms installed from Port of Esbjerg

	Horns Rev 1	**Horns Rev 2**	**Horns Rev 3**
Year of operation	2002	2008	2019
Operator	Vattenfall	Orsted	Vattenfall
Total capacity (MW)	160 MW	209 MW	406.7 MW
Number of turbines (#)	80	91	49
Type of turbine	Vestas V80-2.0 MW	Siemens SWT 2.3-93	MHI Vestas V164-8
Turbine capacity (MW)	2 MW	2.3 MW	8.3 MW
Total height (m)	70 m	114 m	187.1 m
Length of wings (m)	-	45 m	80 m
Rotor diameter (m)	80 m	93 m	164 m
Weight, wing (tons)	-	12 t	33 t
Weight, tower (tons)	220 t	92 t	350 t
Weight, nacelle (tons)	61 t	80 t	381 t
Total weight (tons)	-	400 t	1184-1470 t
Distance to shore (km)	14-20 km	30 km	20 km
Main installation port	Port of Esbjerg	Port of Esbjerg	Port of Esbjerg
Main O&M port	Port of Esbjerg	Port of Esbjerg	Port of Esbjerg (2019), Port of Hvide Sande (2024+)

Source: Vattenfall and Orsted.

Encouraged by the first Danish offshore wind commitments and the promise of more to come, the Port of Esbjerg initiated a year-long port expansion project during the installation of Horns Rev 1 in 2001 – a transformation process which took several years and cost around DKK 1.8 billion. These investments along with the experiences gained from some of the world's first offshore wind farms became instrumental in launching the second fundamental transformation of Port of Esbjerg towards a leading installation- and service hub for offshore windfarms in Europe.

> *"The Port of Esbjerg is a highly specialized port. We can do three things and in one of them – offshore wind – we are second-to-none in the entire world."*
> Interview with Port of Esbjerg [R13]

Today, the port boasts 1 million m2 of preassembly and storage space dedicated to offshore wind, making it among the leading offshore ports in the world. Between 2001-2018, Port of Esbjerg has successfully converted its investments and experiences from the first Danish offshore wind farms into capturing more than 55% of accumulated offshore wind capacity in Europe. Including the 2019 pipeline, this covers a total of 54 offshore wind projects within the North Sea region, equivalent to 20.7 GW and 3,993 offshore turbines [R13].

5.6.2 Emergence of a strong local supply chain specialized in offshore energy

The transformation that has taken place within the Port of Esbjerg over the past two decades from a strategy centered largely around oil and gas to a strategy centered increasingly around offshore wind has to a large extent been mirrored by a similar transformation in the local business environment. Today, Esbjerg is second-to-none in offshore wind not only when it comes to port operations, but also in its ability to provide the full suite of services required for offshore wind projects. Since Horns Rev 1 arrived in Esbjerg in the early 2000s, several new industries and specialized local businesses have emerged as spin-offs, both within the municipality as well as beyond. As Horns Rev 1 was the first commercial offshore wind farm of its kind at the time, a lot of the technology and solutions available today were not available at the time, giving way for a substantial amount of co-development and experimentation.

> *"Esbjerg has seen a number of new industries emerging as the value chain for offshore wind has grown and become more specialized. As an example, demobilization and mobilization of jack-up vessels has become a big business in Esbjerg and companies such as Nicon Industries and Esbjerg Shipyard can easily have a hundred people employed locally on offshore wind projects for several months."*
> Interview with Port of Esbjerg [R13]

Box 8: Ocean Team Group – Patented cleaning systems help offshore wind operators reduce the cost (and need) turbine oil changes and maintenance

Ocean Team Group is a highly specialized provider of systems to clean and change oil in the nacelles used for offshore and onshore wind farms. It was the company's experience from the maintenance of hydraulic oil systems for the Danish Oil & Gas sector that landed OTG its first contracts within the wind sector, starting with onshore windfarms in the late 90s and continuing with offshore wind farms in Denmark and abroad in the decades that followed. "We have significant experiences within the oil and gas sector that we have been able to transfer directly to offshore wind. Requirements in terms of cleanliness on the ocean are the same and here we are a step ahead of everybody else." Through its dedicated wind division, Ocean Team Windcare, OTG developed a 'Filled for Life' concept with a series of patented solutions to help wind farm operators reduce the need for hydraulic oil changes from every 5 years to every 7 or even 10th years. As the costs of frequent O&M operations such as oil changes or maintenance work are significant for offshore wind farms, OTG's concept was widely adopted by wind operators all over the world and today OTG is the only company in the world that can deliver according to customer specifications on e.g. safety and security. The success has however not been without its downsides: As wind operators are now changing oil less frequently, OTG has seen its revenues from offshore wind drop significantly in the past years. Rather than waiting for the next big round of oil change projects to happen, OTG is exploring new concepts for offshore wind where the company will no longer perform the more labour intensive oil changes and maintenance work but lease its technology and know-how to the wind operators themselves. *"We don't want to participate in the Sinus-curve anymore. Our future business is not in providing manpower but in leasing our technology and know-how to the operators themselves. We will no longer be an O&M company that competes on labour and costs but a technology company who has the patents and the expertise."*

Source: Interview with Ocean Team Group, www.oceanteam.eu [R15]

A 2017 survey conducted by Business Esbjerg found that there are around 250 companies involved in the offshore wind sector in Esbjerg today [R18]. Like the Port of Esbjerg, several Esbjerg-based companies were born out of the oil and gas sector but have gradually managed to transition part of their turnover to offshore wind over the past decade.

> *"The momentum around offshore wind started with Horns Rev 1 but was strengthened after the oil crisis in 2014 where the price of oil dropped from 100 to 30 dollars and completely tanked the local market. It was the same story for all the local companies we spoke to at that time who from one day to the next were asked to dump their prices with 30%. It was at this time that even more companies started to seriously consider offshore wind and rethink their strategies".*
>
> Interview with Business Esbjerg [R18].

Of the 250 local companies involved in offshore wind today, over 50% have activities in both offshore wind and oil and gas according to Business Esbjerg's survey. This confirms accounts from other studies which suggest that there are strong synergies for local oil and gas companies by venturing into offshore wind and good opportunities for transferring capital, skills and assets between the two.[47] Some of the Esbjerg-based businesses interviewed further suggest that venturing into offshore wind from (just) oil and gas has benefited their businesses by providing a "greener image", making it easier to attract both investors and employees.

[47] BVG Associates (2016) and Regeneris (2015).

"It's also about having a good story to tell. We can make money in Oil & Gas over the next ten years, but our growth will come from renewables. There is just not a lot of people who want to work in Oil & Gas anymore. It is definitely our green profile and the fact that we are involved in cool, green projects that allows us to attract new employees."
Interview with SEMCO Maritime [R17]

Box 9: SEMCO Maritime – Leveraging Oil & Gas competences and relationships to conquer the global offshore wind market for transformer stations

Based in Esbjerg, Semco is a global leader in production, installation and service of offshore substations and transition pieces. In the early beginnings, Semco started off as a supplier of platforms to the Danish oil and gas sector, but today offshore wind has grown to a sizable 31% of Semco's annual revenue which totalled 2.041 billion DKK in 2018. Semco ventured into offshore wind on the tailwinds of the first Danish offshore wind farms in the early 2000s and have continued to grow its offshore wind business ever since. According to Semco, it was the company's unique competences and relationships within the oil and gas sector that became the entry ticket to the first Danish projects. Experiences that since led into a string of international projects with Semco responsible for between 25% to one third of all global offshore wind substations currently in operation. While oil and gas will likely remain the company's 'bread and butter' for the next 10+ years, Semco has in recent years invested significantly in its offshore wind business, both for commercial reasons and as part of its commitment to green growth. One of the biggest investments that Semco has made in offshore wind has been to set up a specialized wind division to meet customer demands for a faster, better and cheaper end-to-end solution. As the offshore sector has matured, Semco has had to constantly find new ways to improve its productivity and do more with less: *"In 2014, we had the same number of employees as today – we just do twice as much. We have become more effective; we reuse from our last projects and we have digitalized our competency development. Now, due to digitization it takes us just 4 years to onboard new engineers and get them up to speed. In the past, it took 7 years."* In the future, Semco is continuously looking at ways to grow with its customers as they move to international markets. While Semco will continue to have its base in Esbjerg, the company also sees a growing need to build more regionalized supply chains: *"We have an enormous advantage from having a company like Orsted in Denmark. When they go into new markets, we have a chance to join them if we are good enough. But we can't keep producing and shipping from here, especially as the transformer stations are getting bigger. The industry is moving towards regional and local supply chains, and we have to move with it."*

Source: Interview with SEMCO Maritime, www.semco.com [R17]

5.6.3 Gearing up the local supply chain for international growth

Many of the offshore wind suppliers in Esbjerg first ventured into the sector as suppliers to the initial Danish offshore wind farms but have since progressed to become fully integrated in the global offshore supply chain, servicing offshore wind projects in Europe and beyond. In other words, several Esbjerg-based businesses have managed to grow with its offshore wind customers as they have expanded beyond Denmark's (and now beyond Europe's) boundaries, cf. Box 10.

"We have an enormous advantage from having a company like Orsted in Denmark. When they go into new markets, we have a chance to join them, if we are good enough."
Interview with Semco [R17]

Box 10: ESVAGT – The first Danish offshore wind farm became the stepping-stone to success abroad

ESVAGT was founded in Esbjerg in 1981 as a maritime service company for the Danish oil and gas sector in the North Sea. While oil and gas is still the biggest part of ESVAGT's business, offshore wind represents around 40% of the revenue today. Of a total fleet of 42 vessels, ESVAGT currently has 6 dedicated Service Operation Vessels (SOVs) on contract with energy companies and OWT producers in the North and Baltic Sea. ESVAGT's first encounter with offshore wind came when the Danish offshore wind farm, Horns Rev 1, first came to Esbjerg in the early 2000s. At this point, ESVAGT had built up substantial experience transferring technicians from vessels to oil platforms under challenging weather conditions and had a small vessel available in the North Sea for this purpose. This experience gave ESVAGT its first entry ticket to the installation of Horns Rev 1. To ESVAGT, offshore wind was a welcome chance to diversify the core business beyond the oil and gas segment and in the process, ESVAGT quickly found that it could leverage a lot of the same competences*: "When your business only stands on one leg, you are probably smart to be looking into something new. ESVAGT's core competency was the quality of our crew. They could navigate these waters and we had performed rescue operations in 12 to 14 meters – not a lot of companies in the world can do this. This is something we could take with us to offshore wind."* When the oil crisis hit in 2014, ESVAGT was already well ahead with its investments in offshore wind – and luckily so. Despite the initial work performed on Horns Rev 1, the Danish wind farms didn't end up generating much income for ESVAGT as the operators opted for a Crew Transfer Vessel model, cf. Box 10, due to the relatively close distance of the Danish wind farms to shore. Instead, ESVAGT was able to leverage its experiences from Horns Rev 1 to win a contract with another Danish company, MHI Vestas, who brought ESVAGT along on an offshore wind project in Belgium. This contract led ESVAGT to repurpose one of its existing oil and gas vessels which was subsequently used for O&M of MHI Vestas's turbines from 2010-2017. During this same time, ESVAGT won its first contract with Siemens Gamesa for two custom-made SOVs to service two German offshore wind parks. While ESVAGT's offshore wind market is largely abroad, having its home base in Esbjerg is still key to the company, who enjoys good conditions when docking its vessels, recruiting workers, collaborating with local suppliers and being close to key decision makers from their customers: *"There is no doubt that the whole environment around offshore wind in Esbjerg and the collective ambition to become number one on offshore wind also has impacted our strategic deliberations."*

Source: Interview with ESVAGT, www.esvagt.com [R19]

Interviews with offshore wind suppliers in Esbjerg also suggest that the increased globalization and professionalization of the offshore wind sector has led to an added pressure on the local offshore wind supply chain to deliver more value at lower costs. To some of the Esbjerg-based players who have historically served the oil & gas sector, this has required a change in mindset and approach. While the sector was historically characterized by higher returns and shorter payback horizons, the offshore wind sector was born with a pressure to reduce costs which, especially in recent years, has translated into a growing pressure on Esbjerg's offshore wind suppliers to "do more with less".

To a place like Esbjerg with a comprehensive offshore wind supply chain this can have both adverse and positive impacts on local businesses. On the negative side, the growing cost pressure can deter investments and lead to an unhealthy "race-to-the-bottom". As an example, MHO, an Esbjerg-based supplier of CTV vessels to offshore wind farms in the UK and Denmark, often faces rigorous cost requirements in the international tendering process, cf. Box 11. At the same time, long-term exposure to the requirements of offshore wind developers has also urged offshore wind suppliers such as Semco, Esvagt, Jutlandia and Ocean Team Group to constantly find look for new ways to improve productivity while identifying new and more profitable business concepts.

Box 11: MHO – Combining high-quality Crew Transfer Vessels with customer demands for low costs

MHO is an Esbjerg-based shipping company fully dedicated to offshore wind. With a total of three Crew Transfer Vessels (CTV) vessels and two more in the making, MHO is a seaborne taxi-company supporting wind farm operators and OWT producers in all aspects of their operations, including installation and in the future also O&M. The CTV sector is generally characterized by high supply and competition from many local players as well as some of the larger ships (Service Operation Vessels) which are used when windfarms are placed further from the shore, cf. Box 9. According to MHO there is significant pressure on CTV carriers to reduce costs. Further, contracts are often short-term, making it difficult for CTV carriers to make longer-term investments in quality design, safety, environmental innovation etc. In this context, MHO stands out as a carrier that can provide high-quality ship designs at a competitive rate for larger installation projects. This is largely owing to the CEO's background and insight in ship design which allows MHO to control vessel design and specifications down to the individual component*: "Our business secret is that we can build a 35 meter boat for the same price as the competitors can get for a 27 meter boat"* [R14]. While all MHO's vessels are built by yards in Asia and most of MHO's installation contracts take place outside of Denmark, MHO is an integrated part of the local offshore business community in Esbjerg. When ordering new vessels, MHO uses local suppliers in Esbjerg such as Granly Diesel for key components such as engines, generators, and hydraulics. During operations MHO is also a frequent customer of Esbjerg Shipyard and the Port of Esbjerg. In the future, MHO hopes to see more of its wind customers award attention to parameters such as quality, innovation, and environment during the tender process. This is especially the case in the O&M phase where rates are generally lower and where larger CTVs like MHOs are therefore not economically viable.

Source: Interview with MHO, www.mho-co.dk [R14]

Examples of steps taken by some of the offshore wind suppliers interviewed in Esbjerg to meet the cost requirements of the global offshore wind sector while maintaining profitability include:

- **Cross-synergies:** Leveraging assets and competences within complementary business areas such as oil and gas to service offshore wind customers. As an example, NorSea, cf. Box 12, has been able to leverage part of their oil and gas supply fleet to service offshore wind projects in the North Sea.
- **Digitization:** Using digital tools (e.g. track and trace solutions, workflow simulations etc.) to enhance productivity and onboard new employees. As an example, Semco, cf. Box 9, explains that they can now fully onboard a new engineer in 4 years, while in the past it took 7 years.
- **Service-based models:** Progressing from selling labour (hours) which are increasingly commoditized to selling technologies and know-how. As an example, Ocean Team Group, cf. Box 8, is exploring a new service-based model to O&M work on turbine oil changes.
- **Value-added services:** Finding new ways to add value for offshore wind customers beyond price reductions, e.g. offering drone inspection services during SOV operations, cf. Box 10, or upskilling local laborers to perform supervisory work onboard UK offshore wind vessels in Esbjerg, cf. Box 13.
- **Collaborative supply chains:** Meeting the industry's needs for fewer suppliers through consolidated one-stop sourcing platforms such as the recently formed Offshore Network Esbjerg (ONE), a local supplier network of 24 local suppliers to the offshore energy sector. These models can be used both in attracting international offshore wind projects *to* a local port but can also be important in winning tenders in global markets with offshore wind customers increasingly asking for one supplier.

Box 12: NorSea Denmark – Strong synergies between oil and gas and offshore wind

NorSea Denmark (previously Danbor) was originally a company formed in 1974 to service the oil and gas sector in Denmark. In 2014, the company was acquired by the Norwegian company, NorSea Group, a global supplier of full-service logistics solutions, owned by one of the world's largest maritime industrial groups, Wilhemsen. The NorSea Group covers several logistics and supply services within the global offshore energy segment, which consists of oil and gas, hydropower and offshore wind. Within the latter segment, NorSea Group's activities include O&M support for wind turbines and foundations (via NorSea Wind) and offshore wind logistics services which includes contract haulage and trucking, loading and unloading of installation vessels, customs clearance, delivery of supplies and components during installation and more (via NorSea Denmark). While still in a start-up phase, offshore wind has become an important part of NorSea Denmark's business. Despite a reduction in turnover from oil and gas, NorSea Denmark has managed to grow its total turnover, primarily due to increased activities within offshore wind as well as other logistics activities. In the mid 90's NorSea Denmark had 300+ employees working in offshore jobs in the oil and gas sector, today they have just 65 offshore and 260 in total in all segments. One of the main strengths of NorSea Denmark in entering the global offshore wind market has been its long-term experience and assets from the oil and gas sector, part of which they have been able to apply to the offshore wind segment: *"When it comes to the supply and logistics side, offshore wind and oil and gas are 98% the same thing. That's why we say we work in 'offshore energy'. When the price of our oil and gas vessels is down, it makes sense to try to use them for offshore wind projects."* Further, following the incorporation into the NorSea Group, NorSea Denmark has access to a global set-up which allows them to grow with its offshore wind customers in Denmark and Europe as they expand to foreign markets and are faced with local content requirements: *"We have spoken to several of our customers who are faced with local content requirements in markets like Taiwan and North America. Here we can help them because we actually have a local set-up in most of these places. In that way, we are essentially a local-global company, but when we make it into new projects in these markets, it also generates new jobs in Denmark. For instance, all of our freight forwarding staff are based in Esbjerg."*

Source: Interview with NorSea Denmark, www.norsea.dk [R16]

Box 13: Jutlandia Terminals – Finding ways to compete on factors beyond price

Jutlandia Terminals was established in the 1970s with the Oil & Gas sector's entrance in Esbjerg as a local stevedoring company. The company has 91.500m2 available for storage of wind components and supports the installation of offshore wind projects out of the Port of Esbjerg with services such as ware-houses, handling and storage of components and loading and unloading of installation vessels. Jutlandia's first entrance into offshore wind was in 2004-5 where it won its first installation contracts for Bonus (Siemens Gamesa today). In 2015, Jutlandia re-entered offshore wind with a contract from MHI Vestas who was looking to expand its pool of suppliers as part of its focus to reduce costs and risks. In just four years, Jutlandia increased the share of its revenue from offshore wind to around 20%. According to Jutlandia, servicing the offshore wind segment is not without risks: *"In the early days the sector was very collaborative. Today, it has become more procurement-centric. The prices have come down and a lot of the risk is pushed onto the suppliers."* One of the major learnings for Jutlandia has been to focus on how the company can create value for customers without participating in 'the race to the bottom' which has also meant giving up on certain contracts. Rather than competing on rates, Jutlandia tries to differentiate on advisory services, helping customers find the cheapest possible solution from a total cost perspective and identifying new value-added services that can help customers reduce their costs. One example is Jutlandia's investments in educating Lifting Supervisors, which has helped their UK customers reduce the need for having their own people onboard, while creating a new source of revenue for Jutlandia. Jutlandia sees offshore wind as a continued growth area for the company going forward but faces challenges related to capacity planning during slump periods, leading the company to think of new ways to generate value: *"We can dive almost 20% on our revenue from one year to the next which is a significant challenge from a human resource perspective. The key to success in the off-shore segment going forward will increasingly be to invest in assets such as packhouses which can provide a more stable source of revenue until the next installation project hits."*

Source: Interview with Jutlandia Terminals, www.jut.dk [R12]

5.6.4 Looking ahead: Challenges and opportunities for Esbjerg in offshore wind

In the future, offshore wind turbines and components will be so big that only a few ports in Europe will be able to handle them as most ports will not have sufficient space nor the proper supporting infrastructure. As a result of the significant investments made by Port of Esbjerg in 2001 and onwards, the port is likely to continue to play a key role in the regional expansion of offshore wind within Europe.

> *"A lot of smaller ports would like to get in offshore wind, but do not have the size it takes. You need approx. one million square meters to compete in offshore wind, at least if you want to be among the leaders in this segment."*
> Interview with Port of Esbjerg [R13]

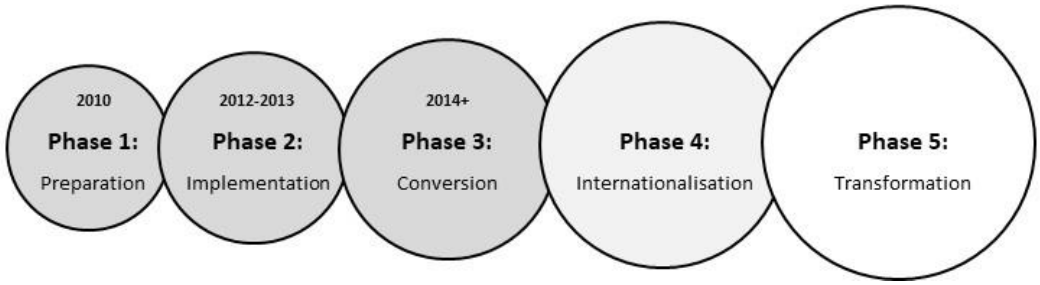
There are however also challenges for the port as well as the local supply chain which increasingly depend on offshore wind. Firstly, attracting new installation and O&M contracts to Esbjerg may become increasingly hard, as the offshore wind sector increasingly consolidates around regional hubs and competition between ports intensifies. Esbjerg is a likely contender for Thor which will generate substantial activity and jobs in the port and among local suppliers, cf. section 4.5, but there are larger installation projects planned for Esbjerg in coming 2-3 years. For local companies like Jutlandia, who depend entirely on offshore wind business within the port, there will therefore be a slump period, which may require adjustments to staff and capacity. This "Sinus curve", characterized by high activity during a the peak project period followed by limited/no activity in others, was called out by several Esbjerg-based suppliers as a particular challenge for port economies who rely heavily on installation projects.

To the Port of Esbjerg itself, one of the major challenges that lie ahead go beyond "just" winning more installation contracts: it is as much about ensuring that Denmark maintains its position as a central hub and eco-system for the planning, production, installation, O&M and decommissioning of offshore wind projects, all of which has a number of positive spill-over effects, both for Danish ports but also for the domestic offshore supply chain at large. To this end, Port of Esbjerg is working to further integrate the local port and supply chain into the global offshore wind sector by attracting new inward investments in a new 200,000m2 onsite production facility for offshore wind manufacturing within its premises. If successful, this would allow the Port of Esbjerg to transition from an installation and O&M port to a production port, cf. Table 17, thereby further strengthening Esbjerg's (and Denmark's) position as a leading hub for offshore wind.

> *"Very soon this is what the industry will need as the future wind farms will be too big to transport from inland locations to the ports. To us, the most important thing is that we keep offshore wind production in Denmark."*
> Interview with Port of Esbjerg [R13]

5.7 THE CASE OF GRENAA

Figure 22: The offshore wind evolution of Grenaa



Source: QBIS.

Located within Norddjurs municipality, Grenaa is the Eastern most city in the Region of Central Jutland with a population of around 37,100 people. Relative to the national average and to Esbjerg, Grenaa is characterized by a relatively smaller population, higher unemployment rates and lower disposable incomes, cf. Appendix C. Moreover, while a substantial part of the local economy derives from onshore and offshore wind in Esbjerg, Grenaa represents a relatively limited share of the jobs created by the primary wind sector in Denmark (between 101-500 jobs compared to >1,000 jobs in Esbjerg).[48]

Table 22: Profile of Port of Grenaa

Main offshore wind functions	Installation- and O&M port
Port revenue (2019)	59.98 million DKK
Size	1,425,000 m2
Quay length	2,5 km
Water depth	Up to 11 m
Offshore wind projects served to date	Installation of Anholt windfarm (2012-13), O&M of Anholt windfarm (2013-)

Source: Port of Grenaa

Following a substantial preparation phase in 2010, Grenaa port managed to secure its first, and so-far only, offshore wind installation contract with Anholt wind farm which was installed in Grenaa port between 2012 and 2013 and is currently serviced out of Grenaa. This provides a unique chance to explore the 'additionality' of a single offshore wind project within a relatively smaller port municipality. Some of the dynamic effects that have occurred in Grenaa port and among local suppliers as a result of the installation and O&M of Anholt are discussed in the following section.

5.7.1 Upgrading the local port and infrastructure to meet offshore wind customer demands

Prior to Grenaa's entrance into offshore wind, the port was faced with several strategic challenges and deliberations. Like many other port economies in Denmark, Grenaa had seen a gradual decline in revenues from traditional port operations over the past decades, including within the local fisheries trade. At the time of Grenaa coming into play as a potential contender for Anholt, cf. Table 23, the port

[48] Wind Denmark (2019).

was already in the process of developing a new strategy, which would transform Grenaa port into a fully modern industrial port, well-positioned for future growth.

Table 23: Overview of Anholt wind farm

Year of operation	2013
Energy company	Orsted
Total capacity (MW)	400 MW
Price per MWh (Euro)	141 Euro/MWh
Number of turbines (#)	111
Type of turbine	Siemens Gamesa SWT 3, 6-120
Turbine capacity (MW)	3.6
Total height (m)	141.6
Length of wings (m)	58.5
Rotor diameter (m)	120
Weight, wing (tons)	18
Weight, tower (tons)	200
Weight, nacelle (tons)	195
Total weight (tons)	450
Distance to shore (km)	15
Main installation port	Port of Grenaa
Main O&M port	Port of Grenaa

Source: Orsted

With the help of private investors, Grenaa port initiated a DKK 150 million port expansion in 2010 to enable the receipt of larger vessels as well as handling and storage of large components in the hinterland.[49] In addition, around DKK 100 million were invested by the municipality in upgrading the local road network to facilitate transport of offshore wind components to and from the port.[50] The opportunity to become part of the future growth in the offshore wind sector played an important role in securing the substantial funding and investor confidence required to upgrade Grenaa port. Most importantly, the initial promise of landing a prestige offshore installation contract in form of Anholt gave the port and its investors the confidence they needed to undertake the investments required to serve the offshore wind segment.

During the port expansion process, the port therefore worked closely with both Siemens and Orsted to ensure that Grenaa's local port facilities were fit for purpose, including the construction of two dedicated warehouses and jack-up areas.

> *"With Anholt some of the big players suddenly came in and started to pose requirements on us. During this period, we learned a lot about what was required. It also helped us customize our investments towards the offshore wind segment and make longer-term decisions. For example, the developers wanted to put up temporary pavilions, but we suggested that we might as well invest in permanent buildings, which were adjusted to their needs and that they could then help finance our investment by paying rent. This meant that we invested in facilities we otherwise would not have, for instance dedicated storage- and jacking areas. Today we are able to use these facilities for other purposes."*
>
> Interview with Grenaa port [R5]

[49] Energy Supply (2011).
[50] Djursland Udviklingsraad (2011).

5.7.2 The Grenaa model: Successful integration of local suppliers through networks, collaboration, and capacity building

The installation of Anholt itself was a massive undertaking for the port of Grenaa, which according to Orsted involved more than 100 ships, 3,000 people and more two million working hours[51]. Importantly, the project, which at the time was the biggest construction project in Denmark, involved several opportunities for domestic suppliers. According to publicly available information from Orsted, around 70% of the contracts for Anholt was with domestic suppliers from all over the country, including planning surveys by GEO in Lyngby, assembly of wind turbines by Siemens Gamesa in Brande, foundation production and delivery by MT Hojgaard and Bladt Industries in Aalborg and installation vessels by A2Sea (now DEME) in Fredericia.

There are no exact estimates of how many of these domestic jobs were generated within the port municipality itself. According to the port and local stakeholders interviewed in Grenaa, the influx of activity was significant when the installation work on Anholt was at its highest. As an example, the presence of onshore and offshore crew members from the developers as well as the various installation vessels generated substantial activity, reportedly occupying the biggest local hotel in Grenaa for 1.5 years. The unofficial story goes that a local politician declared that he would never have opposed the project had he known "how many Danishes that could be sold by local bakeries from an offshore wind farm". Beyond Anholt's impact on companies in the tertiary sector, it also created opportunities for sub-contractors in Grenaa's secondary sectors, ranging from local carpenters, steel manufacturers and paint shops to the local shipyard, surface treatment providers, etc.

The successful integration of local suppliers during the installation of Anholt is mainly attributed to the creation of the local supplier network, DWP, which was formed prior to Anholt's arrival in Grenaa and acted as a one-stop-sourcing platform for the developers and their primary contractors, cf. Box 14. As part of this initiative a proactive effort was made to upgrade the skills of local suppliers to prepare for the demands and requirements of offshore wind customers.

> *"The greatest challenge for us was to ensure that our local businesses would benefit sufficiently from Anholt. That we could generate local jobs from this."*
> Interview with the local mayor of Norddjurs municipality [R8]

The learnings from DWP has since been replicated by other offshore port municipalities in Denmark, incl. Ronne with Offshore Center Bornholm, ONE in Esbjerg, cf. section 5.7, Kriegers Flak Service Group and Hvide Sande Service Group, cf. section 5.9. While these local supplier networks can be set up in various ways – from fully contractually integrated, "one-stop-shop" sourcing platforms to more traditional networks or business associations – they share the same purpose: enhancing participation of local suppliers in the implementation of an offshore wind project through a strength-in-numbers approach.

[51] Orsted fact Sheet. See: https://orsted.com/en/our-business/offshore-wind/our-offshore-wind-farms.

Box 14: DWP System Supplier – A pioneering model for enhancing local capacity and participation in offshore wind

DWP System Supplier – originally short for Djurs Wind Power – was formed in 2010 by a smaller number of local companies in Grenaa (~10) who wanted to strengthen their competences within the offshore wind sector as the port was starting preparations to receive Anholt. Despite some existing experiences within the onshore wind segment, competences and know-how among local suppliers were scattered and there was a need to upskill the local supply chain to meet the specific requirements of the offshore wind industry. As a start, the network began hosting competency development workshops focused on basic aspects such as how to decipher a business card from a large offshore wind company (what do their titles mean, who do they report to), how the supplier approval process works and what requirements local suppliers would need to live up to. During this process the network established a "one-point-of-contact" system, which allowed offshore wind developers and primary suppliers – from Orsted and Siemens to some of the larger installation companies – to easily request support from local suppliers without having to go through many different contact points. The model worked and the members of DWP played an importing supporting role during the installation of Anholt. Estimates from the network suggest that DWP member companies – most of which were based in Grenaa or neighboring municipalities at the time – managed to secure orders for around DKK 450 million and created 333 new jobs during the installation of Anholt. The DWP network has since become an exemplary model for how local ports and suppliers can collaborate to build an attractive value proposition for the offshore wind industry. Even so, the benefits of the experiences gained during Anholt extend well beyond the project itself according to the current CEO of DWP. Today, DWP has grown into a professional business network of 30 member companies from different parts of the country as well as some international members. Immediately following Anholt, DWP began to explore how it could leverage the experiences gained from Anholt to support projects in other parts of Denmark as well as in the growing international offshore wind sector. As an example, in 2013 DWP replicated the concept from Anholt by setting-up shop in the Port of Romo to support Siemens Gamesa and WPD with the German windpark, Butendik. Today, the network is increasingly looking to international markets for growth opportunities as well as adjacent sectors which require some of the same competences as offshore wind: *"The most important spin-off from Anholt was that it helped our members internationalize their business and their order books. The world has moved on since Anholt and the offshore wind sector has become increasingly global. Today our members are just as occupied with winning orders in the USA as they are in Denmark."* [R4]

Source: Interview with DWP Systems Suppliers, www.dwpsystemsupplier.dk [R4] and Orsted fact Sheet. See: https://orsted.com/en/our-business/offshore-wind/our-offshore-wind-farms .

5.7.3 When the rush from the installation phase is over, the hard work begins

Upon the commissioning of Anholt in 2013, Orsted set up its local O&M center out of the Port of Grenaa, which to this day employs 48 full-time employees and 12 service technicians, most of whom live within the municipality. In addition, Orsted makes frequent use of local suppliers and laborers within the municipality to support its daily operations on sea and on shore, cf. Box 15 and Box 16. As an example, several of the seafarers that work on Orsted's two service vessels (CTVs) are Grenaa-based residents who used to work in the local fishery sector.

For the Port of Grenaa, the activity generated from Anholt is relatively modest, accounting for around 6% of the port's annual turnover, which is substantially below the turnover generated from offshore wind in 2012-2013 when the installation of Anholt was at its highest. When Anholt was commissioned in 2013, the port saw a drastic decline in revenue and activity from its offshore wind business. At this time, the port realized they could not sit around and wait for the next offshore windfarm to land in their lab – they needed a new strategy to leverage the investments and capabilities that had been built up in the port as well as among local suppliers in the area. The port decided that it needed to look more broadly towards complementary projects in the offshore energy sector, including Oil & Gas, while maintaining its competences and investments in offshore wind.

Following the change in strategy, the port began to see a gradual increase in revenues from offshore energy projects, also “beyond” wind. In 2018, Siemens Gamesa chose Grenaa as service port for a large wing upgrade project on Anholt and over the past years, Grenaa port has won a series of contracts within offshore energy, notably docking and repair work on the world’s largest jack-up rig, Maersk Inspirer. The Maersk Inspirer project has since been reported to have generated DKK 140 million in orders for local suppliers within the municipality.[52] Further, Grenaa was recently chosen as pre-assembly port for a new pilot project looking to develop floating foundations for offshore wind.

> *“We just had our best year ever in 2018. I am convinced that the main contributing factor for this is our experiences from Anholt and the investments we made in upgrading the port back then.”*
> Interview with Port of Grenaa [R5]

Overall, the Port of Grenaa attributes three key factors to its success in securing long-term advantages and spin-offs from its preliminary investments in offshore wind: 1) A strong local supply chain for offshore wind projects, 2) The ability to proactively identify complementary business areas while maintaining competences and staying relevant within offshore wind, and 3) Strategic foresight and risk willingness to pursue long-term investments and growth opportunities. The experiences from Grenaa also suggests that for investments in offshore wind to pay off, success hinges on the port’s ability to attract a wider portfolio of offshore projects beyond a one-off installation project.

> *”We always tell other ports who are faced with these deliberations to think about what they’ll do when they no longer have a wind project. We tell them to think about how to combine their investments in offshore wind with other business areas. It is extremely expensive to deliver an offshore wind project, so the ports and their suppliers really have to think: What additional value can we leverage from this project in the longer term?”*
> Interview with Grenaa port [R5]

5.7.4 Local suppliers leverage experiences from Anholt to win new orders, at home and abroad

For Grenaa’s local businesses, the choice of Grenaa port for installation and O&M of Anholt meant an opportunity to build critical experiences within a new customer segment. According to one of the initial members of the DWP network, Davai ApS, Anholt first and foremost meant much higher contract sums than many of the local businesses were used to at the time. With a reported DKK 450 million in orders captured by local suppliers, cf. Box 14, Anholt allowed local businesses to invest and experiment with new tools, assets, skill enhancement and/or business processes than they have been able to use for future projects.

[52] Norddjurs Amtsavis. See: https://amtsavisen.dk/artikel/lokale-grenaa-firmaer-h%C3%A5ber-p%C3%A5-ordrer-fra-borerig

Box 15: DAVAI ApS – The local market brings new growth opportunities

Davai ApS is a Grenaa-based company formed in 1984 which specializes in the supply of manpower, equipment and processes for bridge renovations and certified turbine services. Specifically, Davai provides steel inspection- and coating services for offshore and onshore wind turbines and substations. When Anholt first came to Grenaa, Davai's main business was focused on larger bridge renovations in Denmark as well as in EU. Contrary to many of other local companies, Davai was thereby already exposed to the type of requirements involved in supplying large international projects and operations, incl. in terms of safety and documentation, and the learning curve was less steep. Further, unlike some of the other local businesses that were vying to support with the installation of Anholt, the majority of Davai's revenues came from projects outside of the municipality. With Anholt, three things happened to Davai's business: Firstly, the local market in and around Grenaa port started becoming interesting for Davai who saw a ten-doubling of the revenues generated from Grenaa-based projects with Anholt, in some periods even more. Even though the orders generated from Anholt today are around 75% of what they were during installation, Anholt is still a significant source of revenue for Davai, which has around 4-6 people hired to perform work on the wind farm. Secondly, with Anholt, Davai became part of a network of local companies through DWP, which now means they have access a bigger pool of competences and can bid on more and bigger projects, both locally, domestically and abroad*: "I can't afford having a technical drawer hired so prior to DWP I would have skipped contracts that required this. Today, I can just pull in a drawer from one of the other companies and that also works the other way around."* Thirdly, Anholt has also played an important role in securing Davai orders for other offshore projects incl. work on subsequent wind farms such as Horns Rev 3 and on offshore contracts in the Port of Grenaa such as Maersk Inspirer: *"With a project like Maersk Inspirer, I think the customer feels they have arrived to a city where there is a strong drive from local businesses to help solve the task at hand. Before Anholt, we had very little offshore experience on our reference list – all we had was bridges – and you need references to compete in this segment".*

Source: Interview with Davai ApS, www.davai.dk [R3]

Most importantly, with Anholt, local suppliers in Grenaa were exposed to an international customer segment with different and more stringent requirements than conventional customer segments including in areas such as project documentation, quality and safety. This led some local suppliers to upskill in these areas e.g. through investing in internationally recognized certifications and standards.

> *"In the past, some suppliers in Grenaa would just do a task and submit an invoice. If you are a supplier for a project like Anholt, it's a completely different ballgame. You need folders-worth of documentation and a lot of it needs to be electronic as well. Then there are requirements for certifications on quality, environment and safety, and a lot of local suppliers had to go through this to qualify."*
> Interview with Davai ApS

To DWP, the internationalization of local suppliers has in fact been one of the most important spin-offs from Anholt. Just as DWP played a key role in securing participation of local businesses during the implementation of Anholt, the network now plays an important role in helping local businesses leverage the experiences gained from Anholt to pursue new opportunities abroad, cf. Box 14. Like the change in strategy by Grenaa port following the installation phase, this has required DWP to take a broader focus than "just" offshore wind. As a result, the network has since changed names to DWP Systems Supplier, expanded its member base well-beyond local companies and is increasingly looking to international markets for growth.

> *"The most important spin-off from Anholt was probably that it helped our members internationalize their business and their order books. The world has moved on since Anholt and the offshore wind sector has become increasingly global. Today our members are just as occupied with winning orders in the USA as they are in Denmark."*
> Interview with DWP Systems Supplier [R4]

> *"When you perform work on a project like Anholt, there are suddenly also other customers that approaches you for bigger orders on equipment and components. All our contracts are won through competitive bids, with quality, delivery time and price as the highest priority, but a project like Anholt is a good door opener."*
> Interview with HSM Industri [R7]

Box 16: HSM Industri A/S – A project like Anholt can help open doors to new sectors

HSM Industri is one of the larger Grenaa-based suppliers specialized in complex steel and technical piping systems for a wide number of industries. One of these industries include the offshore energy sector where the company has been active for more than 18 years. HSM Industri has a 10,000 m2 steel production located 800m from the port, a dedicated paint shop for coating purposes. HSM Industi is also the owner of Grenaa Shipyard, which is located within the Port of Grenaa. While offshore wind is a relatively small segment for HSM Industri, the company assisted Orsted with several contracts during the installation and O&M phase of Anholt. Most recently, HSM Industri was responsible for the construction of a safety drill steel tower located in Grenaa port that Orsted hopes to turn into a local competency hub for offshore wind safety training. HSM Industri has also helped construct gangways for offshore wind service vessels during Anholt, developed airtights for Anholt's foundation and, via Grenaa shipyard, conducted inspections and repair work for offshore wind vessels, both during installation and now as an annual contract with Orsted's CTV vessels during the O&M phase. Similar to many of the Esbjerg-based companies, HSM Industri has been able to draw on its experiences and competences within the offshore energy sector to win orders on Anholt, where its close proximity to the port has been a significant advantage for off-shore customers. For HSM Industri some of the spin-offs from Anholt have included a greater focus on offshore wind energy projects. As an example, based on their experiences from Anholt, HSM Industri has experienced that other offshore wind customers have approached them and placed larger orders on equipment for offshore wind projects, both in other parts of Denmark and abroad. *"When you perform work on a project like Anholt, there is suddenly also other customers that approaches you for bigger orders on equipment and components. All our contracts are won through competitive bids, with quality, delivery time and price as the highest priority, but a project like Anholt is a good door opener"*.

Source: Interview with HSM Industry, www.hsm.dk [R7]

5.7.5 Looking ahead: Challenges and opportunities for Grenaa in offshore wind

Offshore wind may at first glance be a modest source of revenue for Grenaa's port economy today, however, the case study suggests that Anholt has left a permanent mark on both the port and local businesses.

Most importantly, the experiences from Grenaa illustrate the importance of thinking about how investments and experiences from the implementation phase can be converted to new opportunities at an early stage. In Esbjerg, new offshore projects have continued to flow to the port, creating a permanent flow of new opportunities for local suppliers. For other ports like Grenaa the inflow of offshore wind projects may however be unsteady, at best. Ensuring that the investments, experiences and references gained from an initial installation contract are applied to pursue orders in other offshore wind projects or in adjacent sectors is in other words a critical aspect of driving positive outcomes from an initial offshore wind project over time.

Today, offshore wind remains a strategic focus area for the Port of Grenaa, even though there are no installation or O&M contracts in immediate sight. According to the port, the challenge is to maintain the competences and experiences gained from Anholt within offshore wind, while pursuing opportunities in other sectors. In 2020, the port landed another agreement with an oil and gas platform, Maersk Innovator. Like Maersk Inspirer, the project is expected to generate substantial local turnover, both for the port and for local businesses such as Grenaa shipyard, HSM Industri, Davai and more. According to the port, projects such as these would not have been secured without the investments made in connection with Anholt.

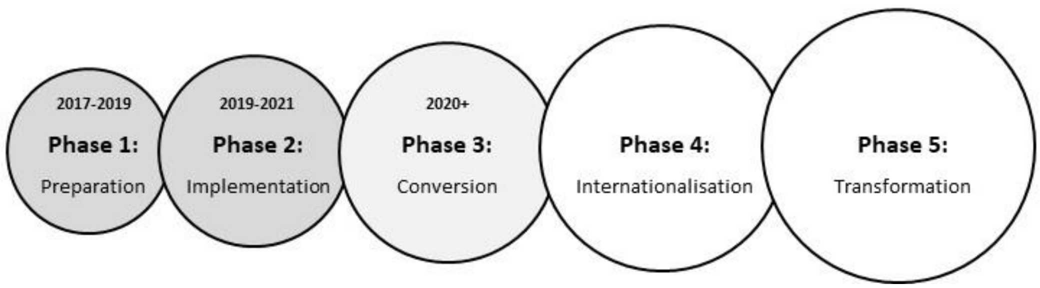
One of the areas that hold transformative yet so far untapped potential for Grenaa is within offshore wind decommissioning. The combination of the port’s dedicated facilities for handling of large components, Grenaa shipyard’s experiences within ship dismantling and a strong recycling sector, place Grenaa as one of the potential beneficiaries from the substantial inflow of decommissioning projects over the coming year alongside other large-component ports in Denmark such as Port of Frederikshavn, Lindo Port of Odense and Port of Esbjerg, cf. Box 4. Grenaa has already converted some of the storage facilities developed for Anholt to support local companies in the recycling and recovery sector and considers recycling of offshore energy structures as one of the port’s strategic focus areas within circular economy.

5.8 THE CASE OF RONNE AND HVIDE SANDE

In addition to Esbjerg and Grenaa, two Danish ports - the Port of Hvide Sande and the Port of Ronne - have only recently embarked on the offshore wind transformation journey. Given the relatively early stages of the two ports in offshore wind, the following sections outline some of the strategic and practical considerations of the two ports as they prepare to enter into a new customer segment with – potentially – transformative implications for the local port economies.

5.8.1 Ronne: Preparing for installation of Kriegers Flak while suiting up for future growth in the Baltic Sea

Figure 23: The offshore wind evolution of Ronne



Source: QBIS.

The Port of Ronne is located on the island of Bornholm and is Denmark's easternmost industrial port. The municipality of Bornholm has a population of around 39,500 people. Even though unemployment has declined over the past years, the municipality has the highest unemployment rate of the four port municipalities, and sits above the national average, cf. Appendix C. Compared to the other three port municipalities, Bornholm also accounts for the lowest level of jobs within the Danish onshore or offshore wind sector.[53]

[53] Wind Denmark (2019).

Table 24: Profile of Port of Ronne

Main offshore wind functions	Installation port
Port revenue (2019)	DKK 77.39 million
Size	690,000 m2 (150,000 m2 for offshore wind)
Quay length	575 meters
Water depth	Up to 11 meters
Offshore wind projects served to date	Kriegers Flak (2021), Arcadis Ost 1 (2022)

Source: Port of Ronne.

With its central location in the Baltic Sea, the Port of Ronne is ideally placed to benefit from the next generation of offshore wind projects in Europe. According to Wind Europe, only 2 GW of the 20 GW of offshore wind sits within the Baltic sea today, however, offshore wind projects in the Baltic Sea can be as high as 9 GW by 2030 and could reach 85 GW by 2050.[54] To future-proof the port and prepare it for the offshore wind potential in the Baltic Sea over the coming years, the Port of Ronne has invested close to DKK 500 million in expanding the port since 2016.

The first phase of the project was completed in October 2019 and included a 150,000m2 expansion, an increase of the water depth to 11 meters and quays to support up to 50 tonnes per square meter.

> *"We have made the investments to future-proof the port but also to prepare for the offshore wind potential we see in the years to come in the Baltic Sea."*
> Interview with Port of Ronne

The port's unique location as well as the recent port expansion allowing heavy-weight components to be brought into the quayside via ship was one of the major reasons that Siemens Gamesa chose Ronne as installation port for Kriegers Flak over other Danish or international ports.

Table 25: Overview of Kriegers Flak wind farm

Year of operation	2021
Energy company	Vattenfall
Total capacity (MW)	604.8
Price per MWh (Euro)	49.9 Euro/MWh
Number of turbines (#)	72
Type of turbine	Siemens Gamesa SWT-8, 4-167
Turbine capacity (MW)	8.4
Total height (m)	188
Length of wings (m)	81.4
Rotor diameter (m)	164
Weight, wing (tons)	34
Weight, tower (tons)	400
Weight, nacelle (tons)	365
Total weight (tons)	867
Distance to shore (km)	15-40
Main installation port	Port of Ronne
Main O&M port	Port of Klintholm

Source: Vattenfall.

Prior to securing the installation contract for Kriegers Flak, the port had already built up preliminary experiences within offshore wind as base harbor for the Dutch Arkona offshore wind farm in 2018. Like the Port of Hvide Sande, cf. next section, Ronne's work on Arkona helped demonstrate the favorable conditions of the port to the offshore wind sector. At the same time, it gave the Port of Ronne an initial feel for what it takes to service the offshore wind segment. As the Port of Ronne plays a critical role in the island of Bornholm's economic development, expectations are building with hopes that Kriegers Flak will mark the start of turning Bornholm into "the Esbjerg of the Baltic Sea".

[54] WindEurope (2019a).

According to the mayor of Bornholm, the port's ability to unlock the potential in the Baltic Sea plays a critical role in building a more resilient local economy:

> *"When I look at the Baltic Sea, I see a lot of big projects in Germany and Poland. We have big expectations of the added value this can bring to Bornholm in terms of jobs and growth. The challenge is that we have a lot of competition and we would of course like to bring these jobs to Denmark."*
> Interview with Mayor of Bornholm

In section 4.5.2, the offshore wind model was applied to Kriegers Flak, which was estimated to generate between EUR 6-29 million and 17-104 FTEs to Ronne port and local suppliers. As the efforts from installing Kriegers Flak are currently ongoing, it is too early to conclude on the project-specific outputs, i.e. actual economic value-add and job creation. It is also too early to conclude on the potential long-term outcomes and impacts from the project, e.g. in form of its contribution to upskilling local suppliers, converting Kriegers Flak into new orders, internationalization of local suppliers etc. Based on the experiences from Esbjerg and Grenaa, the potential contribution of Kriegers Flak in kick-starting a deeper transformation of the local port economy will however largely depend on the ability of the port and local suppliers to gain as many contracts and experiences as possible during the installation phase.

To help facilitate this, several preparatory efforts are already underway in the hinterland. As an example, Offshore Center Bornholm has been created to establish Bornholm as an ambitious player in the Baltic area. The network consists of 17 companies with capabilities within offshore energy. At least one of its members, the local logistics company, BHS, has already managed to secure a contract with several of the primary contractors to Siemens Gamesa for Kriegers Flak, incl. for local agency and stevedoring tasks during the installation of the turbines and the major components. Here BHS will collaborate closely with Jutlandia in Esbjerg to ensure that the knowledge and experiences from the loading and handling of large components from other Danish ports are transferred to Ronne[55].

5.8.1.1 Looking ahead: Challenges and opportunities for Ronne in offshore wind

Kriegers Flak has the potential to play an important role in establishing Ronne and Bornholm as a serious contender for offshore wind projects in the Baltic Sea. However, to Ronne port, the Danish wind farm is just the beginning. Even though the first turbines from Kriegers Flak have yet to be installed, the Port of Ronne is actively working to convert its initial offshore contracts to new inwards investments. In 2020, Ronne was appointed the installation contract for MHI Vestas on Arcadis Ost 1 located just 74 kilometers from the port and close to the German peninsula of Rügen. The port also sees future opportunities in O&M of offshore wind farms in the Baltic Sea.

One of the main challenges for Ronne port and Bornholm going forward is the speed with which the offshore wind supply chain is developing and the growing concentration around a handful of fixed ports

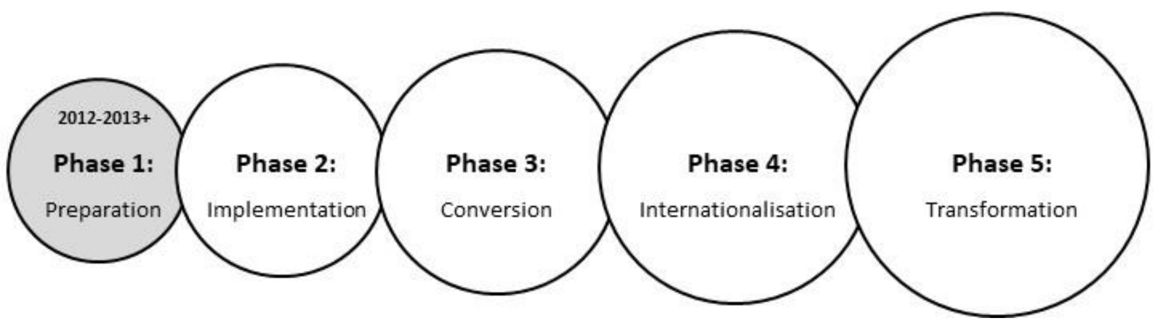
[55] This dynamic is captured in the Theory of Change under interregional synergies, cf. Appendix B.

with the required infrastructure for production, storage and pre-assembly of the ever-increasing offshore wind components. As discussed previously in this chapter, ports involved in the future generation of offshore wind projects will need to handle larger turbines, longer blades, heavier components, larger support and installation vessels and be located further from shore. In this context, Ronne is still a relatively small player compared to some of the larger ports in Denmark, Poland and Germany.

That said, there are other opportunities ahead for Ronne, incl. a 2020 proposal from the Danish government to place an enormous offshore wind farm close to Bornholm and convert the municipality of Bornholm into one of two 'Energy Islands'. Among other things, the proposal involves the establishment of a transformer station on Bornholm, connecting energy markets in Denmark, Sweden, Germany and Poland while converting offshore wind power into hydrogen through Power-to-X technologies.

5.8.2 Hvide Sande: Carving a niche in O&M with the help of a strong hinterland

Figure 24: The offshore wind evolution of Hvide Sande



Source: QBIS.

The Port of Hvide Sande is located on Denmark's West Coast around 70 kilometers north of the Port of Esbjerg. The port sits within the larger municipality of Ringkobing-Skjern with a population of around 56,500 people. Like Esbjerg, the municipality is well-integrated in the wind energy sector with Vestas as the biggest single employer in the municipality. Ringkobing-Skjern ranks as the second biggest wind energy employer in Denmark (mainly onshore) with around 2,200 FTEs employed, or 7% of total wind-related jobs.[56]

[56] Wind Denmark (2019).

Table 26: Profile of Port of Hvide Sande

Main offshore wind functions	O&M port
Port revenue (2018)	40 million DKK
Revenue from offshore wind	~2-5%
Size	1,000,000 m2
Quay length	2.5 kilometers
Water depth	Up to 7 meters
Offshore wind projects served to date	Horns Rev 3 (base port), Horns Rev 3 (O&M) from 2024

Source: Port of Hvide Sande and Danske Havne (2018).

The municipality also ranks high on socio-economic indicators with low unemployment and high disposable income rates, cf. Appendix C. Until the mid-2000s, the Port of Hvide Sande acted primarily as a fishery port and the port remains Denmark's fifth largest fishery port. Like Esbjerg, Grenaa and Ronne, Hvide Sande port has however undergone a significant transformation over the past decade, investing around DKK 150 million in upgrading the port from 2011-2013 – an effort which helped the port grow its revenue from DKK 12 million in 2010 to DKK 40.5 million in 2018 and from 5 to 20 employees [R22].

The main focus of the port upgrade in Hvide Sande was to attract the large commercial fishery vessels back to port, but at the time several of the local businesses operating in and around the port were also starting to explore industries and business areas beyond fishery, including within the offshore wind industry. In 2010, a network of local businesses was created, who started to build up preliminary experiences and know-how within the offshore wind sector, including Hvide Sande Shipyard, cf. Box 17, as well as local steel manufacturers and hydraulic experts. The network has today evolved into more than 40 local businesses under the name Hvide Sande Service Group (HSSG).

> *"Hvide Sande Service Group was formed to help local businesses develop a stronger position in new industries such as the offshore sector. Our discussions were about what it took in terms of competences and capabilities – making sure we would be prepared for what could come in the future. We now have a one-point-of-contact system so that regardless of what an offshore customer needs, they can find it here."*
> Interview with Port of Hvide Sande [R22]

Taking its cue from the discussions in Hvide Sande Service Group, the Port of Hvide Sande started to think about how it could target its port upgrade project towards the offshore sector. This involved thinking about how to meet the offshore sector's demands for quay size, secure storage facilities, service and support, import and export of large components, space for service- and supply vessels as well as a heliport. At the same time, the port started to engage in a proactive effort to communicate to the offshore wind industry that the port was "open for business".

Box 17: Hvide Sande Shipyard – A high-quality yard with fast turn-around times helps put Hvide Sande on the map as O&M port

Hvide Sande Shipyard's (HVSA) entrance into offshore wind came well before the Port of Hvide Sande with Horns Rev 1 in 2001, where the yard got the first orders from MHI Vestas. Like most local companies at the time, HVSA was highly dependent on the fisheries trade at the time and saw the project as an opportunity to become part of the green energy transformation: *"It was an active choice for us back then because we believed it could become really big."* During the initial years of servicing the offshore wind sector, the yard quickly learned that offshore wind was a different ball-game than conventional fishery businesses and they started to solicit the experiences of other Danish suppliers to the offshore wind sector such as Fayard to understand the segment better: *"We learned during this time that servicing offshore wind customers is like servicing a race car in pit. You need to get the customers to tell you exactly when they arrive and what they need and then you need to work around the clock to give it to them."* To HVSA, entrance into the offshore wind sector has meant drastic changes to how it runs its operations, including use of shifts outside of normal working hours at higher rates. The combination of an agile and customized service concept, high quality standards and innovative capabilities in steel design and manufacturing has led to a substantial increase in the yard's revenues from offshore wind which today represents around. 33%, up from 5% just ten years ago. Recently, HVSA has expanded their facilities with 50% and have set up a new company in the UK to service the global market for Davit cranes, a concrete spin-off from HVSA's work on some of the earlier Danish and international wind-farms. Today, the yard services offshore wind projects from all over the world, however, a Danish wind farm still generates substantial activities for the yard in Grenaa – and not just limited to installation and O&M. As an example, on Horns Rev 3, HVSA has performed work on the vessels that conduct-ed sediment surveys (Planning), produced and delivered Davit cranes for the turbines (Construction) and performed service on the installation vessels (Installation. The yard anticipates additional work once local O&M operations of Horns Rev 3 is set up in the Port of Hvide Sande (O&M) where Vattenfall will be located right across the street.

Source: Interview with Hvide Sande Shipyard, www.hvsa.dk [R21]

> *"The strategy was first and foremost to attract the commercial fishing vessels back to Hvide Sande. With the growing consolidation of the fishery sector, it became increasingly clear to us that betting on this sector alone was very vulnerable. Many of the local businesses were already starting to look at new business areas. That applied to us as well."*
>
> Interview with Port of Hvide Sande [R22]

Due to a combination of above factors – i.e. an upgraded port fit to meet the offshore wind sector's needs; a strong local supply chain and a proactive marketing effort – the Port of Hvide Sande won its first offshore wind contract as base-harbor for the crew that installed Horns Rev 3 in 2019. This entailed hosting 30 MHI Vestas technicians in a local pavilion for the around 1.5 years it took to install Horns Rev 3 out of the Port of Esbjerg. Similar to Ronne's initial experiences from the Arkona wind farm, Hvide Sande's preliminary experiences as base-harbor during the installation of Horns Rev 3 ultimately ended up securing the port its first O&M contract for Horns Rev 3 from 2024 and onwards, cf. Table 21.

> *"We are very pleased with the choice of the Port of Hvide Sande. They have cheaper rates than some of the larger ports and there is a fantastic hinterland of local suppliers, incl. the shipyard in Hvide Sande. They are available, competent, friendly and provide good service. Do not forget that choosing a port is much like choosing a suit. There are some physical aspects that need to be in place – you cannot service a cruise ship with 4 meters depth – but it is also a lot of other things.*

Some of the fixed ports are also good for O&M, but they are expensive and big. Sometimes it is better from a customer perspective to be a big fish in a small pond."
Interview with Ziton [R6]

Box 18: ZITON – Smaller ports are sometimes better for O&M customers

Ziton is a fully specialized O&M supplier to the offshore wind sector, offering turn-key solutions for all major offshore wind farm components. The company owns four jack-up vessels that are fully specialized for replacing offshore wind components and performing services related hereto. Based in Horsens, Denmark, the company has been specialized in O&M from the start and has changed more than 800 components on offshore wind farms to date, including 60% of all components on the existing Danish windfarms. According to Ziton, the benefits of specializing in O&M is that there is a steadier flow of work compared to companies who specialize in the installation phase (no Sinus-curve). That said, the O&M sector has other challenges as there is generally a higher focus on costs. Further, the industry is challenged by newer wind projects with fewer turbines to service and growing competition from installation vessels once peak season (summer) is over. When Ziton engages in an O&M contract for a wind farm like Anholt or Horns Rev 3, the work is typically awarded through a tender with the majority of the turnover going into operating the ship, i.e. supplies, water, wage handling, steel work and repairs. Some of the turnover will however be directed to the appointed O&M port and the local suppliers close to the port. The extent to which Ziton uses local suppliers within the O&M port municipality depends largely on factors such as availability, price and quality of the local suppliers: *"Sometimes we might use local suppliers or ship technicians in the O&M port simply because our ships are there. But otherwise we use suppliers from all over the country or abroad. As a rule of thumb, the biggest contribution we make to an O&M port is probably the consumption of local goods and hospitality services used by our crew while onshore."* According to Ziton, while there are only very few ports that can successfully meet the requirements of installation projects beyond a "one-off" project here and there, smaller and medium sized ports such as Hvide Sande are far more attractive when it comes to the O&M phase where the key success criteria include flexibility and adaptation to market demands: *"We are very pleased with the Port of Hvide Sande. They have cheaper rates than some of the larger ports and there is a fantastic hinterland of local suppliers, incl. the shipyard in Hvide Sande. They are available, competent, friendly and provide good service. Do not forget that choosing a port is much like choosing a suit. There are some physical aspects that need to be in place – you cannot service a cruise ship with 4 meters depth – but it's also a lot of other things. Some of the fixed ports are also good for O&M but they are expensive and big. Sometimes it's better from a customer perspective to be a big fish in a small pond."*

Source: Interview with Ziton, www.ziton.eu [R6]

5.8.2.1 Looking ahead: Challenges and opportunities from offshore wind in Hvide Sande

In section 4.5.3, we illustrated how applying the offshore wind model to a project with Horns Rev 3's characteristics, could generate 24-33 FTEs per year and between EUR 1.3-3.7 million per annum in Hvide Sande. However, as discussed throughout this chapter, the 'size of the price' for Hvide Sande port and suppliers in the wider municipality depends largely on the share captured by local suppliers in secondary and tertiary sectors.

To the Port of Hvide Sande, Horns Rev 3 is first and foremost an opportunity to change the perception of the port from a "fishery port" to a modern, diversified port that is specialized in the service of offshore energy projects, including wind and oil and gas. The port sees significant opportunities to grow the share of its offshore wind business over the years to come and estimates that the segment could grow from a modest 2-5% today to as much as 25-30% in the coming 5-10 years.

5.9 Summary of findings from local case studies

The offshore wind model developed in the previous chapter can help estimate how many jobs are likely to be generated within local port municipalities during the installation- and O&M of a specific offshore wind farm. In this chapter, some of the dynamic effects that the model cannot capture were investigated, notably the outcomes and impacts that can evolve from a single offshore wind investment over time. For local port municipalities that manage to embrace the opportunities and overcome the challenges represented at each stage of the offshore wind journey represented in Figure 20, some of these outcomes include:

Diversification of the local port economy: The installation and O&M stages of an offshore wind project offer a potential for local ports to diversify their revenue streams, modernize their facilities and build greater resilience to external chocks. In the cases featured in this report, all four ports were faced with similar scenarios looking to diversify turnover from traditional business segments such as Oil & Gas and/or fisheries. In this context, preliminary experiences from Danish wind farm investments have given the ports and their investors the confidence needed to pursue a new business segment and diversify the port's future income. As an example, in Esbjerg, the installation of Horns Rev 1 became the start of a long string of orders in offshore wind for the port as well as for the local eco-system of suppliers. In Grenaa, the experiences from Anholt has led to several new contracts for the port and local suppliers in adjacent sectors such as oil and gas, recycling etc. as well as in international markets. In Hvide Sande, the initial work as base port during the installation of Horns Rev 3 helped secure the port its first long-term O&M contract, while in Ronne, a new installation contract for a German wind farm has already been signed following Krieger's Flak. As ports are often important gateways to economic development and job creation within their wider municipalities, identifying a viable future revenue stream through attracting offshore wind investments to a given local port can thus play a significant role, not just for the port itself but also for the port's dependents.

Improving skills and competences of local suppliers: As illustrated in the previous chapter, the installation and O&M of an offshore wind farm creates economic activity and jobs within a given port municipality, ranging from EUR 5 million for an installation contract (one-off) to EUR 0.5 million for an O&M contract (per annum). A key variable in the model is the extent to which a given port municipality can capture a sizeable share of the offshore wind contracts, also beyond the service sector. Most importantly, when local suppliers in the primary or secondary sectors get involved in the installation or O&M phase of an offshore wind farm, they are faced with new requirements, which can lead to varying degrees of upskilling and investments, e.g. in terms of safety, quality, documentation, turnaround times, employee skills and, increasingly, productivity. Port municipalities with strong existing supply chains within the offshore energy sector are likely to have a head-start due to strong cross-synergies and overlaps in the assets and competences required. In port municipalities without the required skills and know-how in place, local supplier networks are emerging as a preferred model to build local competences in offshore wind and increase the attractiveness of local suppliers.

Accessing new orders in a growing global market: One of the most important dynamic effects from the early Danish offshore wind investments is the potential they have offered local suppliers in terms of integrating into the global offshore wind supply chain. The comprehensive offshore wind supply chain that have emerged in Esbjerg is the best example of this to date and among the key attributor to Denmark's ability to deliver 35.40% of all new offshore wind assets in Europe from 2010-2018. In Grenaa, while at a much smaller scale, the primary spin-off from Anholt has been the increased internationalization of local suppliers, who have managed to replicate the collaborative sourcing model developed during Anholt to a global market segment.

Greening local port economies and intraregional synergies: A more subtle outcome observed in the installation and O&M port municipalities include a strong focus on sustainable development goals and renewable energy within the port and among local suppliers. Many of the respondents interviewed suggest that becoming a supplier to the offshore wind energy sector has had a fundamental impact on their business practices, encouraging both ports and local businesses to find more environmentally efficient ways of doing things and in some cases helping to attract employees. Finally, the cases suggest that there can be important interregional linkages and synergies between port municipalities involved in the installation and O&M of offshore wind farms. As an example, the Port of Esbjerg will play a key role as feeder port for Kriegers Flak, while local suppliers from Esbjerg such as Jutlandia with extensive experience in handling installation vessels will play a key role in advising the Port of Ronne and its local suppliers on how to handle the installation vessels.

The case studies also indicated a number of challenges involved in the installation and O&M stages of offshore wind, which may stifle local progress or counter some of the potential benefits. These include:

Strategic capacity planning: The installation and O&M of offshore wind projects require ports, investors, politicians and local companies to carefully consider how they can secure a return on their investments. Given the high upfront investments for ports, suppliers and in some cases for the local municipalities, a successful business case will often hinge on the ability to attract a continued portfolio of projects beyond a one-off, especially for installation contracts. Further, several of the companies interviewed indicated that suppliers to the offshore industry often risk getting trapped in the Sinus curve – i.e. high influx of activity in one period and low/no activity in others – which poses significant challenges both from a human capital and financial perspective.

Race-to-the-bottom: With the growing pressure on costs, some of the interviews suggested that it has become increasingly challenging for local suppliers to enter and compete in the offshore wind sector. In the early stages of the industry, where the industry maturing and still supported by subsidies, there was more leeway for local suppliers and willingness from customers to co-create. Today, the installation & O&M of offshore wind farms have become more standardized and procurement-driven, which may reduce incentives for local suppliers to invest in quality, innovation and environmental improvements. Reversely, it may also help suppliers improve productivity and efficiency through innovation, which can help boost competitiveness in international markets.

Concerns over local impacts from industrialization, regionalization and local content requirements: In recent years, the installation of a wind farm has become faster and more efficient. At the same time, each new wind park has fewer turbines to service and are also less likely to break down and need frequent local repair work with much of the O&M work having been significantly optimized and digitized. In practical terms this means that the total workload required during installation and O&M of an offshore wind farm may be reduced over time, leaving less work for local (and other) suppliers. Further, there were concerns by some ports and suppliers over the long-term impacts from sector's continued globalization, notably the movement of production-related activities away from Denmark to global markets as well as the skewed implementation of local content policies and requirement in countries such as Denmark and the UK.

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RESPONDENTS

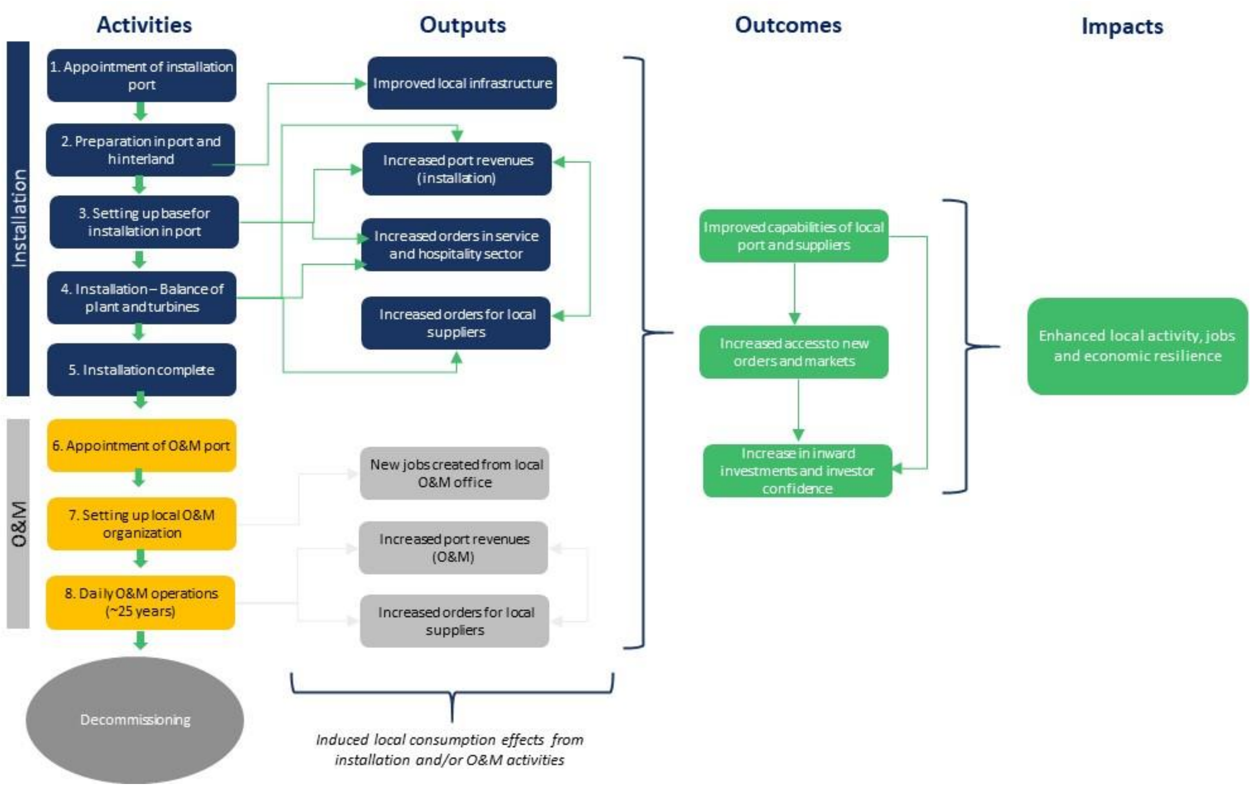
#	Organization	Job role	Case
R1	Orsted	Head of Operations (Anholt)	Grenaa
R2	Siemens Gamesa Renewable Energy	Head of Ports & Assembly	Grenaa/Ronne
R3	DAVAI	Managing Director	Grenaa
R4	DWP System Supplier	CEO	Grenaa
R5	Grenaa Havn	COO	Grenaa
R6	Ziton	CEO	Grenaa
R7	HSM Industri og Grenaa skibsværft	Director	Grenaa
R8	Norddjurs kommune	Borgmester	Grenaa
R9	Ronne Havn	Havnedirektor	Ronne
R10	Sydhavnens motorværksted	CEO	Ronne
R11	Bornholm	Borgmester	Ronne
R12	Jutlandia Terminal	Operations manager	Esbjerg
R13	Esbjerg Havn	COO	Esbjerg
R14	MHO-CO A/S	CEO	Esbjerg
R15	Ocean Team Group	Managing Director	Esbjerg
R16	Norsea Danmark	CEO	Esbjerg
R17	Semco	President and CEO	Esbjerg
R18	Business Esbjerg	Business consultant	Esbjerg
R19	Esvagt	Head of Commercial	Esbjerg
R20	Viking Lifesaving Equipment	Director	Esbjerg
R21	Hvide Sande skibsværft	Direktor	Hvide Sande
R22	Hvide Sande Havn	Havnedirektor	Hvide Sande

APPENDIX A: DANISH PORTS INVOLVED IN OFFSHORE WIND

Port	Type	Size	Offshore projects	Profile
Port of Esbjerg	All functions	4,500,000 m2	Multiple Danish and international offshore wind farms incl. Horns Rev 1-3	One of the leading global ports in pre-assembly, installation and service of offshore wind farms. Also acts as feeder port (secondary port) for other Danish and international ports.
Port of Grenaa	Installation and O&M port	1,425,000 m2	Anholt	Was the main pre-assembly and installation port for Anholt and currently O&M port. Ongoing projects activities related to offshore wind.
Port of Hvide Sande	O&M port	200,000 m2	Horns Rev 3 from 2024	Appointed by Vattenfall as O&M port for Horns Rev 3 which is currently serviced from Esbjerg. Also acted as base port during installation of Horns Rev 3.
Port of Ronne	Installation port	150,000 m2	Kriegers Flak (2020) and Arcadis Ost 1 (2022)	Appointed as installation port by Siemens Gamesa/Vattenfall for Kriegers Flak and by MHI Vestas for Arcadis Ost.
Port of Aalborg	Specialized port (Research and testing)			Host to the world's biggest center for testing wings for on- and offshore windfarms (Blaest)
Port of Romo	Base port		Butendik and Amrumbank	Base port for Siemens Gamesa, WPD and EON and larger service vessels.
Port of Aabenraa	Feeder port			Ships offshore wind towers from Valmont SM in Rodekro.
Port of Fredericia	Import/export port			Unloads large steel plates and components for domestic OWT production
Lindo Port of Odense	Specialized port (Research and testing)			Production and test of offshore wind components like nacelles for MHI Vestas, LORC or Bladt Industries
Port of Nyborg	Specialized port (Decommissioning)			First Danish port to decommission an offshore wind farm (Vindeby) which at the time of its initiation was the world's largest.
Port of Nakskov	Production port			Base to the production of wings for MHI Vestas offshore wind turbines. Recently expanded to fit wings of up to 148.5 meters.
Port of Rodbyhavn	O&M port		Rodsand II	Service port for Rodsand II which is operated by EON with 30 people and two CTVs.
Port of Koge	Base port			Has acted as base harbor for installation vessels and SOVs during the installation of foundations for Krieger's Flak.
Port of Klintholm	O&M port			Appointed by Vattenfall as service port for Kriegers Flak.
Port of Thyboron	O&M port			Strategy to become offshore O&M port and one of the contenders for Thor.
Port of Thorsminde	O&M port			Strategy to become offshore O&M port and contender for Thor.
Port of Frederikshavn	Specialized port (Decommissioning)			Identified by M.A.R.S. as key decommissioning port for the European offshore wind market.

Source: QBIS

APPENDIX B: THEORY OF CHANGE



Outputs (immediate, directly linked to specific offshore wind investment, temporary)

	Installation phase	O&M phase
Improved infra-structure and supporting facilities	The installation of an offshore wind project can require significant investments within and around the port. Within the port itself, initial investments may e.g. be required to ensure space for component storage and assembly activities. Investments may also be required within the wider port municipality, e.g. local road networks, helicopter platforms, emergency preparedness etc. As a result, the installation project is likely to facilitate improved infrastructure within and around the port.	The O&M phase generally require less space and specialized infrastructure than the installation phase as O&M vessels are smaller and the space required onshore is limited to the local O&M center and warehouse operations for smaller components, supplies and spare parts. Some of the ports interviewed were in the process of converting old warehouse facilities into dedicated O&M facilities with a view to attract future O&M contracts.
Increase in port revenues	During the installation phase, port revenues will increase from more vessel calls as well as lease of space, equipment and personnel for component storage, handling and pre-assembly. For a 1 GW wind farm, the model suggests around EUR 5 million total will accrue to the installation port/s. While this can be a substantial amount for an installation port it does not in itself offset the high upfront costs required for ports to facilitate offshore wind installations. The business case for ports therefore largely hinges on their ability to attract a continued flow of offshore wind projects. Further, installation ports also need to	The O&M phase generates a more moderate income for local ports compared to the installation phase. For a 1 GW wind farm, the model suggests the port can generate around EUR 0.5 million per annum. This covers docking fees for CTVs (or SOVs) and rent of space and facilities for the wind farm operator's local O&M operations. A single O&M project will therefore typically represent only a small part of the port's total revenue per annum. Unlike the installation phase which can last as little as 6 months, the O&M phase generates a steady flow of income for the port over a longer period of time as well as indirect and induced

	Installation phase	O&M phase
	consider the potential negative impact on existing businesses (e.g. goods transport) during peak periods.	impacts. Larger O&M operations – e.g. recoating of wings etc. – may also generate additional income for O&M ports with qualified suppliers in secondary sectors.
Increased turnover for *primary* or *secondary* suppliers (offshore wind companies and sub-contractors)	The choice of installation port can create new opportunities for local suppliers in primary and/or secondary sectors, cf. section 5.4. Except for port municipalities with highly specialized offshore supply chains like Esbjerg, the main opportunities for local suppliers are however likely to be within the secondary sector, i.e. as sub-contractors to the primary offshore wind contractors. The ability of local suppliers in secondary sectors to integrate into the offshore supply chain during an installation project depends largely on the quality and price competitiveness of local suppliers and, increasingly, their ability to collaborate with each other in local supplier networks, cf. e.g. Box 14.	Like the installation phase, there are several opportunities for local suppliers to partake in the O&M phase of an offshore wind farm. For O&M ports with specialized suppliers in offshore wind, one opportunity for local value creation is within the maritime operations involved in the daily service of the offshore wind farm, which requires supply of vessels (e.g. CTVs), crew, fuel, supplies etc. For O&M ports with limited activities in the offshore wind supply chain, local O&M operations may still generate activities and tasks which are suitable for local suppliers. As an example, Orsted has used a local steel supplier to build a training tower for them in Grenaa and uses another local supplier for turbine inspection and coating services, cf. Box 15 and Box 16.
Increased turnover for suppliers in *tertiary* sectors (e.g. local service and hospitality suppliers, local shops)	Tertiary sector impacts, including within the service and hospitality sectors, are frequently mentioned as an important local output from the installation of an offshore wind farms. During the installation phase, the wind farm developer and its main contractors will typically assign a team of specialists on the ground who are brought in from other locations. This may lead to a temporary increase in demand for local services such as hotels, restaurants, shops, transport etc. In addition, there will be an influx of crew from installation and service vessels which will need similar services. The size of this effect within the installation port municipality depends on whether hotel ships are used to host the crew but also on whether the project developers choose to set-up a crew base outside the installation port municipality, cf. e.g. Hvide Sande case in section 5.9.1. It is also important to note that as the installation phase gets shorter, tertiary sector impacts will be reduced.	Tertiary sector impacts from the O&M phase are mainly linked to the inputs required to service the local O&M office as well as the suppliers in secondary sectors. As an example, Orsted reports using "hundreds of local suppliers" to support their O&M operations in Grenaa, including local cleaning companies, catering companies, florists, sewage companies, etc. Another example is when large O&M suppliers enter the local port and require the support from local hotels, taxi companies, restaurants etc., cf. e.g. Box 18.
Hiring of local crew (O&M only)	The installation of an offshore wind farm will not normally imply hiring of local installation crew within the port municipality. Rather, the deployment of offshore wind personnel during installation commonly come from other locations as discussed above.	During the O&M stage a local O&M office is set-up within the O&M port. For this purpose, the offshore wind operator will hire administrative personnel and service technicians, some of whom may live within or in close affinity to the port municipality, thereby bringing new jobs to the local area. While the number of jobs is often limited – the model suggests an around 45 FTEs for a 1 GW offshore wind farm – the jobs can remain in the local area for the long-term. To service Anholt, Orsted has around 50 FTE (400MW) while Vattenfall expects to hire around 25-30 local FTEs from Horns Rev 3 in Hvide Sande (400MW).
Increased local consumption (induced)	In addition to the outputs described above, there are also induced local consumption effects for port municipalities during both the installation and O&M phase. Examples include when temporary onshore workers or offshore crew on installation vessels spend a portion of their salaries in local shops, restaurants, etc. during the installation phase. Finally, there are also induced impacts when the administrative workers or seafarers hired for local O&M operations spend part of their salaries within the O&M port municipality.	

Outcomes and impacts – (long-term, uncertain, difficult to attribute)

Diversification of the local port economy	The installation and O&M stages of an offshore wind project offer a potential for local ports to embark on a portfolio-based strategy to diversify their revenue streams, modernize their facilities and build greater resilience to external chocks. In the cases featured in this report, all four ports were faced with similar scenarios looking to diversify turnover from traditional business segments such as Oil & Gas and fisheries. In this context, projects related to the installation and O&M of offshore wind farms is a welcome chance to diversify the port's future income and generate a new source of growth. As ports are often important gateways to economic development and job creation within their wider municipalities, identifying a viable future revenue stream through attracting offshore wind investments to a given local port can play a significant role, not just for the port itself but also for the port's dependents.
Improved capabilities of local suppliers (primary and sec-ondary sectors)	The installation and O&M of an offshore wind projects creates economic activity and jobs within a given port municipality. A key variable is the extent to which a given port municipality can integrate local suppliers into the offshore wind supply chain beyond "just" service sector impacts. Securing orders from offshore wind customers may lead to varying degrees of upskilling and investments among local businesses, e.g. in terms of safety, quality, documentation, turnaround times, employee skills, internationalization, digitization and, increasingly, productivity. Port municipalities with strong existing supply chains within adjacent sectors such as offshore oil and gas are likely to have a head-start due to strong synergies in the assets and competences required. In port municipalities without the required skills and know-how in place, local supplier networks are emerging as a preferred model to build local competences in offshore wind and increase the attractiveness of local suppliers.
Increased access to new orders in offshore wind or adjacent sectors	One of the most important dynamic effects from the early Danish offshore wind investments is the potential they have offered local suppliers in terms of integrating into the global offshore wind supply chain. The comprehensive offshore wind supply chain that have emerged in Esbjerg is the best example of this to date and among the key attributor to Denmark's ability to deliver around 35-40% of all new offshore wind assets in Europe from 2010-2018. In Grenaa, while at a much smaller scale, the primary spin-off from Anholt has been the increased internationalization of local suppliers, who have managed to replicate the collaborative sourcing model developed during Anholt to a global market segment.
Greening local port municipali-ties and busi-nesses	A more subtle long-term outcome observed from the installation and O&M port municipalities interviewed include a strong local consciousness around sustainable development and renewable energy. Many of the respondents interviewed suggest that becoming a supplier to the offshore wind energy sector has had a fundamental impact on their business purpose and practices, encouraging both ports and local businesses to find more environmentally efficient ways of doing things and in some cases helping to attract employees.
Interregional synergies and capacity build-ing	The case studies also suggested that there can be important interregional linkages and synergies between domestic port municipalities involved in the installation and O&M of offshore wind farms. As an example, the Port of Esbjerg will play a key role as feeder port for Kriegers Flak, while local suppliers from Esbjerg such as Jutlandia with extensive experience in handling installation vessels will play a key role in supporting the Port of Ronne and its local suppliers on how to handle the installation vessels.
Enhanced local activity, jobs and economic resilience	An offshore wind farm will generate a number of project-specific economic outputs in its own right, incl. improved infrastructure, increased port revenues, increased orders with local suppliers in secondary and tertiary sectors, opportunities for generating permanent local jobs in the renewable energy sector (O&M only) and induced spending for the project-specific activities. However, given the costs and efforts required by local port municipalities to support the installation and service of offshore wind farms, a net positive contribution will largely hinge on the ability of the port and local suppliers to convert upfront investments and experiences into new projects, at home and abroad. For ports that manage to do so, offshore wind can potentially be transformative for the local economy, creating new sources of income, jobs and growth for the port as well as the economy at large. This has been the case in the port municipalities of Esbjerg and Grenaa, where the installation and O&M of Danish offshore windfarm have led to a number of subsequent outcomes that extent far beyond the scope and reach of the initial project. To understand the full impact potential of an offshore wind investment on local economies and jobs, such longer-term effects must also be considered.

Source: QBIS based on interviews with local ports and suppliers involved in installation and O&M of Danish offshore wind farms

APPENDIX C: SOCIOECONOMIC PROFILES OF FEATURES PORT MUNICIPALITIES

Port	Esbjerg	Grenaa	Ronne	Hvide Sande	DK – all
Municipality	Esbjerg	Nordjurs	Bornholm	Ringkobing-Skjern	
Population (2020)	115.483	37,089	39,499	56,594	5.822.679
Unemployment rate per 100, 17-64-yearold (2018) [1]	2.8	3.6	4.3	2.4	3.1
Share of 25-65-yearolds with higher education (2019) [1]	28.2	17.4	22.5	21.5	24.2
Share of 25-65-yearolds without vocational training (2019) [1]	20.4	23.6	23.8	21.0	21.2
Disposable income, 2018 [2]	224,598	207,855	202,976	221,198	235,312

Source: [1] http://www.noegletal.dk/ and [2] Danmarks Statistik

Appendix D: Model structure

Phase	Activity	
P1 - P5	**All**	
P1-Development	**1.0**	**Design and development**
P1-Development		
P1-Development	**1.1**	**Development and consenting services**
P1-Development	1.1.1	Environmental Impact Assessments (EIA)
P1-Development	1.1.2	Site selection
P1-Development	1.1.3	Project development
P1-Development	1.1.4	Financial feasibility
P1-Development	1.1.5	Access to grid connection
P1-Development	**1.2**	**Environmental surveys**
P1-Development	1.2.1	Benthic environmental surveys
P1-Development	1.2.2	Fish and shellfish surveys
P1-Development	1.2.3	Ornithological environmental surveys
P1-Development	1.2.4	Marine mammal environmental surveys
P1-Development	1.2.4.1	Offshore ornithological and mammal surveying vessels and craft
P1-Development	2.5	Onshore environmental surveys
P1-Development	**1.3**	**Resource and metocean assessment**
P1-Development	1.3.1	Structure
P1-Development	1.3.2	Sensors
P1-Development	1.3.3	Maintenance
P1-Development	**1.4**	**Geological and hydrographical surveys**
P1-Development	1.4.1	Geophysical surveys
P1-Development	1.4.1.1	Geophysical survey vessels
P1-Development	1.4.2	Geotechnical surveys
P1-Development	1.4.2.1	Geotechnical survey vessels
P1-Development	1.4.3	Hydrographic surveys
P1-Development	**1.5**	**Engineering and consultancy**
P1-Development		Engineering design
P1-Development	**1.6**	**Identification of specifications and raw materials**
P1-Development		
P1-Development	**1.7**	**Logistics management**
P2A - Wind turbines	**2.0**	**Wind turbines**
P2A - Wind turbines		
P2A - Wind turbines	**2.1**	
P2A - Wind turbines	2.1	Nacelle
P2A - Wind turbines	2.1.1	Bedplate
P2A - Wind turbines	2.1.2	Main bearing
P2A - Wind turbines	2.1.3	Main shaft
P2A - Wind turbines	2.1.4	Gearbox
P2A - Wind turbines	2.1.5	Generator
P2A - Wind turbines	2.1.6	Power take-off
P2A - Wind turbines	2.1.7	Control system
P2A - Wind turbines	2.1.8	Yaw system
P2A - Wind turbines	2.1.9	Yaw bearing

P2A - Wind turbines	2.1.10	Nacelle auxiliary systems
P2A - Wind turbines	2.1.11	Nacelle cover
P2A - Wind turbines	2.1.12	Small engineering components
P2A - Wind turbines	2.1.13	Structural fasteners
P2A - Wind turbines	2.1.14	Condition monitoring system
P2A - Wind turbines	**2.2**	**Rotor**
P2A - Wind turbines	2.2.1	Blades
P2A - Wind turbines	2.2.1.1	Structural composite materials
P2A - Wind turbines	2.2.1.2	Blade root
P2A - Wind turbines	2.2.1.3	Environmental protection
P2A - Wind turbines	2.2.2	Hub casting
P2A - Wind turbines	2.2.3	Blade bearings
P2A - Wind turbines	2.2.4	Pitch system
P2A - Wind turbines	2.2.4.1	Hydraulic pitch system
P2A - Wind turbines	2.2.4.2	Electronic pitch system
P2A - Wind turbines	2.2.5	Spinner
P2A - Wind turbines	2.2.6	Rotor auxillary systems
P2A - Wind turbines	2.2.6	Fabriucated steel components
P2A - Wind turbines	**2.3**	**Tower**
P2A - Wind turbines	2.3.1	Steel
P2A - Wind turbines	2.3.2	Tower internals
P2A - Wind turbines	2.3.2.1	Personel access and survival equipment
P2A - Wind turbines	2.3.2.2	Tuned damper
P2A - Wind turbines	2.3.2.3	Electrical system
P2A - Wind turbines	2.3.2.4	Tower internal lighting
P2A - Wind turbines	2.3.2.5	Coatings
P2B-Balance of plant	**3.0**	**Balance of Plant**
P2B-Balance of plant		
P2B-Balance of plant	**3.1**	**Cables**
P2B-Balance of plant	3.1.1	Export cables
P2B-Balance of plant	3.1.1.1	Cable core
P2B-Balance of plant	3.1.1.2	Cable outer
P2B-Balance of plant	3.1.1.3	Cable assessories
P2B-Balance of plant	3.1.1.4	Cable jointing and testing
P2B-Balance of plant	3.1.2	Array cables
P2B-Balance of plant	3.1.3	Cable protection
P2B-Balance of plant	**3.2**	**Turbine foundation**
P2B-Balance of plant	3.2.0	Design
P2B-Balance of plant	3.2.1	Monopile
P2B-Balance of plant	3.2.2	Jacket
P2B-Balance of plant	3.2.3	Transition piece
P2B-Balance of plant	3.2.3.1	Crew access system and work platform
P2B-Balance of plant	3.2.3.2	Internal platforms
P2B-Balance of plant	3.2.3.2	Davit crane
P2B-Balance of plant	3.2.3.4	J-tubes, I-tube or monopile entry point
P2B-Balance of plant	3.2.4	Corrosion protection - monopiles
P2B-Balance of plant	3.2.4	Corrosion protection - jackets
P2B-Balance of plant	3.2.5	Scour protection
P2B-Balance of plant	**3.3**	**Offshore substation**
P2B-Balance of plant	3.3.1	Electrical system

P2B-Balance of plant	3.3.1.1	HVAC system
P2B-Balance of plant	3.3.1.2	HVDC system
P2B-Balance of plant	3.3.2	Facilities
P2B-Balance of plant	3.3.2	Structure
P2B-Balance of plant	**3.4**	**Onshore substation**
P2B-Balance of plant	3.4.1	Buildings, access and security
P2B-Balance of plant	**3.5**	**Operational base**
P2B-Balance of plant	3.5.1	
P2B-Balance of plant	**3.6**	**Other costs**
P2B-Balance of plant	3.6.1	Site investigation (not in development phase)
P2B-Balance of plant	3.6.2	Insurance & Other items
P3-Installation	**4.0**	**Installation & grid connection**
P3-Installation		
P3-Installation	**4.1**	**Foundation installation**
P3-Installation	4.1.1	Foundation installation vessels
P3-Installation	4.1.1.1	Foundation handling equipment
P3-Installation	4.1.1.2	Foundation installation equipment
P3-Installation	4.1.1.3	Sea fastenings
P3-Installation	**4.2**	**Offshore substations installation**
P3-Installation	4.2.1.	Substation installation vessel
P3-Installation	**4.3**	**Onshore substation construction**
P3-Installation		
P3-Installation	**4.4**	**Onshore export cable installation**
P3-Installation		
P3-Installation	**4.5**	**Offshore cable installation**
P3-Installation	4.5.1	Cable laying vessel
P3-Installation	4.5.1.1	ROV
P3-Installation	4.5.1.2	Cable-handling equipment
P3-Installation	4.5.2	Cable burial
P3-Installation	4.5.2.1	Cable burial vessel
P3-Installation	4.5.2.2	Cable plough
P3-Installation	4.5.2.3	Trenching ROV
P3-Installation	4.5.2.4	Vertical injector and jetting sled
P3-Installation	4.5.3	Cable pull-in
P3-Installation	4.5.4	Electrical testing and termination
P3-Installation	**4.6**	**Turbine installation**
P3-Installation	4.6.1	Turbine installation vessel
P3-Installation	4.6.1.1	Turbine handling equipment and sea fastening
P3-Installation	4.6.2	Commissioning
P3-Installation	**4.7**	**Construction port**
P3-Installation		
P3-Installation	**4.8**	**Offshore logistics**
P3-Installation	4.8.1	Sea-based support
P3-Installation	4.8.2	Marine coordination
P3-Installation	4.8.3	Weather forecasting and metocean data
P3-Installation		
P4-O&M	**5**	**Operation, maintenance and service**
P4-O&M		
P4-O&M	**5.1**	**Operations**
P4-O&M	5.1.1	Training

P4-O&M	5.1.2	Onshore logistics
P4-O&M	5.1.3	Offshore logistics
P4-O&M	5.1.3.1	Crew tranfer vessels (CTV)
P4-O&M	5.1.3.2	Service operations vessels (SOV)
P4-O&M	5.1.3.3	Turbine access systems
P4-O&M	5.1.3.4	Helicopters
P4-O&M	5.1.4	Health and safety inspections
P4-O&M	5.1.4.1	Health and safety equipment
P4-O&M	5.1.5	Administrative personel
P4-O&M	**5.2**	**Maintenance and service**
P4-O&M	5.2.1	Turbine maintenance and service
P4-O&M	5.2.1.1	Blade inspection and repair
P4-O&M	5.2.1.1.1	Unmanned aerial vehicle
P4-O&M	5.2.1.2	Main component refurbishment, replacement and repair
P4-O&M	5.2.1.2.1	Large component repair vessel
P4-O&M	5.2.2	Balance of plant maintenance and service
P4-O&M	5.2.2.1	Foundation inspection and repair
P4-O&M	5.2.2.1.1	Remotely operated vehicle (ROV)
P4-O&M	5.2.2.1.2	Autonomous underwater vehicle
P4-O&M	5.2.2.2	Cable inspection and repair
P4-O&M	5.2.2.3	Scour monitoring and management
P4-O&M	5.2.2.4	Substation maintenance and service
P4-O&M	5.3	**Other costs**
P4-O&M	5.3.1	OEM WTG monitoring and technical support
P4-O&M	5.3.2	Turbine Electricity consumptions
P4-O&M	5.3.3	Wind & Weather Monitoring
P4-O&M	5.3.4	Fees leases, taxes and insurance
P5-Decommissioning	**6.0**	**Decommissioning**
P5-Decommissioning		
P5-Decommissioning	**6.1**	**Turbine decommissioning**
P5-Decommissioning		
P5-Decommissioning	**6.2**	**Foundation decommissioning**
P5-Decommissioning		
P5-Decommissioning	**6.3**	**Cable decommissioning**
P5-Decommissioning		
P5-Decommissioning	**6.4**	**Substation decommissioning**
P5-Decommissioning		
P5-Decommissioning	**6.5**	**Decommissioning port**
P5-Decommissioning		Included in each of the above
P5-Decommissioning		