Forum Energii
Analizy i dialog

Offshore energy

Downwind or upwind?

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Forum Energii is the Polish think tank forging the foundations of an effective, secure, clean and innovative energy system.

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Preface

There has been much discussion about Polish companies which are becoming more open to offshore wind energy. In addition to solar energy, offshore wind farms are the fastest growing renewable technology in Europe. The most important reason for this success is the increase in generation efficiency and the decrease of costs. Even ten years ago, 1 MWh cost over PLN 1,000. Thanks to the development of technology and the optimization of the costs of connecting offshore wind farms, the costs have dropped to 340-380 PLN/MWh, depending on the project. Because the entire European Union has adopted ambitious goals for the development of the power industry in 2030 with regard to renewable energy and CO_2 emissions reduction, additional cost reduction methods can be sought – for example by synergy with other Baltic projects to reduce the costs of connecting to the grid. Offshore energy has a significant industrial potential and Polish companies can benefit from the creation of the offshore sector in Poland.

However, the fact that offshore energy is becoming cheaper and cheaper and the Polish industry could build a development strategy based on offshore wind energy is not enough. The analysis of the possibilities of integration of this source into the national energy system is the most important. Each source of energy has different unique properties relating to operations and emissivity – atom, coal, gas, sun, and wind provide energy with varying consequences. That is why it is vital to determine the Polish energy mix. There is no doubt anymore that the Polish power industry needs modernization and low-emission diversification. In the following short study we try to answer the question, "In what way offshore energy can supplement the capacities in the national energy system so that it can operate safely in the subsequent years?" We also draw attention to the fact that a reduction of the costs of capital has a significant impact on the price of energy from offshore wind farms.

We encourage you to participate in the debate.

Yours faithfully,

Joanna Maćkowiak Pandera, PhD

President of Forum Energii

1. Introduction

Offshore wind energy is developing very quickly in the European Union and is becoming an important and increasingly cheaper source of clean energy. At the end of 2017, 15.8 GW of capacity was installed across 92 offshore wind farms in European countries. Poland faces an opportunity to develop this sector, which will bring benefits in terms of energy, ecology, and economy. Taking into account the time of completion and progress of the initiated projects, it can be assumed that 8-10 GW of capacity coming from offshore wind farms will have been launched by 2035, as long as the decisions on this matter are made in the next two years. Annual energy generation will amount to around 32-40 TWh, thereby reducing CO_2 emissions by 25-31 million tons per year, i.e. 20-25% in relation to the current level of emissions from power industry.

The development of offshore wind farms will support the Polish target of reducing carbon dioxide emissions and the development of renewable energy sources (RES) in 2030 and will contribute to covering the growing demand for electricity.

The aim of this article is to:

- Determine the potential of offshore wind energy in Poland.
- Estimate the costs of the project and indicate a method for their reduction.
- Assess the possibilities of supplementing the Polish energy mix with offshore wind energy.
- Indicate the most important actions aiming at efficient integration of these sources in the energy system.

2. Recommendations

A decision on the development of offshore wind energy.

It is necessary to implement actions as early as now in order to launch the first power plants before 2030. The most urgent task is to reflect the unique properties of this sector in the Renewable Energy Sources Act.

Reduction of the time of preparation for launching an offshore farm.

Currently, it takes 14 years. In order to accelerate the process of obtaining permits by investors, both legislative actions and a more efficient operation of public administration bodies are required.

Reduction of regulatory risk.

Reduction of regulatory risk decreases the cost of capital obtained by investors, which implies lower energy costs from offshore wind farms. One of the possibilities is to launch a financial instrument that will protect the investors against this risk.

Strengthening and expanding the high voltage network in the northern part of the country.

A stronger network along the Baltic Sea coast is needed to allow for the connection of offshore wind farms. Furthermore, energy transfer from the northern part to the southern part of the country must be ensured.

Strenghtnening international cooperation in the Baltic Sea region.

Construction of subsea cross-border connections will facilitate the integration of large amounts of energy from offshore wind.

3. Context

3.1 Offshore wind farms in the European Union

The European Union is a pioneer and a global leader in offshore wind energy. At the end of 2017, 92 offshore wind farms with a total installed capacity of 15.8 GW operated in its 11 Member States (WindEurope, 2018).

Table 1. Total installed capacity in offshore wind farms in 11 countries of the EU at the end of 2017

Country	MW	Share
Great Britain	6835	43%
Germany	5355	34%
Denmark	1266	8%
The Netherlands	1118	7%
Belgium	877	6%
Other	328	2%
TOTAL	15779	100%

Source: own resources on the basis of WindEurope (2018).

The description of offshore wind energy in the European Union:

- Location

Wind farms have been mainly built at the North Sea (71% of installed capacity), the Irish Sea (16%), and the Baltic Sea (12%).

- Countries

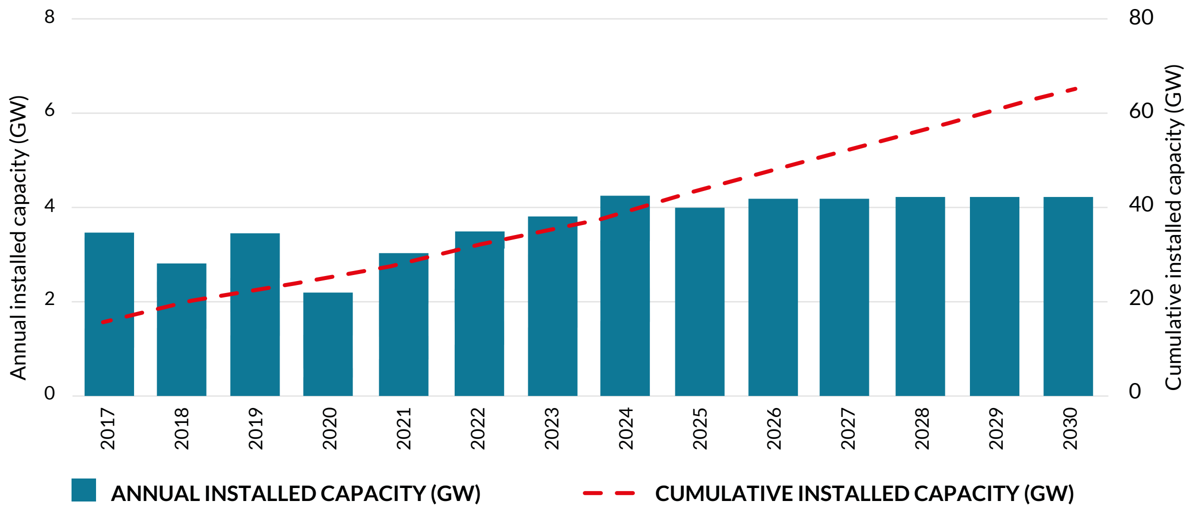
As shown in Table 1, the largest capacities have been installed by the United Kingdom and Germany, 43% and 34% respectively. Significant players in this market are also Denmark (8%), the Netherlands (7%), and Belgium (6%).

- Companies

The companies from Northern Europe have the largest share in the offshore wind farm portfolio. The leaders are: Ørsted (17%), E.ON (7%), Innogy (7%), and Vattenfal (7%).

The prospects for the development of this sector are very good. The European wind energy association, WindEurope (2017) predicts that the volume of installed capacity will have increased more than fourfold by 2030, reaching 64 GW in the EU (base scenario). These resources will be launched with a long-term levelized cost of electricity (LCOE) of EUR 65 per MWh, including the cost of connecting to the network.

Figure 1. Forecast of the increase in the capacity of offshore wind farms in the European Union



Source: own resources on the basis of WindEurope (2017).

3.2. **The needs of the energy system in Poland**

The Polish Power System (KSE) faces a number of challenges that are closely related to the development of offshore wind energy.

The most important challenges are as follows:

- Satisfaction of growing demand for energy.
- Reconstruction and development of generation potential.
- Diversification of generation resources.
- Reduction of CO_2 emissions.
- Development of renewable energy sources.
- Grid reinforcement.

The Polish Power System has to acquire new sources of energy generation due to the increase in demand for electricity and the withdrawal of functioning blocks. In 2017, Forum Energii predicted that this demand would increase by 27% by 2050 in comparison to 2017, i.e. from 172 TWh to 220 TWh. This will require the increase of installed capacities – in the most conservative scenario presented in this article – up to 60 GW (from the current 43 GW). On the other hand, in 2016 Polish Transmission System Operator

(PSE) predicted that the installed capacity in existing blocks would be reduced by approximately 14 GW by 2035.

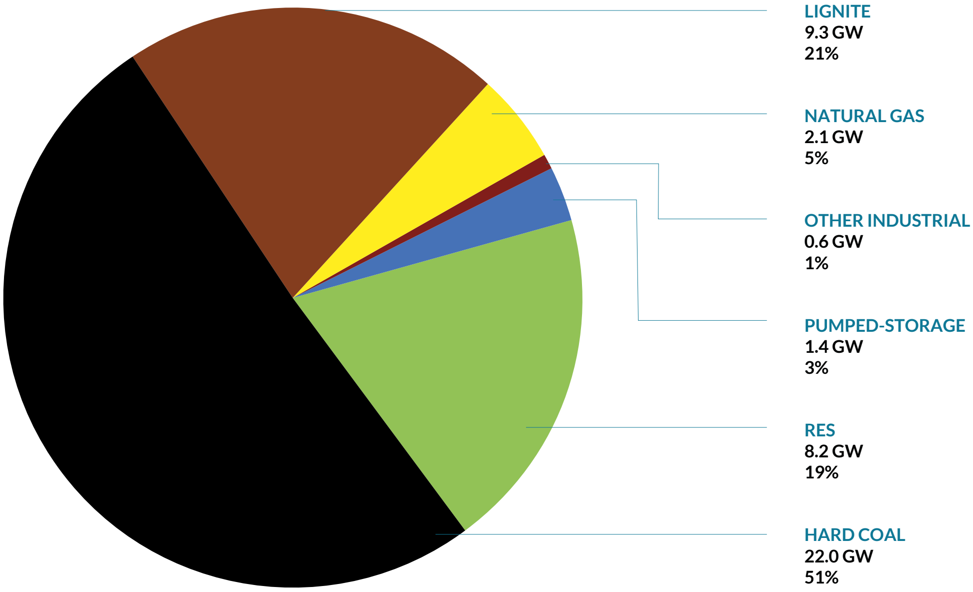
The core of the Polish energy is thermal blocks for solid fuels constituting 72% of the installed capacity in the system (Forum Energii, 2018). Such a monolithic structure may result in a number of threats, such as:

- The risk of a capacity deficit in summer due to the reduced efficiency of thermal blocks with open cooling circuits.
- Relation of the price of energy to the price of CO_2 emissions allowances due to high emissivity of energy generation (781 kg/MWh according to the National Centre for Emissions Management, 2017).
- Difficulties in integrating variable renewable energy sources due to the low flexibility of generation sources.

It is therefore necessary to diversify the generation mix by adding low-emission sources with different properties, e.g.

- Photovoltaic power stations (high productivity in summer and correlation with the peak demand for energy).
- Wind farms (huge generation potential).
- Nuclear power plants (providing baseload).
- Gas-fired power plants (high flexibility).

Figure 2. Structure of installed capacities in 2017



Source: Forum Energii (2018).

The development of renewable energy is an important international obligation for Poland. It is possible that our country will not fulfill the goal planned for 2020 (according to the national action plan – the share of RES in electricity consumption is to reach 19.13%). Thus, it will be more difficult to participate in the implementation of the EU goal planned for 2030 in the amount of 32%. Hence, Poland should develop a strategy to achieve this goal.

The challenge for the transmission system operator is to adapt the grid to the new configuration of generation sources. Networks in the northern part of the country are too weak to receive energy from offshore wind farms with a capacity of 8-10 GW. Moreover, it is necessary to increase the capacity of connections on the North-South route. This is important due to the asymmetric distribution of the KSE loads (the southern part of the country receives comparatively more energy than the northern part).

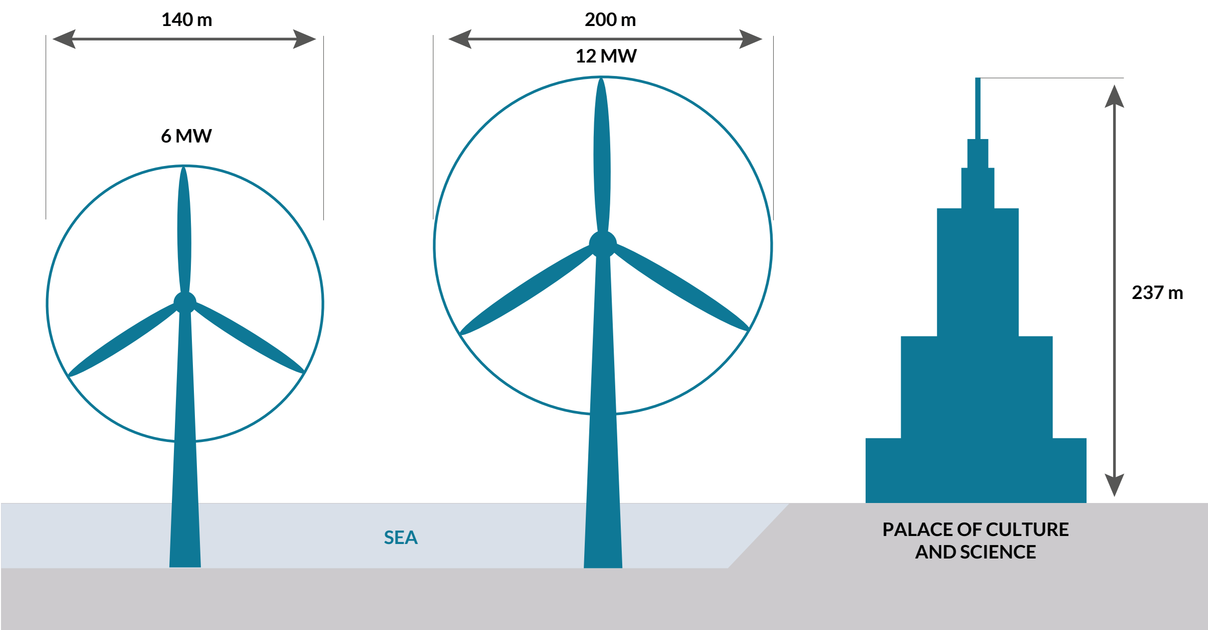
4. Unique properties of offshore wind energy

Offshore wind is a large and inexhaustible resource of clean energy. On the basis of measurements collected since 2009 at FINO 2 station at the Baltic Sea, Fraunhofer IWES (2018) notes that the average annual wind speed exceeds 9 m/s at a height of 92 m in the German economic zone. Similar, though slightly lower results are reported by the Polish Wind Energy Association (PWEA, 2018), which indicates the average wind speed below 9 m/s according to measurements made in the area of Ławica Słupska. In turn, according to PKO BP (2018), this figure is within the range of 8.5-9 m/s.

The capacity of wind turbines depends on the size of the rotor and grows proportionally to the square of their length. In addition, the wind is stronger at higher altitudes. Therefore, as technologies evolve, higher and larger turbines are being built. Offshore wind farms can be assembled with the use of very large elements. The average volume of capacity obtained from marine turbines was 5.9 MW in 2017 (WindEurope, 2018).

The tendency to install larger and larger turbines will continue in the next years. Bet, Fichtner, Prognos (2018) indicate that turbines with a capacity of 8 MW (Siemens Gamesa Renewable Energy) and of 9 MW (Vestas) will be available on sale in 2018, which will translate into an increase in the productivity of offshore wind farms while turbines with a capacity of 12 MW (GE) will be available on sale at the beginning of 2020.

Drawing 1. The size of offshore wind farms designed currently and in the future.



Source: own elaboration on the basis of INNWIND.EU (2017).

Even now, the productivity of offshore wind farms is high. Fraunhofer IWES (2018) estimated that in the case of Baltic 1&2 – two offshore wind farms located in the German economic zone of the Baltic Sea – the full load hours amounted to 3,852h in 2017. In turn, the Danish Energy Agency (2017) stated that this indicator amounted to around 4,200h in 2014 for offshore wind farms constructed in 2009-2013 in Denmark.

Offshore wind farms do not raise social controversy due to the distance from residential areas, although their construction requires an assessment of the environmental impact of wind turbines and network infrastructure.

The construction of power connections is a complex issue. Usually, these are AC cables several dozen kilometres in length. Networks hold a large share in the total investment outlays of offshore farms (around 15-20%).

From the Polish perspective, around 100 domestic companies may participate in the development of offshore wind farms, providing a supply chain and provision of services, e.g. shipyards and ports, electro-technical industry, specialized service companies. McKinsey (2016) estimates that there appear 77,000 new direct and indirect workplaces during the construction of offshore wind farms with a capacity of 6 GW.

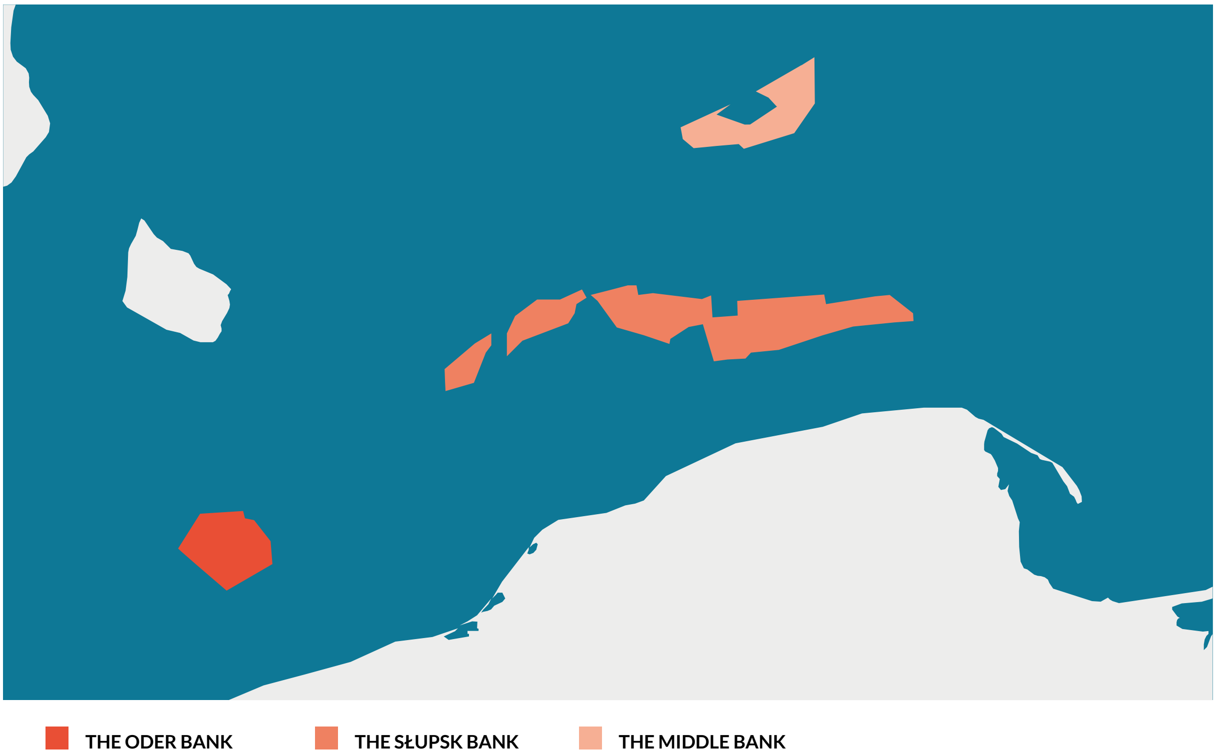
5. Where are we today in Poland?

Offshore wind farms can be built and operated in the area of the Polish economic zone in the Baltic Sea. Currently, work on a development plan of offshore areas is in progress which, among others, indicates the area to be used by the power industry. The total area made available for this goal is about two-thousand km^2 and includes (Figure 2):

- The Oder Bank – 380 km^2
- The Słupsk Bank – 1,210 km^2
- The Middle Bank – 390 km^2

Considering that a capacity of 4-5 MW can be deployed on one square kilometer, the generation potential in this area will be 8-10 GW. The use of this potential should be divided into stages, which will allow for the gradual acquisition of experience and competences by domestic companies and will facilitate their integration into the network and will bring financial savings due to the expected decrease in levelized costs.

Drawing 2. Areas for use by wind energy in the Polish economic zone at the Baltic Sea



Source: Own resources on the basis of the map of the Maritime Office in Gdynia (2018).

According to information obtained from investors, the estimated time for preparation and implementation of the first investments will last around 12-14 years. Subsequent projects will be implemented faster due to the possibility of using some of the obtained research results and streamlining the permit process (Table 2).

Table 2. Indicative time frame for investments in offshore wind energy

Stage of the project	Year													
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Obtaining a permit for the construction and use of artificial islands, structures and equipment in Polish offshore areas	■													
Grid connection conditions		■												
Agreement on grid connection			■											
Environmental research		■	■											
Environmental Impact Assessment Report			■	■										
Permission for cable laying and using cables in off-shore areas				■										
Decision on the environmental conditions of the investment				■	■									
Acquisition and conclusion of a contract for the sale of electricity from RES							■							
Geological and geophysical research			■	■										
Wind, wave and current research					■	■								
Design								■						
Re-assessment of environmental impact									■					
Building permit										■				
Construction											■	■	■	
Occupancy permit														■
License for energy generation														■
Launching energy generation														■

Source: Own resources on the basis of information collected from investors.

Investments in wind energy located in the Polish economic zone at the Baltic Sea have been being prepared for six years. Nine paid[1] location decisions have already been issued for projects with a capacity of around 10 GW (Drawing 3). The following companies have obtained them:

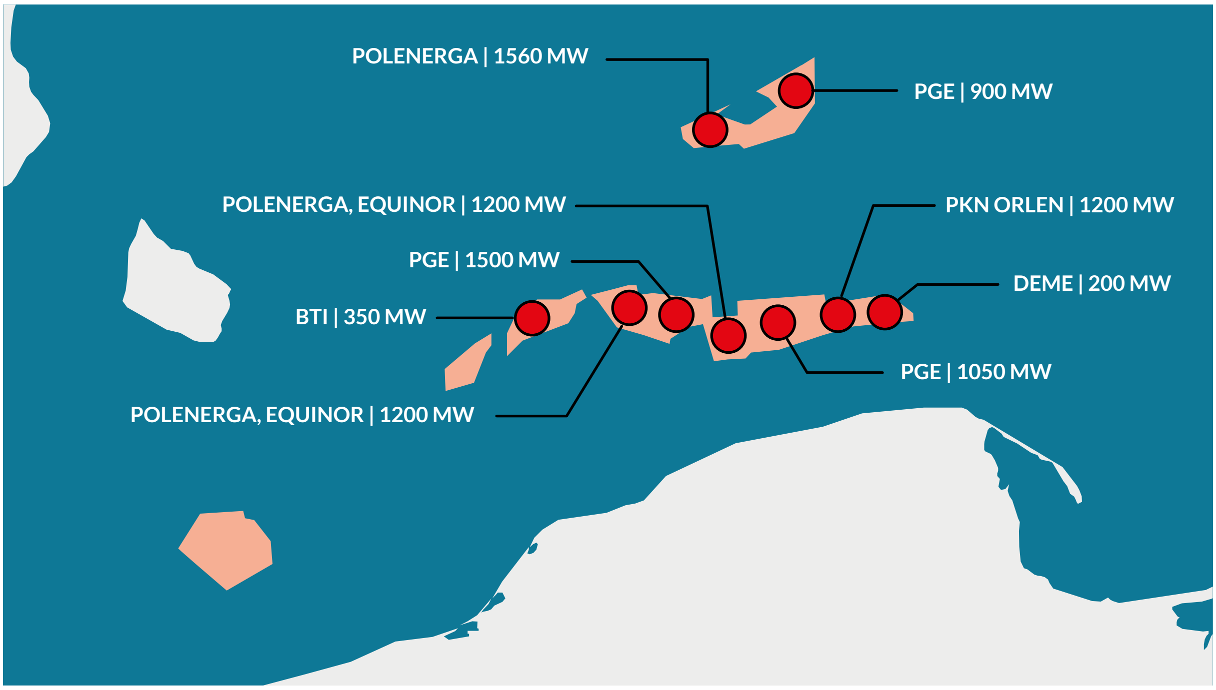
- Polenergia
- Polenergia and Equinor (two locations)
- Polska Grupa Energetyczna (three locations)
- PKN Orlen
- Baltic Trade & Invest
- DEME NV

The advancement of individual projects is different. Polenergia and Equinor have obtained environmental decisions for two projects with a total capacity of 2.4 GW and they signed a connection agreement with PSE for 1.2 GW (to be implemented in two stages of 0.6 GW each). By the end of 2018, Polska Grupa Energetyczna (PGE) is likely to receive an environmental decision for two projects with a total capacity of 2.55 GW. It has already signed a connection agreement for 1.05 GW. Baltic Trade & Invest is applying for an environmental decision for 0.35 GW. In turn, PKN Orlen is at the beginning of the preparation of the project for 1.2 GW, but it intends to join the group of leaders in a short time. Other projects are being developed at a much slower pace.

It is worth explaining that environmental decisions are granted for the maximum possible capacity that results from location decisions. On the other hand, investments are limited by the terms of connection to the network. Therefore, when estimating the capacity that will have in effect been achieved by 2030, it is necessary to analyze the values contained in the conditions and connection agreements. The potential, which is the difference between the connection power and the capacity resulting from the location decision, may or may not be used in the future.

1 Pursuant to Article 27b of the Offshore Areas of the Republic of Poland Act and maritime administration, upon receiving the permits for the construction and use of artificial islands, structures and equipment in Polish offshore areas, the first instalment (10%) of permit fee in the amount of 1% of the value of the implemented initiative should be paid. As of today, the status of permits that have not been paid is not clear.

Drawing 3. Entities that have obtained paid location decisions*



* Provided capacities according to permits for the construction and use of artificial islands, structures and equipment in Polish offshore areas.

Source: Own resources on the basis of data of PSEW (2018).

It should be expected that only the most advanced projects (about 2-3 GW) will have been able to be completed and connected to the network by 2030. Subsequent projects (6-7 GW) may be implemented at the beginning of the 2030s, provided that they start to be prepared from now on.

6. Impact on the Polish power system

6.1 Power and generation

The implementation of the offshore wind farm project is part of a wider transformation process of the Polish power industry. Table 3 shows an increase in capacity from offshore wind farms against the background of a diversified scenario without a nuclear power plant, developed by Forum Energii (2017). The share of capacity from offshore wind farms in the production structure of the Polish power industry is at the following level:

- 3.6–5.4% in 2030
- 12.8–15.9% in 2035

Between 2030 and 2035 there will be profound changes in the generation structure. Coal capacities will be replaced with gas and renewable sources. Increasing gas capacities means more flexibility of the system and the ability to integrate a large volume of variable renewable energy sources. The increase in capacities in offshore wind farms will be greater than the overall increase in RES power, which means that they will replace not only coal capacity, but also older RES technologies (e.g. biomass and biogas installations or worn-out onshore wind farms).

Table 3. Offshore wind farms in a diversified scenario without a nuclear power plant, in GW

Type of generation source	2030	2035
Coal	23.8	14.2
Natural gas	11.1	21.3
RES (including offshore farms)	20.8 (2–3)	27.2 (8–10)
TOTAL	55.6	62.7

Source: Calculations based on the data from Forum Energii (2017) and own assumptions.

Offshore wind energy will have a significant share in covering domestic demand – this indicator will reach 17-21% in 2035. This is due to a high productivity of offshore wind farms – the load indicator will be around 4,000h (Bet, Fichtner, Prognos, 2018).

Table 4. The share of energy production from sea farms in the demand for energy in Poland

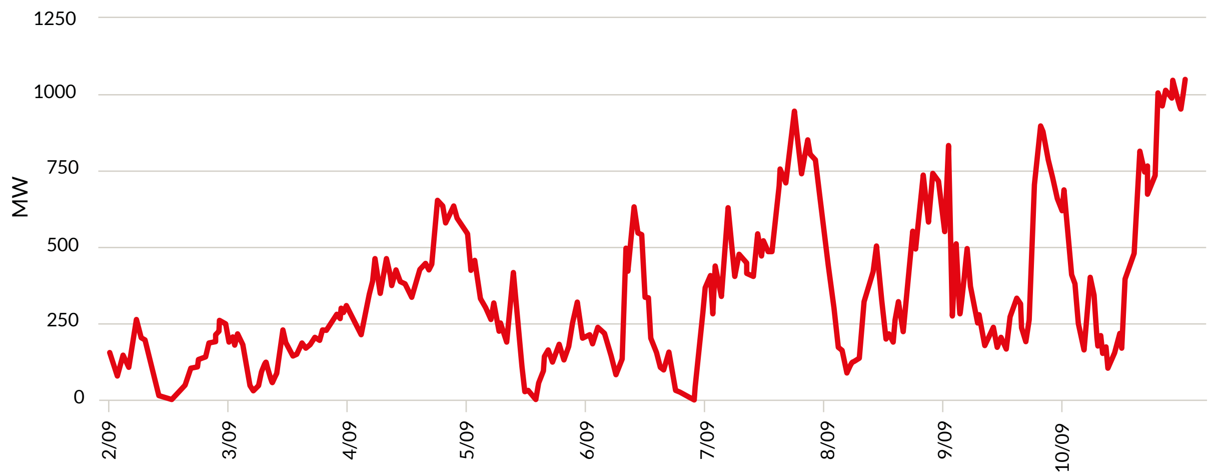
Specification	2030	2035
Demand for energy in Poland, in TWh	180	190
Production from offshore farms, in TWh	8–12	32-40
Share of production from offshore farms	4.4–6.7%	17–21%

Source: Calculations based on the data from Forum Energii (2017) and own assumptions.

6.2. Integration and balancing of energy from offshore farms

The integration of energy from offshore wind farms will require changes in the balancing of the system by the transmission system operator due to the capacity of these sources and the variability of their production. While the capacity of 2-4 GW should not be a problem for the operator, more extensive regulatory changes will be needed when integrating the capacity of 8-10 GW from wind farms. Figure 3 depicts a weekly energy production profile of Belgian offshore wind farms with a capacity of 1,178.2 MW. The capacity supply is characterized by high variability. For example, between 6:00 p.m. on 7 September and 4:00 a.m. of the following day, capacity transmitted to the network decreased from 748 MW to 102 MW.

Figure 3. Weekly work profile of Belgian offshore wind farms with a capacity of 1,178.2 MW in the first week of September 2018



Source: http://www.elia.be/en/grid-data/power-generation/wind-power.

In Polish conditions, the integration of offshore wind farms with the Polish Power System will be facilitated by the fact that their construction will be divided into stages. By 2030, the capacity of 2-3 GW may be connected, and 6-7 GW in the next decade. Until then, the power industry should increase its flexibility, which will allow for balancing these capacities in the system. In the diversified scenario without a nuclear power plant, presented at the Forum Energii (2017), construction of gas facilities is planned (with a capacity of over 8 GW by 2030), which will constitute a reserve for offshore wind farms. Moreover, the improvement of the KSE flexibility may be achieved by lowering technical minima and increasing the speed of loading and unloading of coal-fired units, wider use of Demand Side Response (DSR) in order to make it more flexible, building energy storage, and interconnectors. It is also possible to apply regulatory services provided by wind farms on a larger scale (e.g. reduction of capacity transmitted to the grid).

In addition, the integration of offshore wind farms with KSE may be facilitated by:

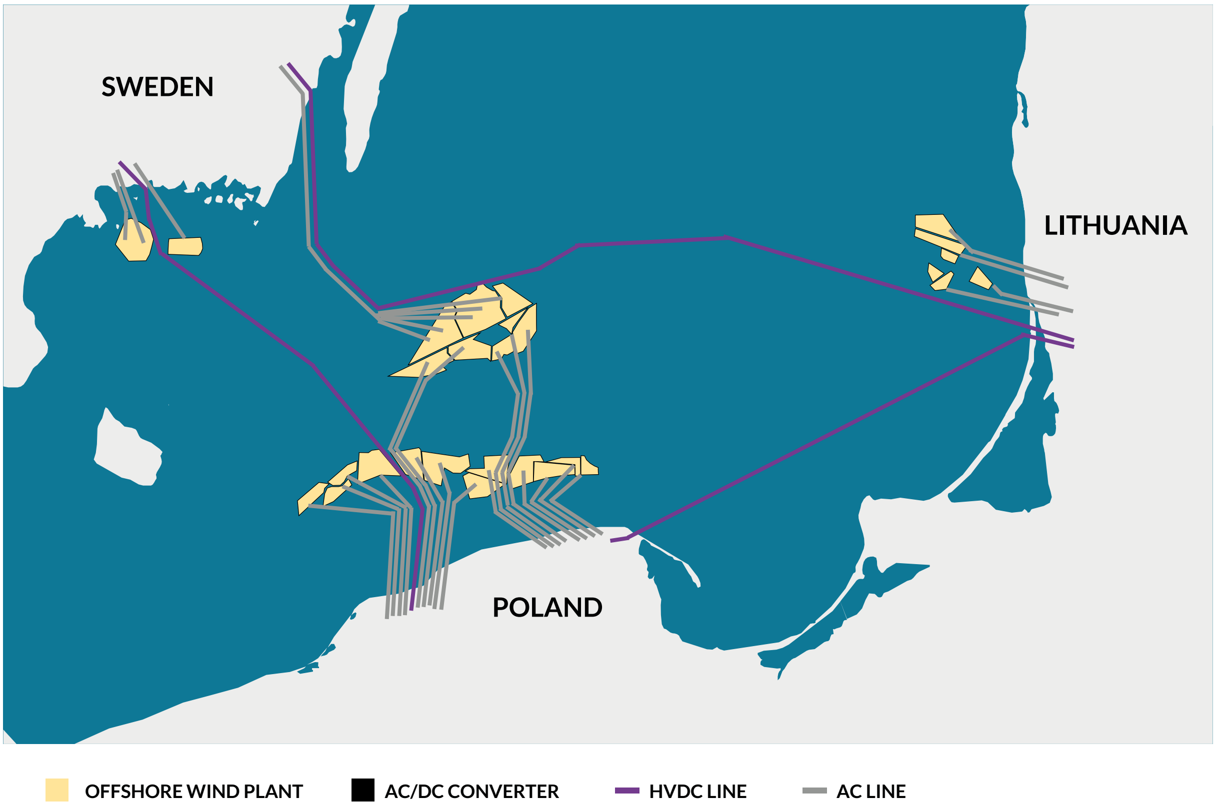
- Improvement of wind generation forecasting methods and tools that will enable the transmission system operator to respond to changes in wind farm production sufficiently in advance.

- Introduction of legal regulations enabling the control of offshore wind farms by the transmission system operator in a situation in which production is too large and cannot be received (e.g. at night, when the wind is strong, and the system load is low).
- Providing regulatory resources that generate energy using rotating masses in order to maintain the stability of the energy system of a frequency (inertia), voltage (reactive power) and dynamic (short-circuit power) character.
- Deepening regional integration, construction of new subsea interconnectors in the southern region of the Baltic Sea which will improve the reception of power from offshore wind farms with high wind power.

On the other hand, the necessary condition for reception of energy from the sea is to increase the capacity of the grid in the northern part of the country and to enable the flow of power from the north to the south. The key project in this area is the construction of the so-called Baltic rail (Krajnik-Dunowo-Słupsk-Żarnowiec-Gdańsk Błonia) and investments covered by the Transmission Network Development Plan until 2025 in the northern part of the country.

Offshore wind farms can be connected to the grid in various ways. If the radial connection model (each farm is connected separately to the onshore network using an AC line, see Drawing 4) is chosen, the impact on the energy will be analogous to the impacts of onshore farms. Thus, fluctuations in the power supplied by offshore wind farms (from 0 to 10 GW) would have to be balanced within the Polish Power System or exported with existing and new cross-border connections. Assuming the implementation of investments provided for in the Transmission Network Development Plan by 2025, it is possible to connect farms with a capacity of 2.25 GW in this model (in accordance with the connection agreements signed by investors from PSE). Connecting additional farms requires additional investments in the networks within the country and the construction of DC cross-border connections with Sweden and Lithuania.

Drawing 4. The concept of radiant connection of offshore wind farms

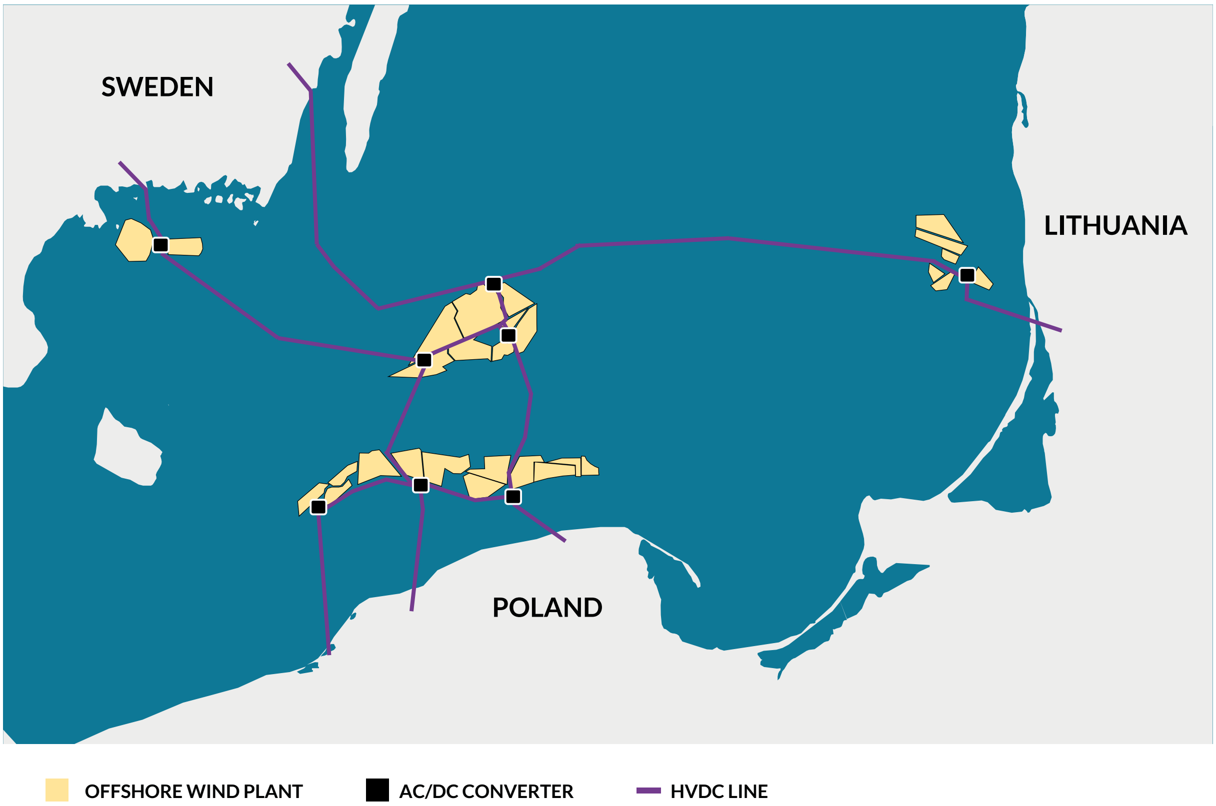


Source: Own resources on the basis of Baltic InteGrid (2017).

If the integrated model with new cross-border connections is selected (see Drawing 5), the nature of impacts will be different. On the one hand, there will be the possibility of exporting energy from Polish offshore wind farms directly to Sweden and Lithuania (if there are buyers) without introducing it into KSE. On the other hand, those countries will be able to offer surpluses from their own offshore wind farms (but also from other sources), increasing pressure on KSE. In this case, the balancing of capacity in KSE may be even more difficult than in the radiant connection model. So the main advantage of this solution is that new cross-border connections will be built and regional cooperation opportunities will increase, but it will not facilitate the balancing of new capacity in KSE.

In addition, it must be taken into account that the technology of DC connections does not as yet allow for the construction of meshed networks, but only linear networks from point to point (alternatively multi-station), which makes it difficult to connect many farms. It is also necessary to take into account the delay of the entire offshore wind energy project, because firstly cross-border connections would have to be built, and it would be later possible to connect the farms.

Drawing 5. The concept of connecting offshore wind farms integrated with offshore cross-border connections



Source: Own resources on the basis of Baltic InteGrid (2017).

Most likely, an indirect variant of connecting wind farms will be implemented, especially as two projects have already concluded the connection agreements (2.25 GW) with KSE, while others are trying to do so. Thus, the capacity of 2-3 GW will be connected directly to the onshore network with AC cables. The use of DC cross-border connections can only apply to other objects that will be implemented in the 2030s.

If Poland starts cooperating with Sweden and Lithuania in the construction of cross-border connections that would serve to receive energy from offshore wind farms, it is possible to obtain co-financing from the European Union. The Connecting Europe Facility will support renewable energy projects in the common European interest. It is aimed at cross-border projects. In the new financial perspective 2021-2027, the energy component is to receive 8.7 billion euros.

6.3. Regional cooperation

The regional cooperation discussed above is implemented as part of *Baltic Energy Market Interconnected Plan* (BEMIP) of June 2015.

The action plan includes:

- Investments in transmission infrastructure (the Sweden-Lithuania offshore and Lithuania-Poland offshore connections have already been implemented, the location of new undersea cables is being considered).
- Internal market (the market coupling mechanism has already been implemented and Lithuania, Latia and Estonia have been added to the Nordpool market).
- Energy security and synchronization of the Lithuanian, Latvian, and Estonian markets with the EU market.
- RES development.
- Improvement of energy efficiency.

One of the elements of BEMIP is *the Integrated Baltic Offshore Wind Electricity Development* project, abbreviated as Baltic InteGrid. Its aim is to optimize the use of wind energy potential by integrating the connections of offshore farms (including those located in the Polish economic zone) with cross-border connections. The works have been going on for a year and are due to end in 2019 (the partial effects of this project are shown in Figures 5 and 6).

Cooperation within BEMIP is an opportunity for an integrated and coordinated plan for connecting offshore wind farms. This will allow for a wider and more effective use of the Baltic wind resources, strengthening cross-border connections and improving the safety and reliability of all systems in the region. It is a long-term project that should be taken into account when planning the first wind farms.

6.4. Market impact of introducing 8 GW of offshore wind farms into the system

Offshore wind farms will have a strong impact on the energy market due to the large and variable volume of energy introduced. They will be a vital element of the low-carbon transformation of the Polish power industry. The phenomena described below refer to a broader class of RES power, not only to offshore wind farms.

The differences in the merit order will increase on windy and windless days. Along with the flexibility of the market, this will result in high price volatility on the day-ahead market and the intraday market. Sometimes (e.g. at night during strong winds) prices will be low, below the short-term marginal cost of production in coal-fired units.

In the case of an increase in hard coal prices and prices of CO_2 emission allowances (which can be observed in the past year), the relative market position of particular classes of energy resources will change. The increase in conventional energy costs will translate into a simultaneous increase in the profitability of renewable energy sources. Electricity consumers will benefit, because electricity from offshore wind farms will not be charged with the expense of CO_2 emission allowances.

Revenues from the sale of energy will be reallocated into conventional coal-fired units, zero-emission sources (wind and solar farms), as well as flexible energy resources (gas-fired units, demand management, energy storage facilities).

7. Costs

Unit investment outlays for wind farms are falling fast. Bet, Fichtner, Prognos (2018) note that offshore wind farms from 2015-2016 incurred outlays in the amount of EUR 3.3 million/MW (the outlays for connection to the grid are also included in this amount). They also assume a decrease in outlays down to EUR 2.28 million/MW in 2025.

This is in line with data on projects approved for implementation in the European Union. WindEurope (2018) reports that the investment decisions regarding six projects (in Great Britain and Germany) with a total capacity of 2.5 GW for EUR 7.5 billion were made in 2017. Outlays per one MW currently amount to around EUR 3 million.

The main technological reason for the decline in unit investment outlays is the increase in the size and efficiency of turbines and the optimization of the supply chain and investment connections. In 2005-2017, the average capacity of turbines increased from 3 MW to 5.9 MW (WindEurope, 2018). Scale effects are associated with a smaller number of connections and construction works, which are carried out per MW.

The implementation of the Polish project of construction of offshore wind farms with a capacity of 8-10 GW will take approximately 15 years. During that time, the unit investment outlays will continue to decrease due to current trends, e.g. the forecasted increase in the capacity of offshore wind turbines (up to 10-12 MW). At the same time, it should be taken into account that these will be the first investments of this type in Poland, therefore levelized investment prices may be, especially in the initial period, higher than in countries with developed executive potential. For this reason, investments implemented in Poland can be up to 10% more expensive in comparison to these countries. For 2025-2029, the range is from EUR 2.28 to 2.51 million/MW (including the connection to the grid) at 2017 prices. However, in 2030-2034, there may be a decrease in unit outlays by 5%.

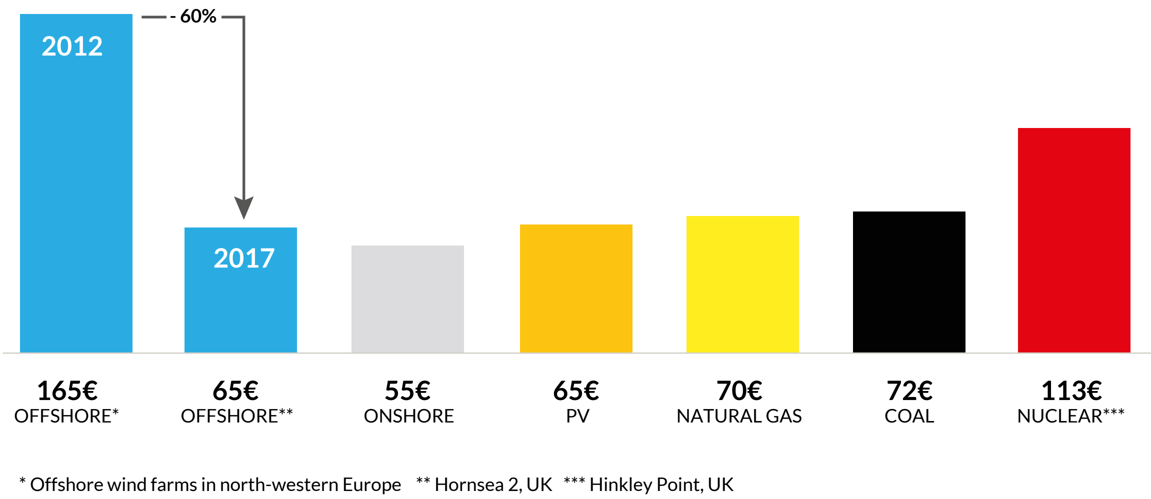
Table 5. Expected outlays for the construction of offshore wind farms with an AC link within the territory of the Polish economic zone

Years	Outlays per MW with AC connection, in million EUR/MW		Capacity in GW		Investment outlays, in billion EUR	
	Min.	Maks.	Min.	Maks.	Min.	Maks.
2025–2029	2.28	2.51	2	3	4.56	7.53
2030–2034	2.05	2.26	6	7	12.30	15.82
TOTAL			8	10	16.86	23.35

Source: Calculations on the basis of data from Bet, Fichtner, Prognos (2018) and own assumptions.

The levelized cost of electricity (LCOE) by offshore wind farms have dropped significantly in recent years. According to Ørsted data, in the United Kingdom they decreased by around 60% between 2012-2017 and became competitive in relation to other energy sources. On the other hand, Bet, Fichtner, Prognos (2018) state that the cost was EUR 116/MWh for German farms from 2015-2016, and by 2025, in the reference scenario, they forecast a decline to EUR 68/MWh (including the cost of connections).

Figure 4. Comparison of the levelized cost of electricity generation from energy sources in north-western Europe, in EUR/MWh at constant prices from 2016



Source: Own resources on the basis of Orsted (2018).

It should be assumed that the levelized cost of energy generation by farms in Poland will be at a higher level than in countries with a developed potential of offshore wind energy. The main factors are:

1) Higher cost of raising capital.

2) Early stage of the sector development – no advanced supply chain.

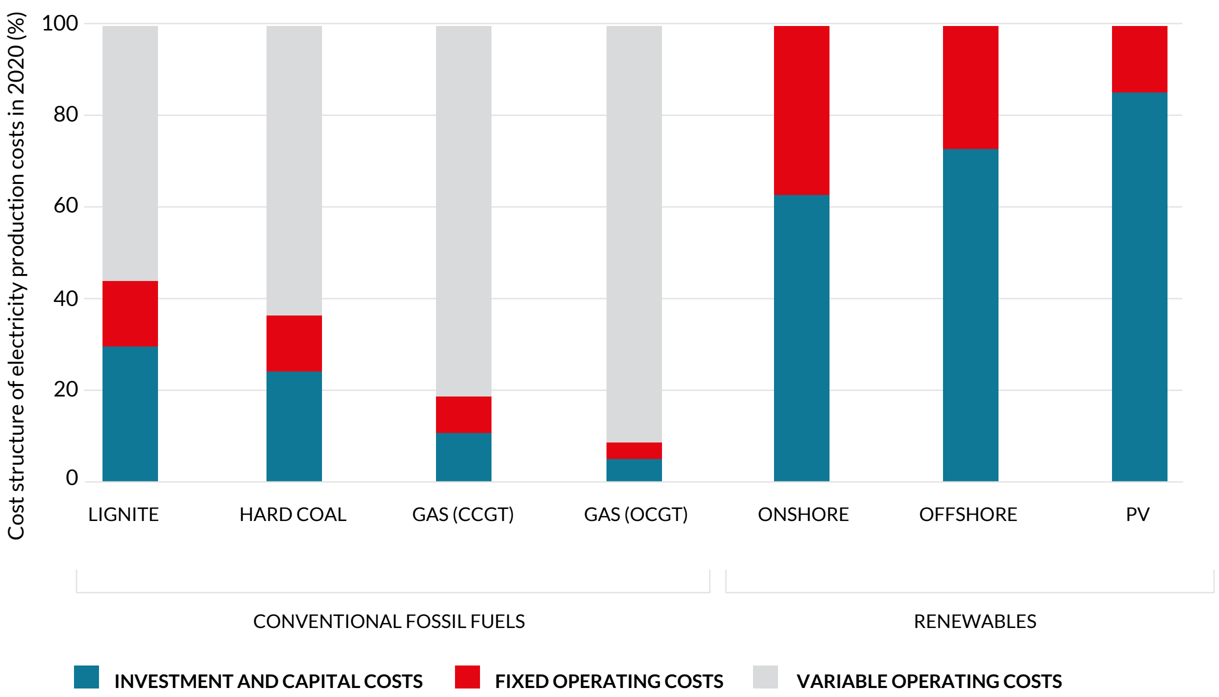
3) In the first phase too small scale of optimization of operating costs.

Construction and operating costs may be partially offset by acquiring partners with experience in the construction and operation of such facilities. This will allow for the transfer of know-how and implementation of investments based on best practices.

8. Possibilities of reducing the cost of capital

In comparison to conventional sources, offshore wind farms are characterized by a high share of investment costs (depending, among other things, on the cost of capital) in the cost of electricity generation. For example, the share of these costs for a hard coal-fired unit does not exceed 25%, and for offshore wind farms it is over 75%. For this reason, the levelized cost of electricity from offshore wind farms is very sensitive to changes in the cost of capital (WACC).

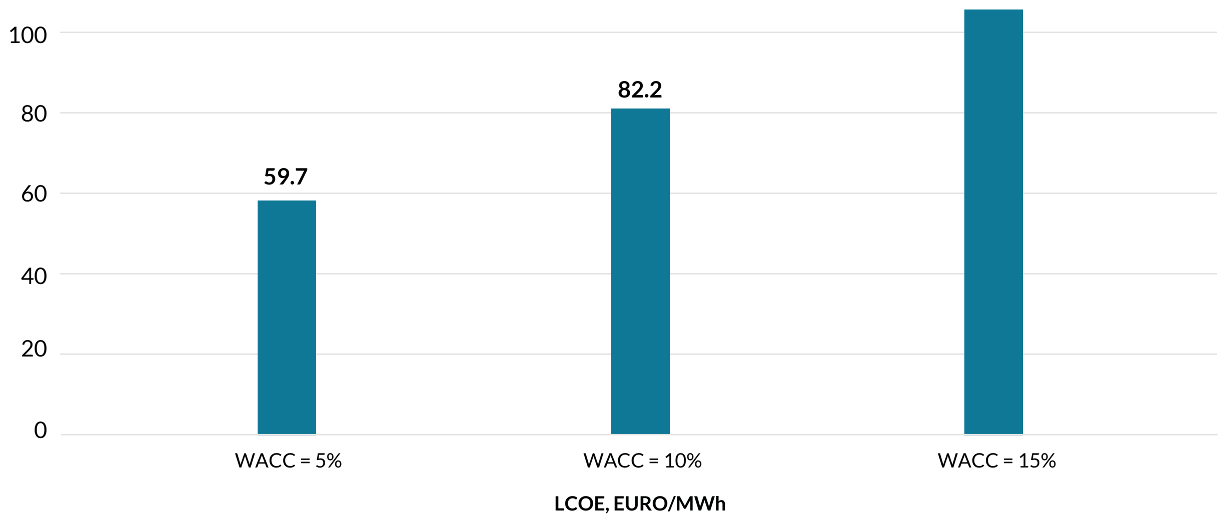
Figure 5. Comparison of the cost structure for different technologies



Source: Own resources on the basis of Agora Energiewende (2018).

Figure 6 shows how this indicator changes for various capital cost values. The change in the cost of capital from 5% to 15% translates into almost a twofold increase in the levelized energy cost. A cost of capital higher by one percentage point means an increase in the levelized energy cost by about EUR 4.5/MWh. If this additional cost is multiplied by the annual energy volume, which will eventually be generated in offshore wind farms (32-40 TWh), then the total cost for recipients will increase by EUR 144-180 million. This example illustrates how important it is to reduce the cost of capital acquired by investors.

Figure 6. The amount of the levelized cost of energy obtained from the offshore wind farm depending on the cost of capital



Source: own calculations based on the assumption that investment outlays together with the connection amount to EUR 2.28 million/MW, and operating costs and insurance – 80 thousand euro/MW/year; 25-year period of analysis.

The 2014 financial data illustrate large differences in the cost of capital for the construction of onshore wind farms (Agora Energiewende, 2018). The cost of capital in different countries is:

- In Poland – 8.7–10%
- In Germany – 3.5–4.5%
- In Denmark – 5–6.5%
- n Great Britain – 6.5%

These differences result from the risk of investing in a given country. An important factor is the risk connected with the way the RES sector is regulated and with the support system. If the regulations and support system are predictable and there are guarantees of respect for the acquired rights, financial institutions are willing to lend money upon better terms. Due to serious disturbances on the Polish RES market caused by the transition from the green certificates system to the auction system, investments in offshore wind farms may be exposed to the need to pay a higher bonus for regulatory risk. One of the possibilities of avoiding this financial burden is to launch a new financial instrument that will insure investors against this type of risk (Agora Energiewende, 2016 and 2018). The proposed mechanism of cost reduction in renewable energy construction may be an attractive option for the Polish offshore wind farm project.

Mechanism to reduce investment costs

As part of this mechanism, Poland concludes an agreement with a European financial institution with high financial credibility. The subject matter of the agreement are guarantees for investors in offshore wind farms, including the risk of regulating the RES sector and the support system (e.g. due to a decrease in the cost of technology). Poland undertakes to 1) design, implement, and maintain the support system in accordance with best practices for this sector, and 2) pay compensation to the financial institution if the support system is changed to the detriment of investors. Then, the European financial institution grants the investors in offshore wind farms a guarantee with regard to regulations and support system. As a result, the investors can get loans with a lower interest rate. The costs of energy generation are lower, which will be beneficial for Poland.

When the support system operates in accordance with the assumptions, the loans are repaid from the received income and the guarantee remains unused. If the support system is modified to the detriment of investors, they can obtain compensation from the European financial institution, which in turn will receive reimbursement from the Polish government. Polish investors benefit from this since their reduced risk motivates them to invest, and Polish consumers pay less for electricity.

The InvestEU Fund may be used to implement such a mechanism. In the financial perspective 2021-2027, this Fund is set to have a budget of EUR 38 billion for EU financial guarantees. Poland may sign an agreement to supply the InvestEU Fund with funds intended for guarantees for offshore wind farms. These may be resources from the structural funds or the Cohesion Fund. Currently, the European Commission is developing guidelines that will specify the detailed rules for the InvestEU Fund's supply and the use of its guarantees. The European Parliament is preparing a draft regulation establishing the InvestEU (European Commission, 2018).

The launch of this or a similar mechanism by the Polish government is needed to increase the stability and financial credibility of the energy investment support system – in the discussed case – in offshore wind farms. Otherwise, there is a high probability that the high cost of raising capital will unnecessarily increase the cost of electricity generation from these installations.

9. Reduction of CO_2 emissions

The most important ecological effect of offshore wind energy is the reduction of CO_2 emissions. Table 6 presents estimates based on the average emissivity ratio of 781 kg/MWh for 2016 calculated by the National Centre for Emissions Management (2017). The use of this indicator for the entire analysis period is justified by the fact that offshore wind farms will replace high-emission coal-fired power plants. From 2035, offshore wind farms will contribute to the reduction of CO_2 emissions by 25-31 million tons per year, i.e. 20-25% in relation to the current level of emissions from the power industry.

Table 6. Ecological effect of launching offshore wind farms with a capacity of 8-10 GW

Specification	2030	2035
Energy generation, in kWh	8–12	32–40
Drop in CO_2 emissions, in mln t	6.2–9.4	25.0–31.2

Source: Own calculations.

CO_2 emissions have not only an ecological, but also an economic dimension. With the forecast price of CO_2 emission allowances in the amount of EUR 30/t in 2030 (National Centre for Emissions Management, 2018), the cost of electricity production from conventional units will increase by even EUR 12/MWh (from EUR 20 to 32/MWh for a lignite-fired unit). The production of energy from non-CO_2 sources can be seen as a stabilizing factor in electricity prices and limiting their growth. This is important due to the fact that prices of CO_2 emission allowances are difficult to predict and may be much higher than what appears in current forecasts.

Table 7. The cost of purchasing CO_2 emission allowances for conventional energy sources

Fuel	Average CO_2 emissions in t/MWh	The forecast price of CO_2 emission allowances (2020) – EUR 19/t	The forecast price of CO_2 emission allowances (2030) – EUR 30/t
		The cost of purchasing CO_2 emission allowances	
Lignite	1.065	20	32
Hard coal	0.900	17	27
Natural gas	0.370	7	11

Source: Own calculations on the basis of the National Centre for Emissions Management (2018), Dołęga (2016).

10. Summary

Offshore wind farms are an opportunity for the Polish power industry. By 2035, it will be possible to have 8-10 GW of capacity. As a result, annual energy production from this national, inexhaustible resource will amount to 32-40 TWh, which will allow for avoiding CO_2 emission at a level of 25-31 million tons per year.

The development of offshore wind energy will:

- improve energy security and diversify the energy mix through the use of a national, inexhaustible resource of energy.
- increase the reliability of the energy system by expanding and reinforcing the power grid in the northern part of the country, as well as by ensuring north-south energy transfer.
- give impetus to the development of domestic industry and the creation of new workplaces.
- reduce CO_2 emissions.

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Notes

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Downwind or upwind?

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