POLISH WIND
ENERGY ASSOCIATION

VISION FOR THE BALTIC SEA. VISION FOR POLAND. DEVELOPMENT OF OFFSHORE WIND IN THE BALTIC SEA REGION

PWEA Report

September 2020

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SUMMARY

The Baltic Sea has always played a key role in economic development of the region. Today it has an opportunity to become a foundation for Europe's energy transition based on offshore wind power. The European Union is a leader in the fight against global warming. The Member States have committed to increase the production of energy from renewable sources. During the next decade (2021-2030) the share of RES in the EU is set to increase from 20% to 32%. The Baltic Sea has a number of advantages favouring the development of offshore wind farms. Offshore farms will contribute to meeting the region's energy demand, especially in Poland. There are currently twelve offshore wind projects under development in the Polish part of the Baltic Sea, and two projects have already received grid connection agreements: Bałtyk III, a joint project of Norwegian company Equinor and Polenergia, and PGE Baltica 3. The total capacity for grid connection agreements amounts to 2,245 MW.

According to data from the report "Our energy, our future" developed by experts from BVG Associates in cooperation with WindEurope, offshore wind farms in the Baltic Sea are expected to reach a total capacity of 83 GW. The report expects the highest capacity to be located in Poland (28 GW), Sweden (19.8 GW) and Finland (15.5 GW). For these plans to become reality, we need involvement of investors, suppliers, governments and international cooperation between all the countries in the Baltic Sea region. There are currently five fundamental challenges of key importance to the development of offshore wind farms in the Polish part of the Baltic Sea. These include: ensuring adequate legal framework, providing a support scheme for investment projects, increasing interconnection capacity in cooperation with other countries of the region, environmental impact assessment studies and creating a stable supply chain. Cooperation between countries in offshore wind can result in hybrid projects that can pave the way to a more coordinated and cost-effective development of offshore wind in the whole of Europe.

Offshore wind farms will be commissioned gradually. A wind farm in its operation phase is expected to operate for 25 years and generate revenues to the public finance sector throughout that period. The development of offshore wind power will also generate new jobs. During the stage of development and construction of offshore wind farms approx. 34,000 full-time jobs will be needed, while operation and maintenance of completed wind farms will generate about 29,000 jobs. Demand for workforce will increase not only in the sectors directly linked to the power and wind industry, but also in public administration, construction, finance, transport, services, etc. This means that the development of offshore wind farms can become not only a driver for the maritime industry, but also for other sectors of the economy. Poland has a particular potential for development of offshore wind. Already now the country has multiple manufacturers, e.g. of cables and power equipment, who are able to supply materials and equipment to build the grid connection for offshore wind farms.

Offshore wind power is a key technology for development of renewables in Poland. Poland's Energy Policy (PEP 2040) recognizes the development of offshore wind power as one of strategic projects for the Polish energy sector. Offshore wind is the most predictable source of electricity among all renewables, with higher capacity factors than onshore wind and PV. In addition, similarly to onshore wind, it has the highest share of domestic suppliers and the highest potential of positive impact on the economy. Moreover, offshore wind power is a technology that could allow for emissions reduction and help Poland meet its EU climate obligations recommended by the European Commission.

Full utilisation of the potential of onshore and offshore wind will allow for a transition of the energy system towards a low-carbon economy and help ensure energy security of the region. Development of offshore wind farms will make our electricity "greener" and more affordable, and the power sector more environmentally friendly.

1 INTRODUCTION

Europe is exploring how to become the first carbon-neutral continent by 2050. This would contribute to limiting global warming to less than 2°C and pursuing efforts to limit it to 1.5°C in line with the Paris Climate Agreement. To achieve this, Europe will have to transform its energy system by replacing fossil fuels with renewable electricity across the economy. According to the Communication "European Green Deal" of 4 March 2020, the European Commission issued a legislative proposal on European Climate Law. The European Climate Law proposal sets a binding target for climate neutrality, including reducing greenhouse gas emissions to zero net levels by 2050 (compared to 1990) at the level of the entire European Union and obliges the European Parliament, the Council and the EC and Member States to introduce EU and national funds necessary to achieve this goal.

The Polish energy mix, which is 80 percent coal-based, needs essential changes. Poland should look for alternative energy sources. One of such directions is the development of green technologies – renewable energy. Polish government documents indicate the importance of offshore wind energy as a key technology in the further development of renewable energy in Poland and point to the development of offshore wind energy as one of the strategic projects across the Polish energy policy.

The development of offshore wind energy is an opportunity for energy transformation in Poland and increasing the share of renewable energy to at least 25% in 2030 according to the recommendations of the European Commission from June 2019 to be compatible with the GHG emissions reduction targets. Offshore wind farms will enable safe operation of the power system during the period of necessary shutdown of inefficient power plant blocks based on hard coal and lignite. This will create an opportunity for the Polish power system to be based on cost-effective, environmentally friendly and innovative solutions.

Offshore wind energy is at the core of how Europe can go carbon-neutral. The European Commission estimates that an installed capacity of between 230 and 450 GW could be needed by 2050, making it a crucial pillar in the energy mix together with onshore wind. As emphasized by the European Commission in the European Green Deal, increasing offshore wind production will be essential, building on regional cooperation between Member States. The European Commission's offshore wind strategy is expected to be presented in October 2020.

Recent offshore wind projects are cheaper than new nuclear power capacity and gas-fired power plants. Offshore wind has lower variability and high capacity factors, which according to the International Energy Agency (IEA) range between 40% and 50% for new projects.

Today there is over 22 GW of installed offshore wind capacity in European waters, of which around 2.2 GW is in the Baltic Sea (Denmark 879 MW, Finland 70 MW, Germany 1,074 MW and Sweden 192 MW). According to the report, prepared by BVG Associates (BVGA) for WindEurope, scaling up from 22 GW today to 450 GW by 2050 will require a visionary approach. The current 2030 policy framework could deliver 111 GW by 2030. WindEurope expects that 9 GW could be easily deployed in the Baltic Sea by 2030. With the right ambitions from governments and intensified regional cooperation, this could increase to more than 17 GW. Governments must start setting the course for enabling higher levels of deployment. And they need to do it now. Countries with offshore wind resources have a geographical responsibility to lead Europe in this.

Installations in the Baltic Sea could reach 83 GW by 2050, according to WindEurope's latest report. This would make the Baltic Sea the second-largest basin for offshore wind in Europe, after the North Sea. The cumulative potential capacity identified in the Baltic Sea by the European Commission (BEMIP Final Report, 2019) exceeds 93 GW, with a generation of 325 TWh/year (around 30% of the total energy consumption of the Baltic countries in 2016). Members States shall define clear climate and energy targets to build the basis for the expansion of the internal offshore markets and exploit the added value that the sector brings.

The Polish share in the total offshore wind farm capacity in 2050 forecast by WindEurope amounts to 28 GW. Therefore, Poland may become the offshore wind leader in the Baltic Sea, with potential for one-third of capacity that could be installed in the area.

PWEA welcomed the publication of the Polish draft law on the promotion of electricity generation in offshore wind farms (the Offshore Wind Act), whose adoption and entry into force is a necessary condition for investors to invest in offshore wind farms, adapt the necessary infrastructure and prepare for the provision of services and supplies of goods by supply chain entities for the offshore market.

As the wind industry, we count on the smooth handling of the document in Parliament and we hope that the regulations contained in the Act come into force before the end of 2020. This is a key condition enabling the production of energy from wind farms in the Baltic Sea as early as 2025. According to the industry, these regulations should ensure predictability and stability of the development of the first projects thanks to the support system, which is based on contracts for difference (CfD).

2 METHODOLOGY

Preparing the report let us through several stages. This document is based on the report "Our energy, our future. How offshore wind will help Europe go carbon-neutral" by WindEurope and BVG Associates. The data and methodology of this report are based on BVG Associates standards.

First BVG established a realistic basis for the location of 450 GW of offshore wind across the North Seas and southern Europe. We expect that 380 GW of the 450 GW of offshore wind (85% of the expected capacity by 2050) will be developed in the North Seas (the Atlantic off France, Ireland and the UK, the North Sea, Irish Sea and Baltic Sea). This is based on the good wind resources, proximity to demand and supply chain efficiencies. BVG expect that large demand centres continue to be located around these North Seas because the wind resources and site conditions are good, and because there is less potential for economic solar electricity generation than in the southern parts of Europe.

Second, BVG established a vision for offshore wind and associated infrastructure in 2050, covering four areas:

- The wider energy system;
- Offshore wind technology;
- Offshore grids;
- Spatial planning and site allocation.

Third, BVG discussed and validated:

- The locations for offshore wind and the 2050 vision;
- The key challenges in achieving the vision of 450 GW by 2050;
- The national and international actions needed to address these challenges.

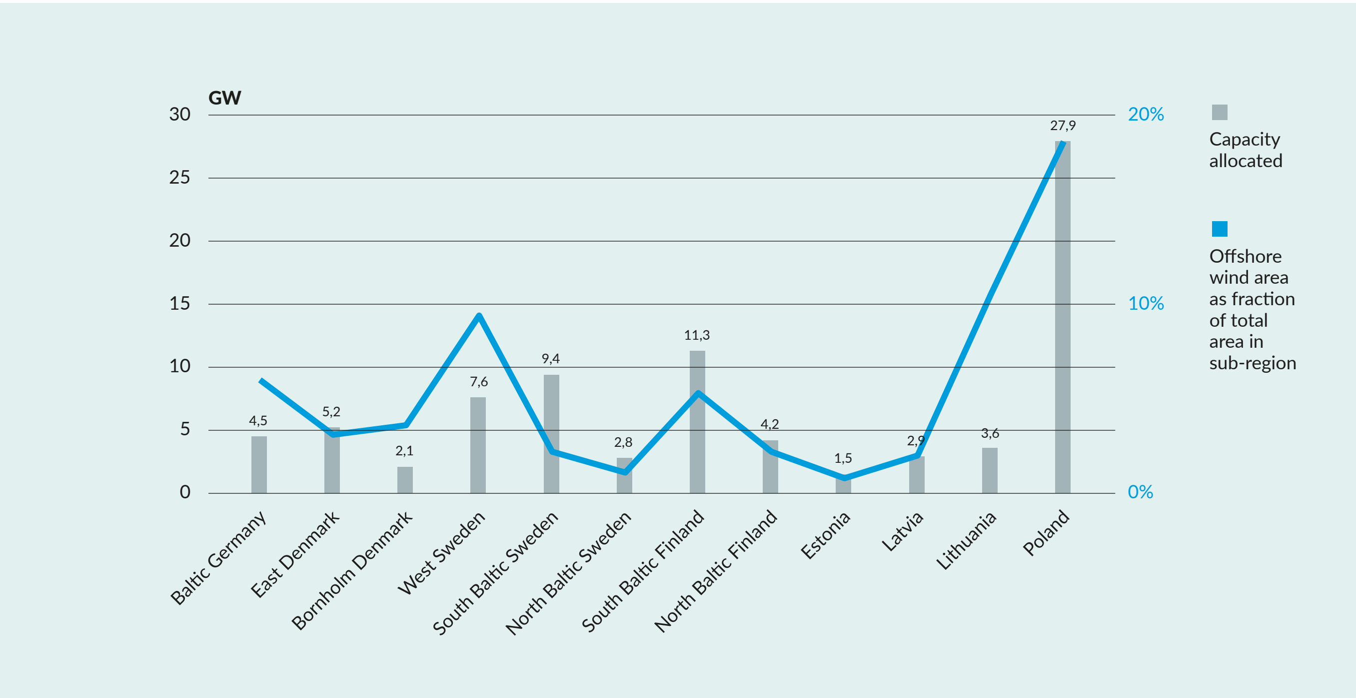
BVG subdivided the EEZs of Ireland, France, the UK, Denmark, Germany, Sweden and Finland because of the complexities associated with the use of these areas. BVG did not subdivide the EEZs of Belgium, the Netherlands, Norway, Estonia, Latvia, Lithuania and Poland.
For each country, BVG calculated the offshore wind capacity needed to meet the electricity demand located 100 km from the coast and for the rest of the country. Where more capacity is available than the total demand in a country, this is used for exports.

3 BALTIC SEA

3.1 General information for Baltic Sea Region

Using the methodology outlined above, we allocated the 380 GW of offshore wind to the sub-regions of the all North Seas which results in 83 GW of the Baltic Sea. In Table 1 and Figure 1, the sub-regions are shown by country: Germany, Denmark, Sweden Finland, Estonia, Latvia, Lithuania and Poland. The biggest capacity allocated is in Poland (28 GW), Finland (15.5 GW) and Sweden (19.8 GW). Additionally, the chart presents offshore wind area as fraction of total area in each sub-region (%). The offshore wind area covers almost 16.6 thousand km^2 and the total sub-region sea area is almost 400 thousand km^2.

Figure 1 Offshore wind capacity (GW) allocated in Baltic Sea countries and offshore wind area as fraction of total area in each sub-region (%)



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

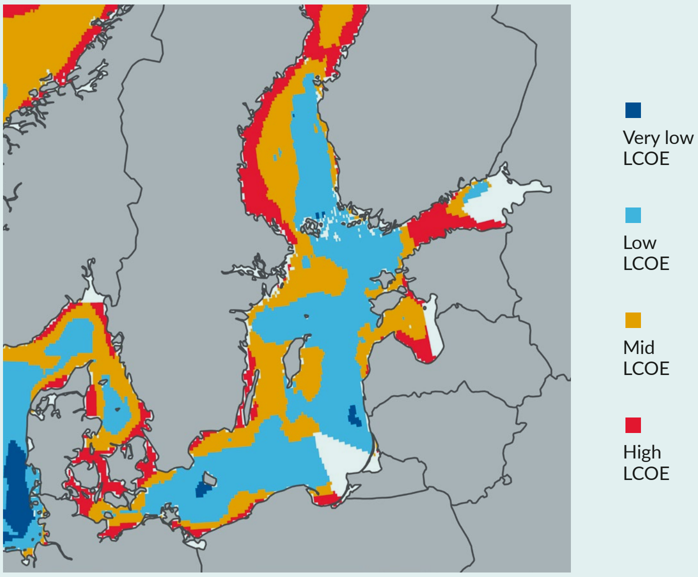
Table 1 Location of offshore wind in Baltic Sea, by subregions

Sub-region of country	Capacity allocated (GW)	Offshore wind area (km^2)	Total sub-region area (km^2)	Offshore wind area as fraction of total area in sub-region
Baltic Germany	4.50	900	14,998	6.00%
East Denmark	5.20	1,040	33,443	3.10%
Bornholm Denmark	2.10	420	11,520	3.60%
West Sweden	7.60	1,520	16,206	9.40%
South Baltic Sweden	9.40	1,880	86,381	2.20%
North Baltic Sweden	2.80	560	52,794	1.10%
South Baltic Finland	11.30	2,260	42,983	5.30%
North Baltic Finland	4.20	840	38,493	2.20%
Estonia	1.50	300	36,438	0.80%
Latvia	2.90	580	28,360	2.00%
Lithuania	3.60	720	6,839	10.50%
Poland	27.90	5,580	29,984	18.60%
TOTAL	**83.00**	**16,600**	**398,439**	**4.00%**

3.2 Costs without spatial exclusions

Figure 2 shows the LCOE ranges for the Baltic Sea including the grid connection cost. It is based on the wind speed, distance to shore and water depth of each 5 x 5 km coordinates in the map. It assumes 15 MW turbines and connection to the nearest onshore point. We grouped the values into the following LCOE bands:

Figure 2 **Relative LCOE for offshore wind in the Baltic Seas (without spatial exclusions)**



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

We consider the first two LCOE bands economically attractive today. But in reality, these estimations are conservative for future projects. Table 2 shows the amount of sea area in each sub- region in different LCOE bands overall, and the amount that would require floating technology. Generalizing, low LCOEs dominate in the whole Baltic Sea area. In Poland, 27% of the area is low-LCOE for bottom fixed and 38% for floating technologies due to water depth.

Table 2 **Percentage of area in the Baltic Sea, split according to LCOE range (without spatial exclusions) and water depth (<50m, >50m)**

SUB-REGION	Very low LCOE		Low LCOE		Mid LCOE		High LCOE		Points not analysed
	<50 m	>50 m	<50 m	>50 m	<50 m	>50 m	<50 m	>50 m	
Baltic Germany	0%	0%	48%	0%	20%	0%	18%	0%	14%
East Denmark	0%	0%	21%	0%	31%	1%	30%	0%	16%
Bornholm Denmark	9%	0%	20%	70%	0%	0%	0%	0%	2%
West Sweden	0%	0%	4%	9%	28%	24%	20%	4%	11%
South Baltic Sweden	0%	0%	15%	28%	18%	29%	4%	0%	6%
North Baltic Sweden	0%	0%	0%	0%	7%	34%	25%	23%	11%
South Baltic Finland	0%	0%	12%	28%	12%	19%	23%	1%	6%
North Baltic Finland	0%	0%	42%	18%	7%	11%	7%	3%	12%
Estonia	0%	0%	14%	26%	22%	6%	9%	9%	14%
Latvia	2%	0%	16%	41%	13%	3%	12%	0%	12%
Lithuania	5%	0%	37%	46%	1%	1%	0%	0%	9%
Poland	0%	0%	27%	38%	13%	7%	7%	2%	6%

0%–14% 15%–39% 40%–100%

Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

3.3 Costs with spatial exclusions

In at least 65% of the Baltic Sea it is currently not possible to build offshore wind farms. This amounts to 260,000 km^2. The total area of the Baltic Sea needed for 83 GW of offshore wind would be 16,600 km^2. This is 4.1% of the total area of the Baltic Sea, without considering exclusion zones. Table 3 shows the extent of spatial exclusions, like: protecting biodiversity, economic development at sea and national security. Fishing, shipping lanes, sand extraction, telecoms, pipelines and other activities could coexist with the right policies.

Table 3 Offshore wind use and exclusions in the Baltic Sea by sub-region

SUB-REGION	Percentage of total sea area available for offshore wind	Percentage of total sea area excluded for offshore wind	Offshore wind as a percentage of total sea area	Offshore wind as a percentage of total non-excluded sea area
Baltic Germany	7%	93%	6%	88%
East Denmark	8%	92%	3,10%	41%
Bornholm Denmark	19%	81%	3,60%	19%
West Sweden	16%	84%	9,40%	58%
South Baltic Sweden	36%	64%	2,20%	6%
North Baltic Sweden	46%	54%	1,10%	2%
South Baltic Finland	50%	50%	5,30%	11%
North Baltic Finland	22%	78%	2,20%	10%
Estonia	27%	73%	0,80%	3%
Latvia	55%	45%	2,00%	4%
Lithuania	54%	46%	11%	20%
Poland	52%	48%	19%	36%

Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

There are 5 sub-regions (Baltic Germany, East Denmark, West Sweden, Lithuania and Poland) where offshore wind would need more than 20% of the available area outside the exclusion zones. These are shaded in Table 3. Moreover, there are two additional sub-regions where offshore wind would need more than 50% of the area outside the exclusion zones. These are the west of Sweden and the German Baltic. For the Swedish and German areas, the main reason for the exclusions is the proximity to shore of large areas of the sub-regions. These are excluded as there is typically a preference to avoid near-shore areas which are visible from the coast. For the west of Sweden and the German Baltic to deliver their share, social acceptance of viewing offshore wind from the shore would need to be explored.

3.4 Reducing the impact of exclusions

For 83 GW to be developed with the most efficient use of space and at the lowest cost, multi-use of space and international collaboration will be needed.

Having the ability to easily share the sea area with other users is central to having cost-effective offshore wind. Offshore wind can coexist with other activities such as aquaculture, some fishing techniques, energy generation, e.g. by PtX, and storage. Crucially, offshore wind can also contribute to seabed restoration and the protection of marine biodiversity. To enable this, multiple-use options should be clearly defined in each country's maritime spatial planning (MSP) and they also need to be backed up by a clear regulatory framework to ensure that all different activities take place safely and efficiently.

For sub-regions where offshore wind will take up more than 10% of the sea area, the neighbouring sub-regions could have an increased amount. For example, the amount of offshore wind in Poland could be shared with areas to its north, like Denmark and Sweden. Collaboration between countries will clearly be needed to maximize these opportunities. Such sharing could further reduce overall average LCOE. For example, in Baltic Denmark, there are low LCOE areas that could be of use in powering western Sweden. In Bornholm, there are low LCOE areas that could be of use in powering Poland.

Therefore, countries should explore how to do joint projects where exclusion zones in one country increases the cost of offshore wind. Today there are no examples of projects developed jointly under this approach.

Countries could also execute offshore hybrid projects, which combine an interconnector with offshore wind farms connected to it. This would reduce the overall space needed for both offshore generation and transmission. Offshore hybrids are also attractive because they would increase the interconnectivity across countries, allowing the electricity to flow where needed, making offshore wind the new baseload generation. Especially for the Baltic Sea they would allow the region to become independent from the Russian and Belarusian systems.

The European Commission has found in preliminary assessments that hybrid offshore wind projects would generate environmental and planning benefits as well as potential costs savings.

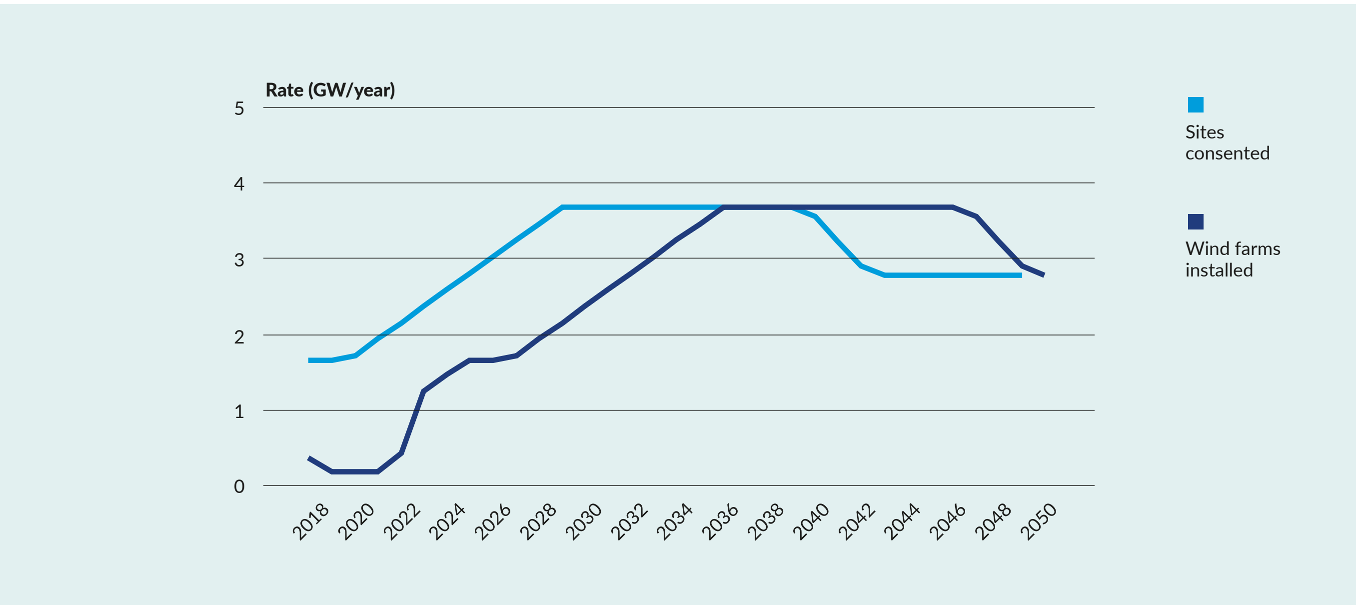
4 HOW TO DEPLOY 83 GW IN THE BALTIC SEA?

Today the whole of Europe installs around 3 GW of offshore wind per year. To become carbon-neutral it will need to significantly accelerate the installation rate over a sustained period.

Figure 3 shows the consenting and installation rates required in the Baltic Sea to achieve the 83 GW needed to meet the 450 GW overall in 2050 in all Europe. The annual rate of consenting needs to increase from 2.2 GW (430 km^2) to 3.4 GW (670 km^2) in the late 2020s. In the 2030s, this rate needs to grow even further: we need 3.6 GW (720 km^2) per year between 2030 and 2040.

Table 4 shows the consenting rates required to achieve this. The highest consenting rate is 3.6 GW p.a. or 720km^2 p.a. across the Baltic Sea. This is over 50% more than the rate required up to 2025.

Figure 3 Consenting and installation rates required to achieve 83 GW by 2050 for the Baltic Sea



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

Table 4 Consenting and installation rates required to achieve 83 GW by 2050 for the Baltic Sea

	AVERAGE RATE						TOTAL CAPACITY
	2019 to 2025	2026 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	by 2050
Installed (GW p.a.)	0.8	2.0	3.0	3.6	3.6	3.4	83
Consented (GW p.a.)	2.2	3.4	3.6	3.6	3.2	3.2	
Consented (km^2 p.a.)	430	670	720	720	640	630	

OFFSHORE WIND FARM DEVELOPMENT STAGES

The timing to build offshore wind farms shown in Figure 4 is indicative. There can be a large variation per project and activities can be carried out in a different order across countries.

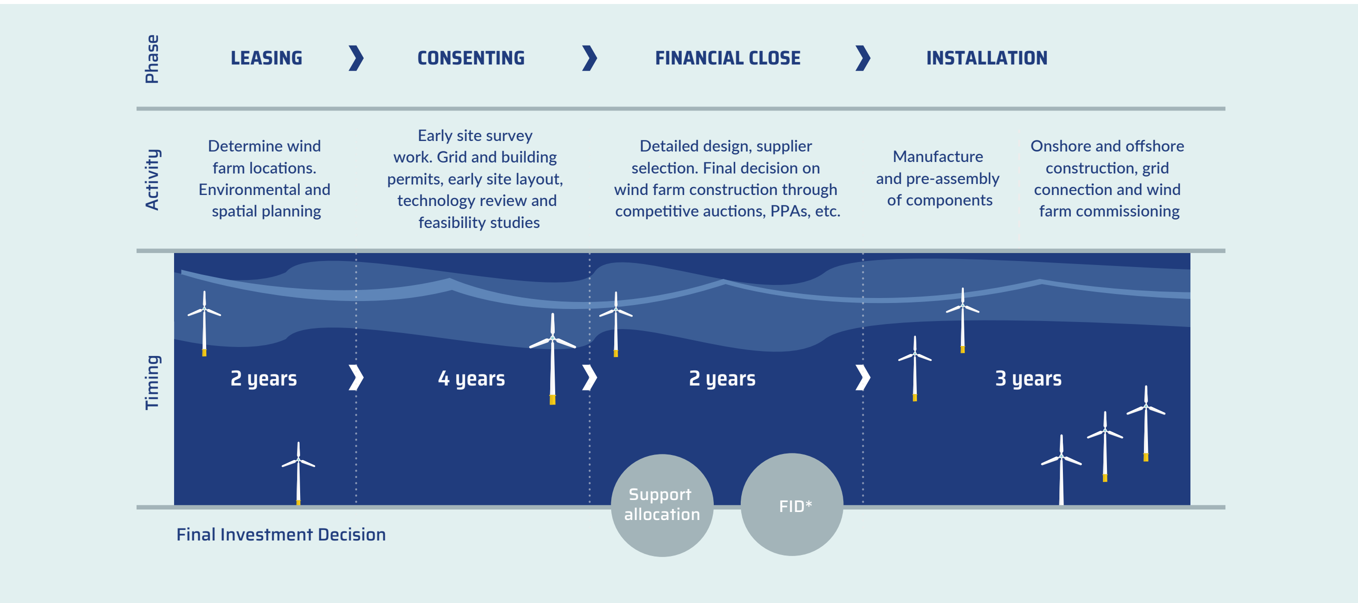
→ Leasing. This comprises the process of selecting wind farm locations, taking into account environmental, maritime spatial planning (MSP) and other user considerations. Typically, it takes 2 years. Leasing is complete when a developer has secured the exclusive right to develop a wind farm in a given location, normally as part of a competitive process.

→ Consenting. This comprises securing the relevant permits to construct and operate the project including transmission assets. The front-end engineering design and the early site surveys run in parallel to the permitting process. Typically, it takes 4 years; 2 years to gather data and 2 years to gain consent. In some cases, projects can take significantly longer. Some projects may fail for economic or environmental reasons during this stage. Consenting is complete when a developer has obtained consent to install and operate the project.

→ Financial close. This phase includes a detailed design, procurement and positive financial investment decision to construct the wind farm. Often this stage also includes securing a power purchase contract for the electricity that will be produced. This may be as part of a competitive process. Typically, this process takes 2 years from consent, depending on the timing of any competitive auctions. Some projects may fail to proceed beyond this stage, but the impact of this on necessary development rates is not modelled.

→ Installation. This phase includes onshore and offshore construction and grid connection. It also comprises the manufacture and pre-assembly of components prior to installation. It takes about 3 years from the point of financial close to completion. The wind farm is commissioned once it starts generating and transmitting power back to shore.

Figure 4 Offshore wind farm development stages



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

In parallel with the development of the site, the onshore grid needs to be ready to receive the power. This may only require a new connection to the wind farm, but may also require reinforcements to the grid. It could experience long delays given the multiple stakeholders along the cabling route. Therefore, early planning is essential to deliver projects on time. Onshore grid development can take up to 10 years to plan and coordinate with the offshore grid.

5 CHALLENGES FOR 83 GW IN THE BALTIC SEA

There are many challenges to realising the 450 GW in the whole Europe from which 83 GW could be installed in the Baltic Sea region. In this chapter we analyse some of them in depth to provide actions and recommendations to policymakers and the industry. The main challenges are: ensuring enough sites, environmental impacts, getting supply to the demand; enabling timely investment, and expanding the supply chain. We present country-specific recommendations in the last section to realise this vision.

5.1 Ensuring enough sites

The point at which the developer (or in some cases, government) starts its activities for a site will typically begin approximately nine years before the farm is installed. This period will vary between jurisdictions. This shows that we need a significant ramp-up in the rate of site development from 2020.

Site development also requires that maritime spatial planning (MSP) has secured broad agreement that the site is to be used for offshore wind and that the site will have a grid connection to enable the transmission of power to users, so early progress in these areas is especially important.

Offshore wind can share the sea with other activities, such as aquaculture and some fishing techniques. It can share space with natural protected areas too. Conversely, offshore wind may be excluded from areas for sand and gravel dredging, major shipping lanes, cable and pipeline routes, and military uses. However, investment in infrastructure to deploy current radar and other mitigation technology and further advances in technology with time will help minimize the impact of offshore wind in this regard.

Governments will need to coordinate with one another on maritime spatial planning. They will also need to provide signals to industry that they understand the rate of development required and that this will be supported. Such signals are particularly powerful if provided at a pan-European level. They help support a stable market in which successful development leads to further certainty and stability.

National governments will need to facilitate national and local consenting bodies and statutory consultees with the resources to assess and go through consenting on enough sites to achieve the necessary rate of offshore wind development. This is especially important in terms of maritime spatial planning which is most beneficial if it informs site decisions before leasing commences.

To ensure that jurisdictions meet the required rate of development, it may be necessary for governments to become more involved in facilitating early site identification and timely consenting processes. As an industry we cannot afford to expend resources developing many projects that do not get built.

Finally, governments can support the offshore wind industry by reinforcing the message that the use of the seas for offshore wind will help us to achieve our climate goals. They must work to maximize shared use, so that offshore and coastal stakeholders are as supportive as possible about offshore wind at this scale.

5.2 Environmental impacts

As a society and as an industry, we need to know that building this level of offshore wind is the right decision for the environment. To know this, we need comprehensive data about the offshore environment: both about species and habitats, and about the cumulative environmental impact of offshore wind. This also includes the shoreline and onshore impacts of export cabling.

Gathering and analyzing this environmental information can take many years. National and international bodies will need to work together and take a strategic approach to the assessment of future offshore wind impacts, both at a project level and also with regard to underpinning research and survey work.

The environmental impacts of offshore wind can be positive. Offshore wind can improve the marine environment by supporting new growth on the artificial reefs created by cabling and turbine foundations, and by protecting sea life in non-fishing areas.

The environmental and social acceptance of development of more farms is vital for the energy transition. The offshore wind industry will therefore need to continue to work closely with governments and non-governmental organizations (NGOs) to achieve this.

5.3 Getting supply to the demand

The development of offshore wind needs the right electricity infrastructure. It needs to anticipate the growth of offshore (and onshore) wind energy so that there is a strong system to get the power produced to the demand locations.

Across Europe transmission system operators (TSOs) will need to connect more offshore wind to the grid.

Planning for enough grid infrastructure is crucial to ensure that current and future projects will not be jeopardized by delays or high costs of deployment and significant curtailment rates.

Overall, a good electricity grid will support household and industrial consumers across Europe, providing affordable renewable electricity. The direct use of electricity is the most efficient method of electricity deployment. Therefore, the major part of the electricity infrastructure will be the electricity grid. Complementing this, power-to-x should be a solution for decarbonizing industry or transport, where direct electricity use is less efficient or is not possible.

BUILDING THE GRID

Offshore point-to-point connections

In most markets, offshore wind farms are connected back to dedicated points on the onshore grid, e.g. in locations at the edge of the grid, or some offshore wind farms can be connected straight back to shore.

Hybrid offshore projects

A hybrid offshore wind project is one where an offshore wind project connects into an offshore electricity interconnector. Hybrid offshore wind projects allow offshore wind power to be used by more than one country. The links between countries mean that power can be used where it is needed by being traded between the countries. This further enables the energy system to match supply with demand.

Building a transmission connection to the offshore interconnector (rather than to the shore) reduces shoreline connections, along with the environmental impact on the shoreline. Generally, the length of the transmission link for the offshore wind farm will also be shorter, reducing cost.

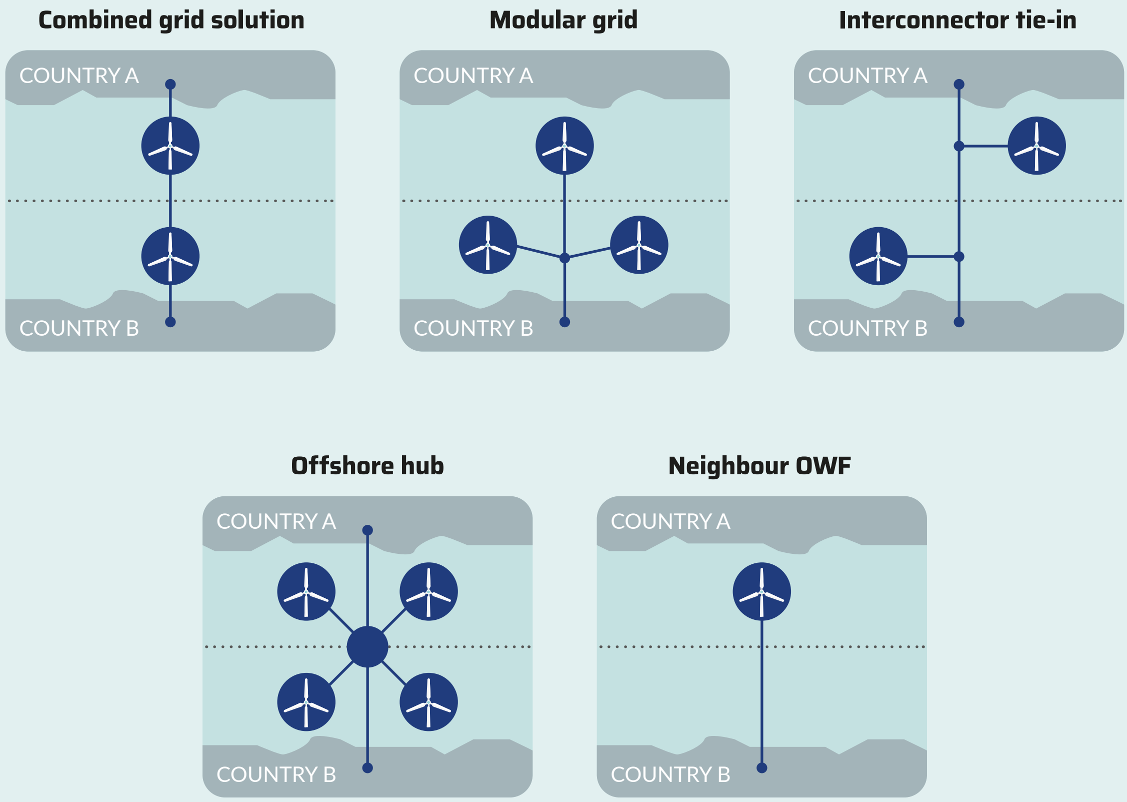
It makes sense to jointly develop offshore wind farms and their grids. However, cross-border hybrid projects are currently not straightforward. The only such example of such a project – Kriegers Flak – has been in the making for 10 years. After overcoming multiple challenges, the project is going ahead connecting Germany and Denmark, a downsizing of its original plan (which had included Sweden).

Planning for the right hybrid projects could pave the way towards more coordinated offshore wind development in Europe, and ultimately deliver the significant volume of projects and grids on time at an affordable price for society.

OFFSHORE HYBRID PROJECTS: THE BEGINNING OF AN OFFSHORE MESHED GRID

A hybrid offshore project is one where an offshore wind project connects into an offshore electricity interconnector. Hybrid offshore wind projects therefore allow the offshore wind power to be used by more than one country and allow for more efficient use of space in the sea. They could potentially enable the integration of innovative technologies like power-to-x.

Hybrid projects are classified as follows:



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

Hybrid projects should be always evaluated on a case-by-case basis. They will not always be advantageous over a regular wind farm to the different conditions and technical design. However, the most advantageous hybrid projects studied so far can realise savings of €300m–€2500m over the project lifetime, saving 5–10% of the total project cost*.

Given these potential benefits, Members States should act decisively in removing the barriers for offshore hybrids. Key actions include starting the regional cooperation between countries in an early stage, and together with the European Commission, enhancing the allocation of different funds to de-risk the projects. Hybrid projects could improve the efficient use of space in the North Sea, ensuring meeting both the offshore wind volumes and interconnection targets on time.

** U. Weichenhain, S. Elsen, T. Zorn and S. Kern, "Hybrid projects: How to reduce costs and space of offshore developments. North Seas Offshore Energy Cluster study," Roland Berger BmbH, Brussels, Belgium, 2019.*

Developing an offshore meshed grid

Offshore wind farms can connect to offshore infrastructure that is purpose-built for them (modular grid), as well as to dual-purpose offshore interconnectors (offshore hubs). In Germany and Belgium, there are already shared offshore connection points where multiple farms connect offshore and use the same link back to shore. Any shared connections including combined grid solutions and the interconnector tie-ins can be called "meshed" grids. Meshed grid connections can be primarily interconnectors (electrical connections between countries) or primarily offshore wind links. Once wind farms are connected in this way, they form part of a single and resilient grid system, combined with the onshore grid. A meshed grid imposes a lower environmental burden on the coastline than multiple single connections. It also uses the infrastructure in a more efficient way, which helps reduce cost and increase social acceptance. In the long-run, it could increase the overall security of supply in Europe. In particular, it could enable the dispatch of wind power generated from one country to another during periods of low demand.

The technical and regulatory requirements for an international meshed grid are more demanding than for the dedicated wind farm grid connections. To ensure that the investments can be made in parts of a meshed grid system in time to meet the 450 GW ambition in the whole of Europe, including 83 GW in the Baltic Sea, we need to start developing the regulatory framework now.

The ENTSO-E Ten Year Development Plan (TYNDP) foresees to 2030 €27bn (out of €114bn) for 21 individual projects that would develop into a "Northern Seas Grid Infrastructure". This is a step in the right direction. But the ENTSO-E modelling is based on 40-59 GW offshore wind by 2030 and a maximum of 127 GW by 2040. Government ambitions in the draft National Energy and Climate Plans (NECPs) submitted to the European Commission by Member States have indicated 78 GW of offshore wind by 2030. This is likely to increase to 89 GW in the final documents. ENTSO-E therefore should include these developments in its planning and revise investment upwards.

Offshore gas legislation ensures that pipeline priority is given to gas supplied from the home country over gas using the pipeline as an interconnector. If offshore wind can use the same approach to ensure that moving power from the offshore asset gets priority over trading power between countries, then this is likely to smooth the regulatory process.

Onshore grid connections

To accommodate more offshore wind on the onshore grid, TSOs need to coordinate with governments to have 10- year plus visions for development. Such visions are likely to need input from developers, governments and other stakeholders. Different models could work in different countries, but there must be collaboration between jurisdictions.

COORDINATION BETWEEN COUNTRIES

To plan the grid, long-term thinking is vital if we are to make the best use of the existing onshore grid and make sufficient, timely progress. This requires planning at a national level and international co-ordination to facilitate cross-border energy flows, using both offshore and onshore interconnectors. The countries surrounding the North Sea are already doing this to some extent. Progress is being made by the Baltic Sea countries. Central European countries may have grid interconnect constraints to overcome before they can utilize offshore wind generation.

As emphasized by European Commission in the European Green Deal increasing offshore wind production will be essential, building on regional cooperation between Member States. The European Commission's offshore wind strategy is expected to be presented in October 2020.

ENTSO-E, ACER and the European Commission coordinate the Ten-Year Network Development Plans. To realize 450 GW of supply to meet the demand by 2050, they will need to take a longer-term view and collaborate at a deeper level.

Cross-border cooperation becomes even more relevant in the Baltic Sea, where an interconnected market would help to overcome the issue of different power pricing zones with different patterns and technical standards. This will allow decreasing system costs caused by congestion and ensure the grid readiness for future offshore installations.

The Baltic Energy Market Interconnection Plan (BEMIP) is a trans-European initiative led by the European Commission and the governments of the eight countries surrounding the Baltic Sea. BEMIP recently developed (Aug 2019) a roadmap for the implementation. This includes the identification of offshore wind concession zones based on existing national plans and other scenarios on the transformation of the power sector. The initiative also focuses on grid expansion, energy security and the synchronization of the Baltic system with the central European electricity network.

In parallel, the Baltic Sea Offshore Wind Forum (BaSOF) is an initiative that advocates the development of offshore wind energy and its industry in the Baltic Sea region to realize a regional energy transition. WindEurope, together with the national wind energy associations from Estonia, Denmark, Finland, Sweden, Latvia, Lithuania, Poland and the German Offshore Wind Energy Foundation signed the Baltic Sea Declaration in 2017 with the objective to work together in developing a well-functioning integrated energy market, regional cooperation in maritime spatial planning, grid development, capacity planning and support schemes.

Member States should relaunch the Baltic Sea Declaration and secure equal competition conditions among countries to maximize efficiency.

SYSTEM INTEGRATION

Storage and power-to-x

The expansion of offshore wind from 20 GW today to up to 450 GW by 2050 as envisaged by the EU Commission presupposes the wider decarbonization of the energy.

The latter in turn requires a significant increase in the share of electricity in the energy: from its current level of 24% to over 50%. It's very important therefore that the expansion of offshore wind is accompanied by ambitious action on the electrification of heating, transport and industrial processes.

Offshore wind can play an important role in supporting the electrification of these sectors, not least because of its relatively high capacity factors, as noted in the IEA's Offshore Wind report for the World Energy Outlook 2019.

It can also play a role in supporting the indirect electrification through renewable hydrogen of those parts of the energy system, especially in heavy industry, which it is difficult to electrify directly.

Indeed, the electricity generated by 450 GW may not all be used directly but at least 5% and possibly up to 25% could go into power-to-x, mainly as power to hydrogen or other gases. Significant amounts of direct and indirect electrification mean increased opportunities for demand-side management.

Demand management can shift the use of electricity away from peak times, enabling the use of renewable energy at times when it is generated. Power-to-x and electrical storage will enable additional flexibility from short-term storage (up to 12 hours) to seasonal storage. It may also help de-bottleneck the grid. However, the extent of use of power-to-x in 2050 is uncertain given the current technology costs and process efficiency. Large demonstration projects to achieve economies of scale are urgently needed.

The combination and optimization of all these different technologies will be crucial for allowing the system to become fully renewable in 2050.

System stability

By 2050 the electricity grid will be a converter-based system, with little physical inertia in the system. This could lead to grid stability and balancing challenges. Many existing solutions can overcome these. Industry and TSOs would need to cooperate and coordinate on the implementation of such solutions.

5.4 Enabling timely investment

Investors do not need the same lead-time to make their investments as key suppliers and project developers. Investors (and especially debt providers) need visibility on the revenue stream that will be generated by projects in which they have invested.

The current merchant electricity markets will not provide the certainty that investors need to provide the required volume of funding at affordable rates. Although LCOE for offshore wind will be close to the wholesale market electricity price from 2025, the average price received for that electricity will not necessarily be the same as the average market electricity price (because of demand-matching). To enable the volume of investment required from financial investors, electricity markets will need to evolve to enable investors to have confidence in a more stable price for electricity, even if at no more than average electricity prices. This could be provided by a combination of:

- Contracts for difference;
- Corporate renewable PPAs; and
- High and stable carbon prices.

Other developments such as demand management, electrification of transport and heating and power-to-x are likely to play a part in stabilizing prices, as will corporate PPAs. But together these will not be enough to provide the revenue confidence needed for the volume of investment required.

Mechanisms will also need to be agreed on a Europe-wide basis for the transmission and trading of offshore wind energy, including energy generated in one country's EEZ, transmitted across another and supplied to a third. This is especially important for countries around the Baltic Sea, which will need substantial investment in ports and in onshore transmissions. The scale of this means that some countries will need significant own investments.

If some price stabilization is used to give financial investors' confidence in their returns, it is likely that at least some of the sources of capital that currently feed into other energy projects will transition into investment in offshore wind. Mobilizing the volumes of investment is therefore likely.

In summary, the challenges of delivering annual rates of 20 GW p.a. after 2030 in Europe are daunting. But if policies are ambitious enough in the next decade and regulation is stable, the European industry will have amassed unparalleled experience over more than two decades of offshore wind development, which will mean these challenges can be met.

5.5 The supply chain

The key suppliers on the critical path for investment to achieve competitively priced offshore wind capacity are: wind turbine suppliers, installation contractors, vessel suppliers and construction ports. They invest in the development of next generation products, manufacturing capacity and skills training. The investment from key suppliers is needed to increase installation rates and to keep reducing the cost of energy through new generations of technology, especially larger wind turbines.
The challenge in getting timely investment from key suppliers is that they need confidence in the market for a duration that will give a return on their investment. This duration could be around 10 years for preparation and amortizing of major investments in a market where margins are kept low by competitive auctions.
It is likely that in time, there will be increased supply from outside Europe, but as the global market for offshore wind grows, there will also be many more opportunities for the European supply chain to export, balancing this effect.

WIND TURBINE MANUFACTURERS

For turbine supply, around 1,000 units per year (of which between 20–35% would be installed in the Baltic Sea) will be needed, which could be produced by four or five main turbine manufacturers in up to ten main facilities located at key ports across Europe (or beyond).

OFFSHORE INSTALLATION SUPPLIERS

There will be a need for investment in new vessels capable of installing the expected future large turbines and their foundations. We anticipate that at least ten new primary vessels will be required, each capable of annually installing up to 100 turbines or their foundations. This may include some new heavy-lift floating vessels for deep water sites. However, innovations in installation approaches and the use of floating wind turbines (built near-shore or in harbours and towed to site using cheaper vessels) may reduce the investment required. In addition to investment by the current key suppliers, those transitioning from the oil and gas supply chain also have the potential to bring investment to the offshore wind supply chain.

PORTS

Construction port investment will be needed in all sea basins. We envisage that in the Baltic Sea (up to 2.5 GW p.a.) there will be only a few ports that invest in being capable of building out 0.5 GW to 1 GW p.a. With floating wind installations being significant, at least one port in each sea basin will either be capable of (or fully dedicated to) the build-out of floating wind projects. Floating is mainly to be deployed in Southern European waters. Therefore, the focus should be on deploying large scale bottom-fixed sites for Poland and most of the Baltic States. For more detail on the scale of early-stage investment required see the study performed for WindEurope's offshore wind ports platform. In certain jurisdictions, governments could support port infrastructure, directly helping to grow construction port volume capability.

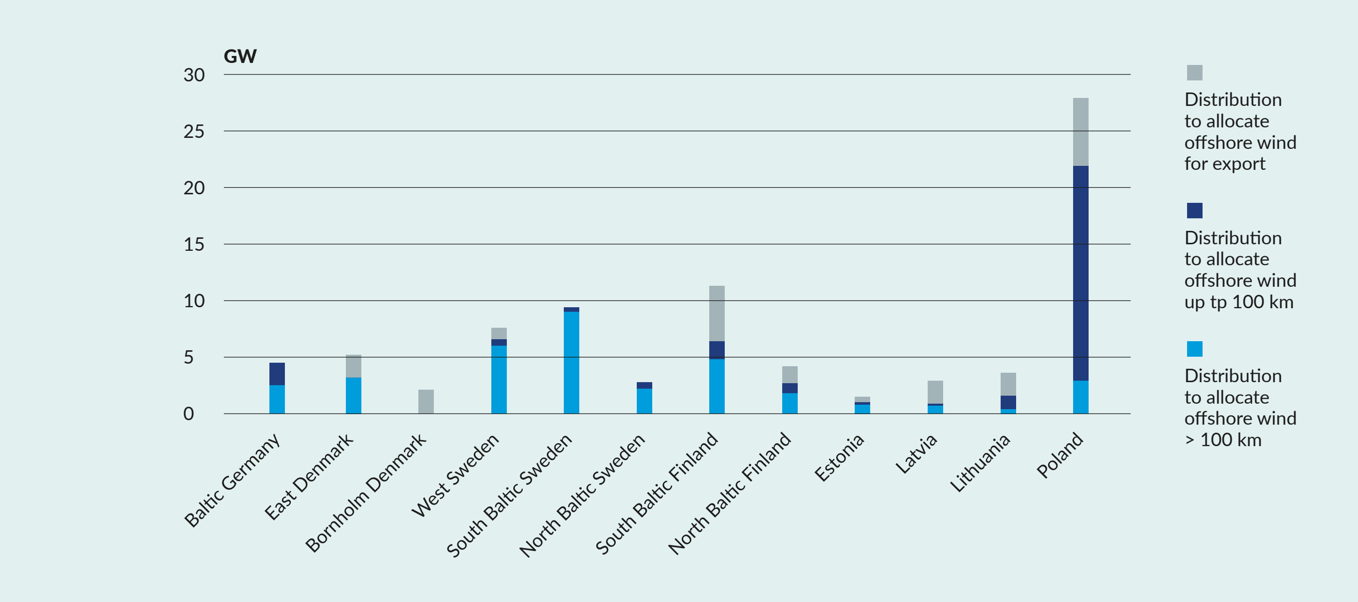
PROJECT DEVELOPERS

To enable timely investments, project developers need to know that key suppliers are investing for the expected volumes. The project developers need to have the confidence to invest in expanding their project development teams. The timeframe needed by project developers is a little shorter: five to seven years ahead of installation. Project developers also need to have confidence that grid connections will be in place to supply their power to customers, or that they will be compensated if these connections are not ready. Lastly, project developers also need to know that project revenues will provide returns at low enough risk to enable progress, often with significant debt funding.

5.6 Country-specific challenges for Baltic Sea countries

In this chapter, we analyzed only subregions specific to the Baltic Sea: Baltic Germany, East Denmark and Bornholm, Sweden (West, South Baltic and North Baltic), Finland (South Baltic, North Baltic), Estonia, Latvia, Lithuania and Poland.

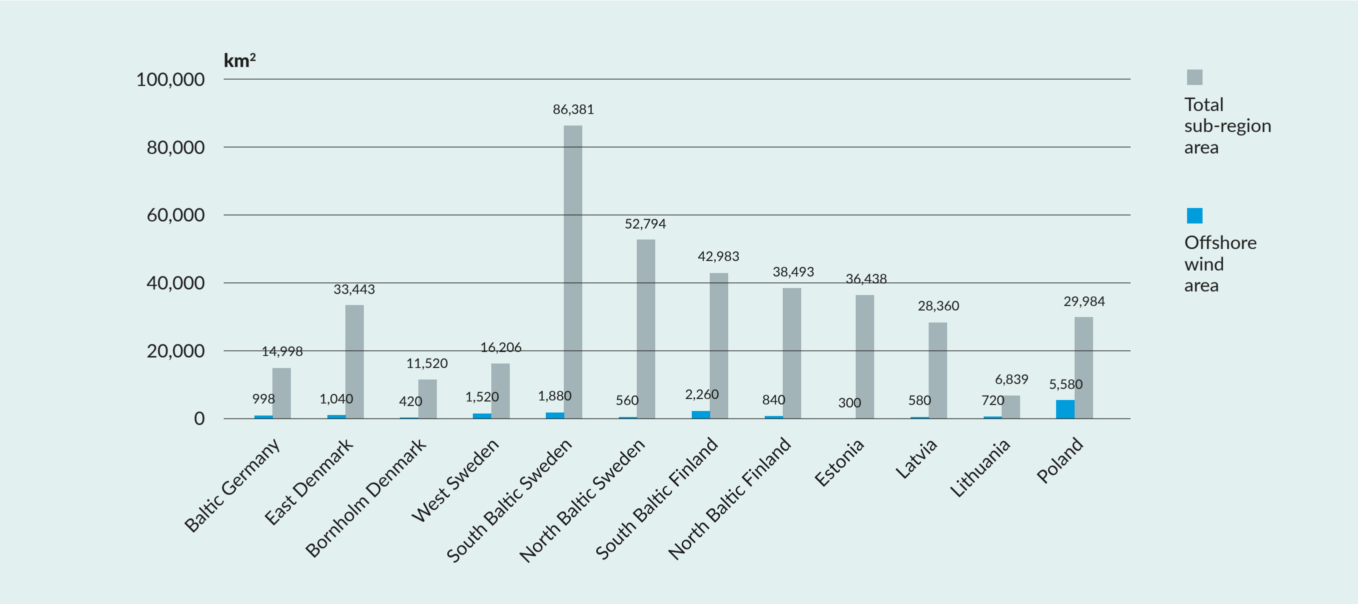
Figure 5 Distribution per country sub-region to allocate offshore wind up to 100km, >100km and for export



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

Germany will face challenges in enabling new sites, particularly in its part of the Baltic Sea. Even though there are projects already within 22 km of the coast, we see the tendency for larger projects to move further from the shore to avoid landscape disturbances. If this exclusion continues, ensuring enough sites will be difficult in this region. In addition, Germany should review the current exclusion of offshore wind projects in nature protection areas.

Figure 6 Offshore wind area and total sea area in Baltic Sea (subregions)



Based on: "Our energy, our future" BVG Associates for WindEurope, November 2019

The total capacity of subregion for Baltic Denmark: East Denmark and Bornholm is 7.3 GW. Almost 4.1 GW offshore wind energy should be available for export to other European countries.

Sweden's main challenge is to enable sites for offshore wind by solving the current exclusions due to military radar issues and the lack of a framework for offshore wind. Crucially, it will have to step up its grid build-out to inland enhancement, as more than 17 GW out of the 20 GW it could have by 2050 would be to serve demand up to 100 km from the coast. It would also need to cooperate internationally to address possible environmental impacts of large-scale offshore wind deployment in the Baltic Sea.

Finland's main challenge is to enable sites for offshore wind by solving the military radar issues leading to current exclusion zones, particularly in the southern Baltic Sea. Additional challenges include enabling revenue stabilisation mechanisms for projects and the lack of a comprehensive regulatory framework for grid connection.

For the three Baltic States – Estonia, Latvia and Lithuania – the main challenge is to address their interconnection and system synchronisation with central Europe. Internal grid enhancement would be key for Estonia, which could use more than half of its 1.5 GW of offshore wind in 2050 to serve its local demand. Lithuania and Latvia could have more than half of their offshore wind electricity for trade to other countries, so interconnections would be essential. In the three countries, timely investment in port infrastructure is a major challenge and should be addressed as early as 2025.

Poland's main challenge is to accelerate the enhancement of its national grid. Poland could host up to 28 GW by 2050, 22 GW of which would serve its national demand. Poland's interconnection use needs to be improved in order to enable higher electricity trade level with other Central and Eastern Europe countries. Work on grid enhancement should start as early as possible. The proposed new Offshore Wind Act considers that by June 2021 (first phase) the electricity regulator can select up to 5.9 GW. In the second phase it proposes to hold two competitive tenders in 2025 and 2027 for a total 5 GW of additional capacity. This enhances Poland's total capacity awarded to more than 10 GW by 2028. In their final National Energy and Climate Plan (NECP) Poland had committed to having at least 3.8 GW of offshore wind operational by the end of the decade.

Table 5 Key tasks for national energy and climate plans

COUNTRY	KEY TASKS FOR NATIONAL ENERGY AND CLIMATE PLANS
Germany	Should step up in enabling new sites. Crucially Germany has to immediately start its grid enhancement, particularly the onshore grid from north to south. It will have to cooperate with its neighbours for interconnection expansion, and to build offshore hybrid projects.
Denmark	Should step up its grid enhancement for trade, so interconnection to other countries will be key. Needs to accelerate its international cooperation in order to develop offshore hybrid projects and to address the cumulative environmental impacts of large-scale offshore wind.
Norway	Should increase its interconnection capacity. Should also enable more sites in the southern areas of the North Sea. The currently planned sites in the north of the country are too far from the demand centres, and would require expensive grid investments.
Sweden	Should enable sites for offshore wind by solving the current exclusions due to military radar issues. Needs to cooperate internationally to address possible environmental impacts of large-scale offshore wind deployment in the Baltic Sea.
Finland and Estonia	Need to enable sites for wind energy by solving the military radar issues leading to current exclusion zones. Estonia needs to address its interconnection and system synchronisation with central Europe and possible environmental impacts of large scale offshore wind deployment.
Latvia and Lithuania	Need to address their interconnection and system synchronisation with central Europe. Timely investment in port infrastructure is a major challenge and should be addressed as early as 2025.
Poland	Needs to accelerate the enhancement of its national onshore grid. Poland's interconnection use needs to be improved to enable higher electricity trade level with other Central and Eastern Europe countries. Poland needs to have clear streamlined permitting rules which allow the deployment of large offshore wind volumes.

Based on the Wind Europe report „Our energy. Our future"

6 GENERAL ASSUMPTIONS FOR DEVELOPMENT OFFSHORE WIND FARMS FOR 2050

What will the future be like? Here, we describe the typical technology operating in 2050. This is based on average 2040 installations rather than state of the art in 2050.

6.1 Technology

Turbines

The offshore wind turbines at a typical site in 2050 will have rated capacities of 20–25 MW. Radical developments such as airborne wind could be available but are not assumed to be a major part of the energy mix. Reuse or recycling solutions at net-zero cost will be available for most wind farm components being decommissioned, including blades.

There will be reduced reliance on human effort through the use of automated systems, drones, sensors and actuators. Wind farms will produce electricity for at least 30 years before a site is repowered or decommissioned, with offshore substations and export cables being designed such that they can be maintained and re-used for at least one further project.

Offshore wind farms

Turbines will be installed in farms of 1 GW to 5 GW. Installation methods will be similar to current practices, but with larger installation vessels available. Operations, maintenance and service (OMS) will mainly involve service operation vessels (SOVs) and will also make extensive use of technologies to reduce human effort and exposure to risk.

Floating offshore wind

Floating offshore wind will be considered as simply another choice of foundation solution available for deployment on a site-specific basis, rather than as a separate offshore wind sector. Floating foundation solutions for areas with sea ice will be available. Between 100 and 150 GW of the 450 GW are anticipated to be floating in Europe.

6.2 Supply chain

The supply chain will have reached a capacity and installation rate of over 20 GW p.a. to get to 450 GW by 2050, but will have ramped down (or diversified to other markets) over a reasonable period to the required replacement rate by 2050.

The supply chains for turbines, foundations, cables, vessels and ports services will have the capacity to produce and install between 12 GW and 15 GW of offshore wind per year. This is the average replacement rate required to repower older wind farms and maintain offshore wind capacity at 450 GW from 2050 onwards in Europe.

6.3 Offshore wind market dynamics

Between five and ten project developers will be active in the market, ensuring competition for new projects.

There will be at least three turbine suppliers and a competitive supply chain for fixed and floating foundations, cables and substations, installation vessels and Operation and Maintenance Services activities.

Multiple ports will support each part of the Baltic Sea. Some will provide capability to support installation and Operation and Maintenance Services, while some will focus on one or the other, depending on location and regional demand.

6.4 General assumptions about the energy system

The vision of 450 GW of offshore wind capacity in Europe is predicated on the assumption that, by 2050, Europe has transitioned to an energy system that is based on renewable sources of energy, with electrification and integration across all energy consumption sectors.
This analysis assumes that:

- Europe will have 650–700 GW of onshore wind capacity in addition to the 450 GW in offshore wind;
- All European countries will develop and implement national renewable energy action plans that consider the EU's long-term greenhouse gas emissions reduction objective;
- National permitting procedures are streamlined to allow for the cost-effective deployment of offshor wind energy;
- A reformed EU Emissions Trading System provides for a high and stable carbon price, disincentivising investments in carbon-intensive and inefficient power plants;
- There will be ongoing contributions to the development of the energy system from electrification, hydrogen, power-to-x, energy efficiency and pursuit of a low waste circular economy; and
- There will be more bio-energy with carbon capture and storage (BECCS) and carbon capture and storage (CCS) than the COMBO scenario of the EC's A Clean Planet for All.

6.5 Offshore grid

In 2050 there will be a mix of grid ownership models.

GRID TECHNOLOGY

In 2050, the electricity grid will be a converter-based system, with little physical (spinning) inertia in the system. The grid will transmit power from many geographically dispersed generators, rather than from a few large generators. To facilitate this change, we assume that Europe will have overcome the technical challenges of transient stability.
Generation, transmission, distribution, and customer systems will be a long way towards a single, dynamic and holistic system. Distributed systems, micro-grids and customer assets (such as batteries) will be an integral part of the system.
The physical grid will be optimised to meet demands, mainly via upgrades of dynamic line and transformer ratings, but also with much new-build. Transmission lines will be reused when thermal generating assets are retired. Additionally, new technologies for AC and DC transmission and modular power flow control will be needed. We have assumed that by 2050 there will be cost-competitive long- distance underground transmission.

GRID LOCATIONS

According to our estimates, six offshore wind connection hubs will be built over the next three decades: four in the North Sea and two in the Baltic. All of these will connect to different countries, adding strength and flexibility to the network.

The longer links and large farm sizes mean that high voltage direct current (HVDC) grid infrastructure will play an increasingly important role. By 2050, we have assumed that HVDC links will make up a large proportion of the grid, both offshore and in onshore interconnection.

6.6 Maritime spatial planning and multi-use

SEA USE

We estimate that:

- Shipping corridors will be adapted to new transport needs, available technology, hydrographic conditions and port facilities, taking environmentally sensitive areas and key permanent structures into consideration.

- Visual impact from offshore wind farms will remain modest, with no wind farms developed close to shore or important tourism areas.

- Through improvements in technology, Europe will have overcome deployment constraints imposed by interference with military aviation, civilian aviation and aviation and weather radars. The resolution of spatial conflicts with the military will have unlocked other areas.

- Multi-use of the space occupied by offshore wind farms will be common, for example with aquaculture, passive fishing, the combination of energy sources, and/or environmental restoration.

We have assumed a reduction in the currently excluded areas. However, new constraints will likely emerge, so the overall excluded area is likely to remain the same.

ENVIRONMENTAL IMPACT

We have assumed that all EU Member States will prioritise reaching and maintaining the EU's Marine Strategy Framework Directive's Good Environmental Status.

Environmental impacts of offshore wind farms will decrease through new foundation and installation technology, use of low-emission vessels during the operational phase and through new environmental monitoring (real-time monitoring of bird migration, for example).
New technologies may allow biodiversity restoration or creation measures, which will increase the social acceptance for wind farms in protected areas.

MARITIME SPATIAL PLANNING

We estimate that areas for different uses will be assigned using maritime spatial planning (MSP), maintaining an adaptive management approach and allowing change based on emerging conditions (demographic, economic or climate change), technologies and new forms of multiple uses.
We estimate that, in addition to National Plans, there will be coordinated maritime spatial plans at the level of each sea basin, agreed between jurisdictions as a "shared vision" by 2025 and "legally binding" before 2035. This will require major cross-border cooperation and planning. And it will enable leasing and project development to progress for much of the 450 GW with confidence in the ability to consent and deliver projects.
Maritime spatial planning at sea-basin level will improve the definition and planning of connectivity corridors (shipping, electricity, pipelines and environmental). Maritime spatial planning at sea-basin level will also regulate cross-border projects, particularly related to energy and environment and the balancing of their costs, impacts and benefits.
We anticipate that national maritime spatial plans will be developed by the end of 2021 (as required by the European maritime spatial planning Directive) before being used as input at sea basin level. For this reason, it is important that in time, single country maritime spatial plans are developed based on commonly agreed environmental, economic and social objectives and targets developed for the whole basin.

7 DIRECTIONS FOR THE DEVELOPMENT OF OFFSHORE WIND ENERGY IN POLAND

7.1 The development of offshore wind energy market in Poland

Offshore wind is a key technology for further deployment of renewable energy in Poland. The Polish Energy Policy (PEP 2040) indicates the development of offshore wind energy as one of the strategic projects for the Polish energy sector. Offshore wind is the most predictable source of electricity among renewable energy technologies, with higher capacity factors than onshore and PV farms. Moreover , similarly to onshore wind, it has the highest share of domestic suppliers and the potential for a positive impact on the economy.

Industry representatives jointly confirm that the first wind farms in the Polish exclusive economic zone in the Baltic Sea will be built and commissioned as early as 2025. In addition, offshore wind is an appropriate technology that will allow for emissions reduction and help Poland meet its EU climate targets recommended by the European Commission, i.e. a 25% share of energy from renewable sources as Poland's contribution to the implementation of the EU target for 2030.

7.2 Investors

Currently, there are twelve offshore wind energy projects in the Polish part of the Baltic Sea. Two projects have already received grid connection agreements:

- Bałtyk III, belonging to Norwegian Equinor and Polenergia
- PGE Baltica 3

In total, these two projects have grid connection agreements for a capacity of 2.245 GW

The following seven projects received grid connection conditions for a total capacity of 7.95 GW: Bałtyk I, Bałtyk II, Bałtyk III, PGE Baltica 1 and PGE Baltica 2, Baltic Power and FEW Baltic-2 RWE. The complete list of projects with the assigned area in the Baltic Sea is presented in Table 6 below. The map below also shows the locations of planned wind farms in the Polish part of the Baltic Sea.

GCC (Grid Connection Conditions) – specifies the technical requirements for connection to the grid.

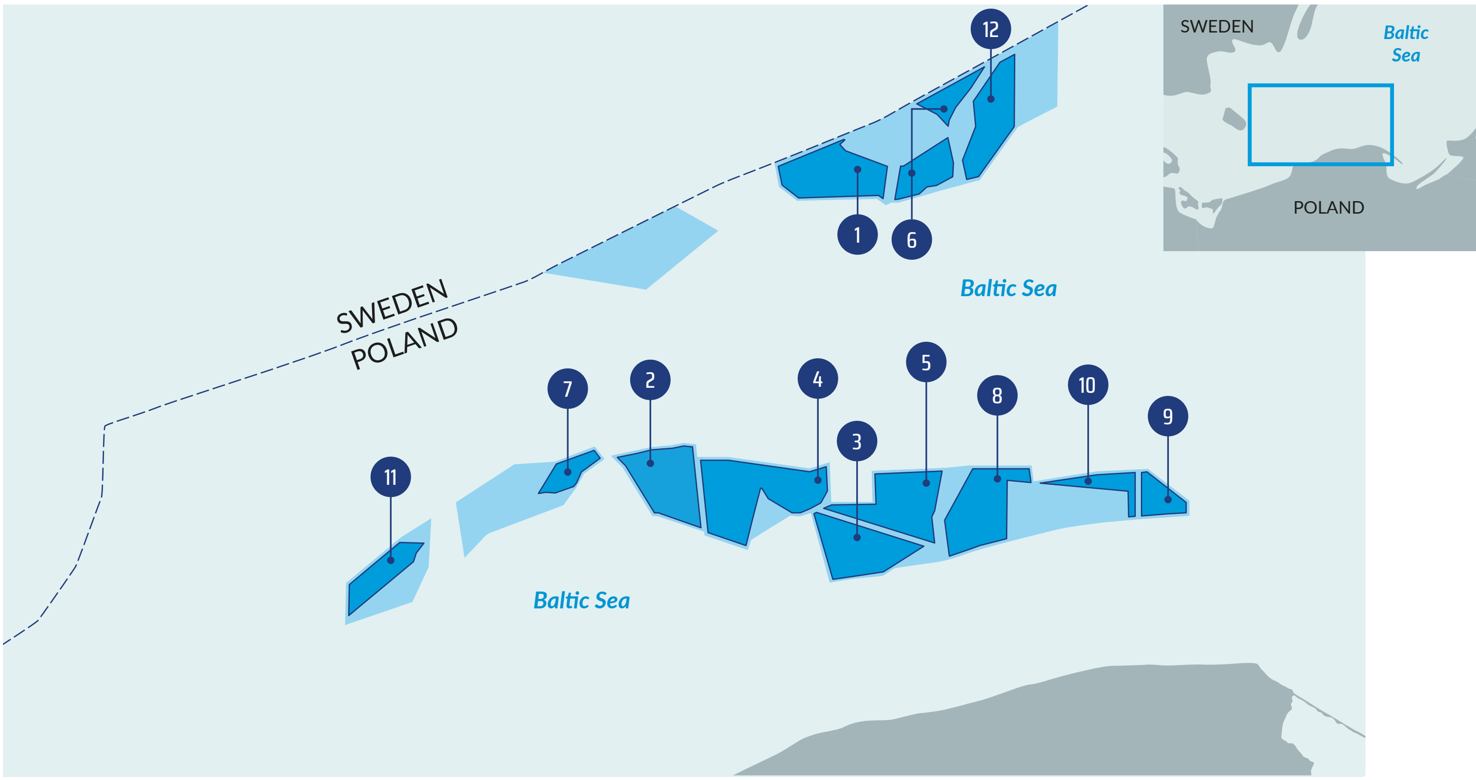
GCA (Grid Connection Agreement) – connection agreement with the grid operator.

Table 6 Offshore wind energy projects in the Baltic Sea

NO	PROJECT	AREA	GRID CONNECTION CONDITIONS/GRID CONNECTION AGREEMENTS
1	Equinor/Polenergia – Bałtyk I	128 km²	1,560 MW (GCC)
2	Equinor/Polenergia – Bałtyk II	122 km²	240 MW (GCC)
3	Equinor/Polenergia – Bałtyk III	116 km²	1,200 MW (GCA)
4	PGE – Baltica 2	189 km²	1,498 MW (GCC)
5	PGE – Baltica 3	131 km²	1,045 MW (GCA)
6	PGE – Baltica 1	108 km²	900 MW (GCC)
7	RWE – FEW Baltic-2	42 km²	350 MW (GCC)
8	PKN Orlen – Baltic Power	131 km²	1,200 MW (GCC)
9	EDPR – B-Wind	42 km²	200 MW
10	EDPR – C-Wind	49 km²	200 MW
11	Baltex 2	66 km²	800 MW
12	Baltex 5	111 km²	1,500 MW
	TOTAL	**1,261 km²**	**10,693 MW**

Source: Impact Assessment of proposed Offshore Wind Act

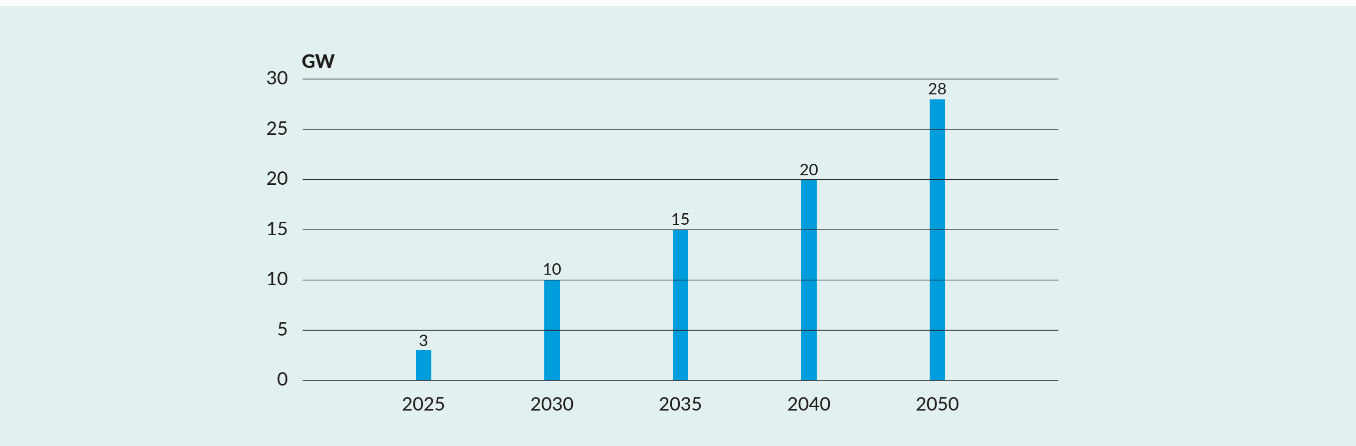
Figure 7 Location of planned wind farms in the Polish part of the Baltic Sea



7.3 Forecast of offshore wind development in Poland

PWEA prepared a forecast for the development of offshore wind in Poland. Ultimately, by 2050, the development potential for offshore wind is 28 GW. The first offshore wind farms should be built in 2025 and in 2030 their capacity should be 10 GW, followed by 20 GW in 2040. Setting ambitious targets is particularly important for suppliers and sub-suppliers of offshore wind farm components who need a precise project schedule to make the necessary investments in their production facilities. Polish investors declare support and development of offshore wind projects with the presented capacity.

Figure 8 Forecast of development of offshore wind capacity in Poland to 2050 year (GW)

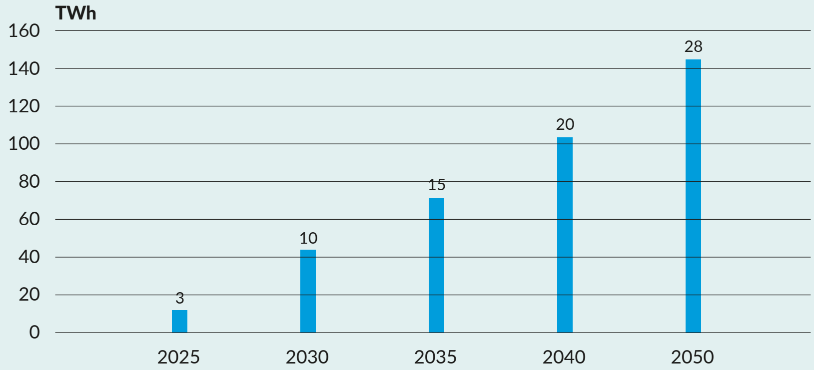


Source: PWEA

7.4 Forecast of energy production from offshore wind farms in Poland

Based on the estimated new capacities in offshore wind farms presented above, the forecast of energy production until 2050 has been presented. Capacity factor between 45% and 60% was adopted for the calculations. The results indicate that offshore wind is a predictable source of energy and the most efficient among renewable energy technologies. In fact, offshore wind farms will operate with a higher load than most hydropower plants in Poland and with a load comparable to coal-fired power plants.

Figure 9 **Forecast of energy production from offshore wind farms to 2050 year (TWh)**



Source: PWEA

7.5 Investment costs (Capex)

The development of offshore wind will have a significant impact on the Polish economy, both nationally and regionally. According to PWEA analyses, companies operating in Poland can provide the vast majority of components needed to build offshore wind farms. Suppliers include companies partially or entirely owned by the Polish state. PWEA has identified several hundred Polish enterprises that can provide the required products and services, ranging from design and planning of wind farms, manufacturing and installation of wind farm components and connection infrastructure, to operation and maintenance. Some of these entities are already suppliers of goods and services for the onshore wind energy sector. Other entities are not currently related to the wind industry, however, the range of products they offer, their production potential or resources allow us to believe that after adjusting their business profile, they could provide goods and services for this market. As shown by examples from abroad, the development of offshore wind energy will contribute to the development of Polish companies not only in the immediate vicinity of this sector, but also in other areas where the implementation of wind farm projects will result in the possibility of changing the operating strategy, business models or implementing new investments, for example in development of local infrastructure, tourism and vocational education.

The value chain for offshore wind farms can be broken down into five parts:

1. Design and planning:

- Offshore wind farm design;
- Design of connection infrastructure;
- Research on marine environment;
- Geotechnical surveys of the seabed;
- Obtaining the necessary permits.

2. Turbine manufacturing.
The turbine is the main component of an offshore wind farm. In total, turbines account for an average of 40% of investment expenditures for the construction of a new wind farm. It consists of three main elements: the nacelle, the rotor (with blades as main components) and the tower.

3. Production of connection infrastructure and foundations.
In this phase, the most important elements include:

- Foundations;
- Transformer stations;
- Cable connections: export and internal (array)

4. Installation.
Installation works apply to both the turbine components and the connection system and foundations. Specialized vessels and well-developed port infrastructure play a key role in this phase. The installation process includes: laying submarine cables, installing foundations, installing offshore turbines and installing an offshore transformer station.

5. Operations and maintenance (O&M).
The operations and maintenance phase includes all activities related to ensuring the proper functioning of the wind farm after it is put into operation. Those are:

- operation and preventive maintenance,
- unscheduled maintenance works (corrective maintenance).

70%	25%	5%
The main part of the investment is the production costs of the turbine, foundations and connection infrastructure; together they make up about 70% of capital expenditure.	The installation process can consume about 25% of the total cost...	...and the design and planning of the farm about 5%.

The development of the sector will also benefit ports, which will need new quays and basins. This also applies to smaller harbours such as Ustka, Darłowo, Kołobrzeg, Władysławowo and Łeba. According to preliminary assumptions, these will be used by construction vessels and later by service vessels. Silesia could also benefit from the development of offshore wind – it is the region where the Polish Wind Energy Association plans to establish a training centre that would become a human resources development hub for RES, giving engineers and specialists a chance to gain competitive advantage on the labour market, and access to economic entities involved in the development of renewable energy sources for skilled workers.

7.7 Maritime spatial plan

Directive 2014/89/EU establishing a framework for maritime spatial planning requires all Member States, including Poland, to submit maritime spatial development plans. The deadline for submitting the plan to the European Commission is March 2021. The Polish draft maritime spatial development plan prepared by the Ministry of Maritime Economy and Inland Navigation has been subject to public consultation, and the final draft is expected in the third quarter of 2020. The maritime spatial development plan takes into account the development of offshore wind farms in the exclusive economic zone and should take into account the issued location decisions.

According to PWEA, the following changes should be introduced to the maritime spatial development plan:

- Increasing the area for future investments in offshore wind. Areas marked in the draft plan as areas for the development and extraction of hydrocarbons should also allow for development of offshore wind energy. Such coexistence of both functions will allow the use of areas in accordance with the best economic interest, as well as future conditions and needs.
- Allowing for more frequent updates of the master plan. The plan should be revised every 5 years, and not every 10 years as it is currently envisaged. There are several reasons, including rapid technological development and dynamically changing legal and regulatory environment.
- Adopting a more flexible approach to the width of bird migration corridors. Currently fixed at 4 kilometres, the minimum width of the migration corridors is unjustified and may limit investors' rights. A more sensible approach would be to delimit the width of migration corridors once the projects are finalized and environmental studies on the passages of migratory birds and wintering species are available.

7.8 Ten Year Grid Development Plan (PSE)

In 2020, the President of the Energy Regulatory Office approved the "Development Plan for meeting the current and future electricity demand for 2021–2030". In the document, three scopes of transmission grid development needs were identified:

- The "passive" variant, based on a scenario that does not take into account the development of offshore wind farms, for which there was no need to develop a significant part of projects in the northern part of the Polish Power Grid, presents the smallest scope of required tasks.
- The "balanced" variant, requiring additional investments in the northern part of the Polish grid for connection of 3.6 GW in offshore wind, has a broader scope of required investment tasks.
- The largest investment scope was identified in the "expansion" variant based on the scenario of dynamic development of offshore wind with a capacity of 10.1 GW, which, apart from investments in the north of the country, requires strengthening the transmission grid in the central part of Poland.

Currently, connection conditions for offshore wind farms for a total of 7.95 GW have been issued, and a connection agreement has been concluded for a capacity of 2.2 GW. Additionally, the document presents the potential directions of development of the transmission grid until 2040. These directions of transmission grid development for 2030–2040 also take into account potential new cross-border interconnections with Denmark and Germany. The need to implement these connections is to be discussed at the international forum in the context of the market justification of the need to increase interconnection capacity. Four development scenarios were presented, each of them taking into account the development of offshore wind, with one "balanced" scenario at the level of 3.6 GW, and the other scenarios at the level of 10.1 GW of installed capacity.

7.9 The Offshore Wind Act

In July 2020, the draft act on promoting electricity generation in offshore wind farms ("Offshore Wind Act") was sent for consultations and opinions. The draft was welcomed by the offshore industry. It presents a support system that, according to representatives of the sector, is suitable for the emerging Polish offshore wind market. The support scheme consists of two phases:

1. Initial phase
– projects with a total installed capacity of no more than 5.9 GW will be able to apply for support without the auction procedure. Support decisions will be approved by the European Commission. The first phase will cover projects until mid-2021.

2. Auction phase
– with at least 3 auctions to be carried out by the President of ERO throughout the lifetime of the scheme:

- 2025 – 2.5 GW
- 2027 – 2.5 GW
- 2028 – remainder, min. 0.5 GW.

Auctions will be announced at least 6 months in advance. In order for the auction to be successful, a minimum of 3 auction bids are required. Auction contracts / investor support will be granted for a maximum of 25 years. The investor will be responsible for evacuation of power from the offshore wind farm, meaning that the investor will have to develop the connection between the wind farm and the onshore substation. However, generation and first delivery to the grid of electricity generated in an offshore wind farm after obtaining a license must take place within 7 years from the closing of the auction session. Moreover, the investor may submit more than one application for reduction of installed capacity of the offshore wind farm by no more than 25% of the installed capacity. The act is to be adopted by the end of 2020.

7.10 Economic impact of investments in offshore wind in Poland

The chapter has been prepared on the basis of analyses prepared for the impact assessment of the Offshore Wind Act, which assumes the development of offshore wind farms with a potential of 20 GW until 2040 and 28 GW until 2050.
In this chapter, we present the estimated economic effects to be generated in Poland, broken down into the investment (development) and operational phase of the projects. The development phase will be carried out between 2020 and 2033. The operational phase is between 2025 and 2058.
Offshore wind farms will be commissioned successively, most likely from 2024 to 2033. The investment phase should start in 2022 – 1–2 years before commissioning date. The period of operation of such a farm is 25 years (operating phase), during which it will provide tax revenues to the public finance sector.

NEW JOBS

The development of the offshore wind market in Poland will generate demand for additional jobs both in the energy sector (electricity generation and transmission), as well as in other sectors of the economy – construction, finance, transport, services, etc.
In the investment phase (during the development and construction of offshore wind farms) about 34,000 full-time jobs will be needed, while in the operational phase (servicing of completed wind farms) it will be about 29,000 jobs.
The creation of new jobs in innovative sectors of the economy will stimulate the need to build new competences in the labour market, which will have a positive effect on the entire sector of the economy – building a knowledge-based economy.

The changing structure of electricity generation will also force workforce movements between various sectors of the economy, but their pace and scale will depend on the pace of investment in new generation capacity (mainly related to renewable energy sources, including offshore wind energy).

GROSS VALUE ADDED

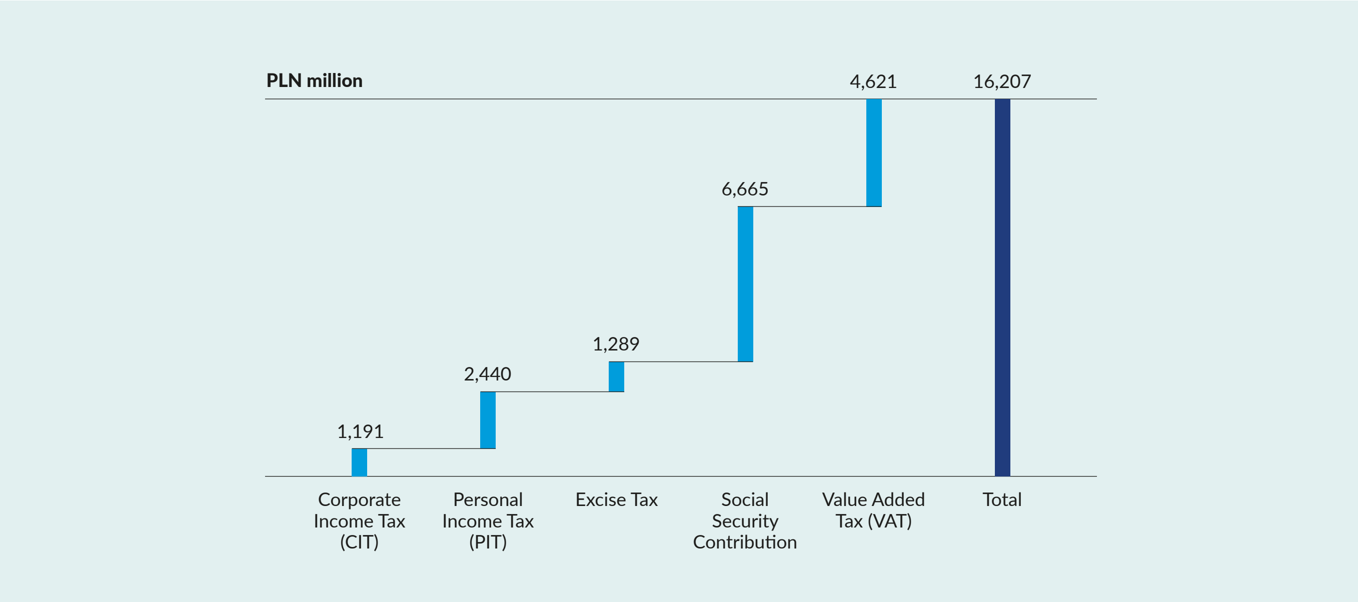
Gross value added can be defined as the surplus of a company's revenues over expenses incurred on goods and services that are necessary to conduct current operations. Gross value added indicates how a company, through the transformation of goods and services from other companies into a new product or service, generates a new value in the economy.

The total effects in the investment phase measured by the value added will amount to PLN 53,509 million, and the average annual effects in the operational phase – PLN 14,257 million.

GOVERNMENT TAX REVENUES

This includes revenues from corporate income taxes (CIT), personal income taxes (PIT), indirect taxes (e.g. VAT and excise duty), property tax, and other charges.

Figure 10 Cumulative effects for general government revenues in the development phase (2020–2033) by source (PLN million, current prices)



Source: PWEA

Cumulative effects in the investment phase (2020–2033) are as follows:

- Corporate Income Tax (CIT) – PLN 1,191 million,
- Personal Income Tax (PIT) – PLN 2,440 million,
- Excise Tax – PLN 1,289 million,
- Social Security Contribution (ZUS) – PLN 6,665 million,
- Value Added Tax (VAT) – PLN 4,621 million,
- Total effects in the investment phase: PLN 16,206 million (approx. PLN 1.2 billion on average annually).

Figure 11 Average annual effects for general government revenues in the operational phase (2025–2058) by source (PLN million, current prices)

Source: PWEA

The average annual effects in the operational phase (in 2025–2058) are:

- Corporate Income Tax (CIT) – PLN 45 million per year
- Personal Income Tax (PIT) – PLN 227 million per year
- Excise Tax – PLN 93 million per year
- Social Security Contribution (ZUS) – PLN 632 million per year
- Value Added Tax (VAT) – PLN 41 million per year
- Property tax (on the land part of wind farm assets) PLN 24 million per year
- Property tax (on the offshore part of wind farm assets) PLN 283 million per year
- Total effects in the operational phase: PLN 1,345 million annually

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