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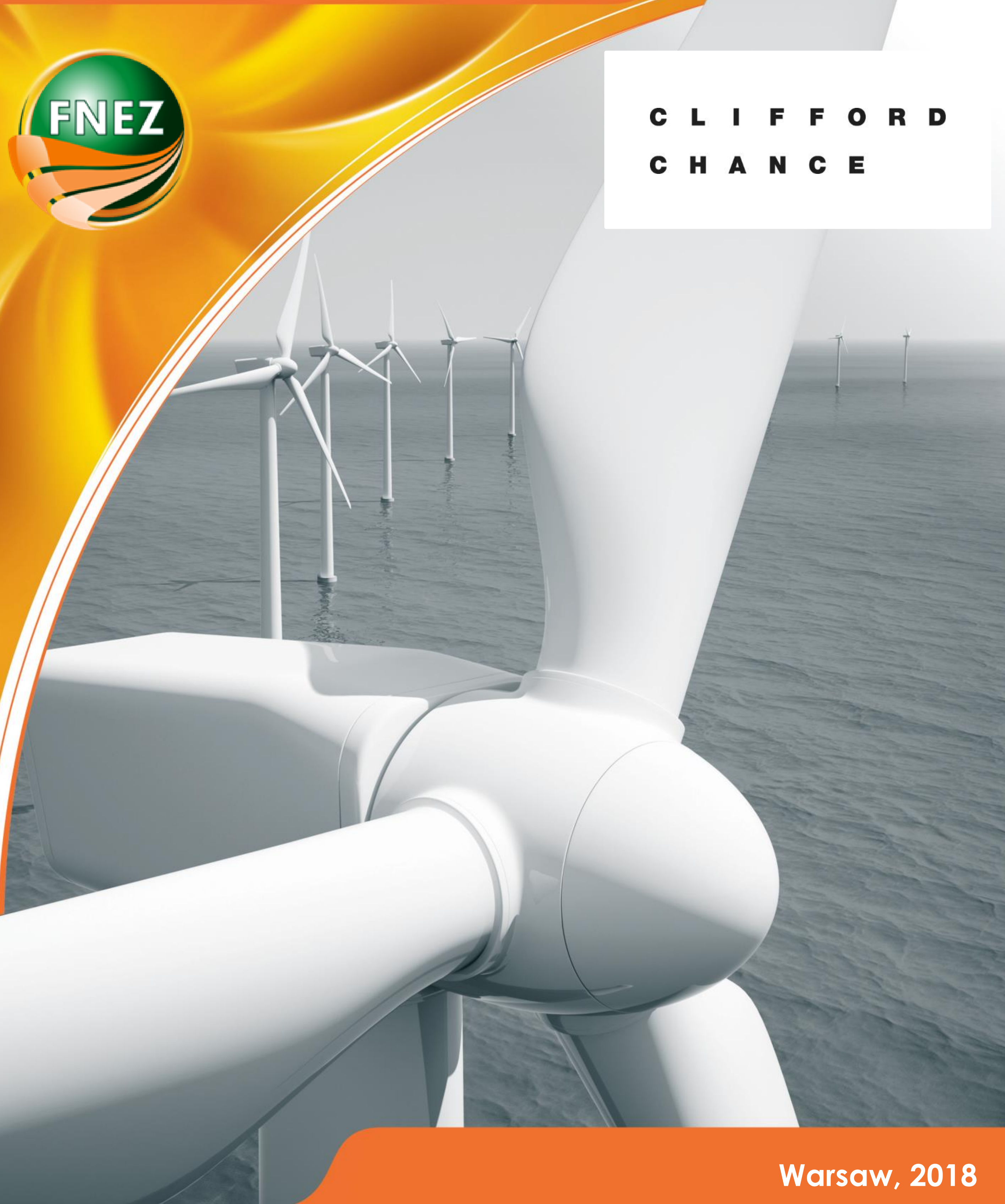

Warsaw, 2018

Programme for the development of offshore energy and maritime industry in Poland

– update 2018

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Programme for the development of offshore energy and maritime industry in Poland
[version for consultation]

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Abbreviations and Definitions

FEED analysis – determination of the reasonable amount of fixed unit purchase price for electricity generated by different types of renewable energy sources (RES) connected to the distribution grid – so-called Feed-In Tariffs (FIT)

UXO studies – unexploded ordnance studies

CAPEX – investment cost

ULICP decision – decision made to determine the location of a public project

DSU – decision on environmental conditions

EIA Directive – Directive of the European Parliament and the Council 2011/92/EU of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment

EEZ – Exclusive Economic Zone

ENTSO-E – European Network of Transmission System Operators for Electricity

EWEA – European Wind Energy Association – current name WindEurope

FNEZ – Foundation for Sustainable Energy

GW – gigawatt

HVAC – High Voltage Alternating Current

HVDC – High Voltage Direct Current

JKWE – cost per unit of energy generation

PIC – project information card

APC – Administrative Procedure Code

NPS – National Power System

kV – kilovolt

kWh/m^{2}a – unit of the average annual wind potential per area

LCOE – levelized cost of electricity

OWE – offshore wind energy

OWF – offshore wind farms

MTI – marine transmission infrastructure

LDP – local development plan

MW – megawatt

MWh – megawatt hour

NSCOGI – North Seas Countries Offshore Grid Initiative

EIA – Environmental Impact Assessment

OPEX – operating cost

RES – renewable energy sources

BP –building permit

PMA – Polish maritime areas

Programme – Programme for the development of offshore energy and maritime industry in Poland

PSZW – permit to erect and exploit artificial islands, constructions and equipment in Polish maritime areas.

PUUK – permit for the laying and use of cables in maritime areas

EIA report – Environmental Impact Report

RDEP – Regional Directorate for Environmental Protection

RWMA – Regional Water Management Authority

TWh – terawatt hour

TWh/a – terawatt hour per year

UOM – Act of 21 March 1991 on maritime areas of the Republic of Poland and maritime administration (Journal of Laws of 2017, item 2205)

RES Act – Act of 20 February 2015 on renewable energy sources (Journal of Laws of 2017 item 1148 as amended)

EU – European Union

URE – Energy Regulatory Office

VIEP – Voivodship Inspectorate of Environmental Protection

HV – high voltage

ROCE – return on capital employed

PDP – peak demand for power

Introduction

The merits of offshore wind energy (OWE) and its development have been discussed in Poland for a decade. Very high efficiency and stability of zero emissions renewable energy generated from this source, as well as relatively low operating costs and low level of social and environmental conflict make this sector one of the fastest growing in the global energy industry. By the end of 2017 17,6 GW has been installed, worth over 30 bn €. Sadly, not in Poland.

Changes in legislation introduced in 2011 resulted in a peaking interest in this technology. Consequently, initial project concepts have been developed for the Polish Exclusive Economic Zone. Over a dozen location permits were issued, however, the Polish government did not launch an assistance program that could support investors' decisions to continue with their projects. Despite the lack of clear political declarations to develop OWE in Poland, there is several projects in progress. Connection contracts have been signed with the grid operator that enable 2,2 GW of offshore wind energy to enter the grid by 2026. For three of these projects comprehensive environmental studies have been completed, and two of them received environmental permits in 2016 and 2017. Nevertheless, no further investment decisions have been made by 2018, which thwarted the possibility of first offshore wind farms becoming operational in 2020.

But despite all that, the topic of OWE development in Poland is still reverberating in conversations about the future of the Polish energy sector. A compelling factor that supports this technology and its further development is that it has direct links to the maritime industry. Manufacturing of offshore wind farm components and construction vessels, servicing farms in shipyards and ports – these are some of the major stimuli driving the process of modernization, and growth of the European, and Polish, maritime industry. Some Polish companies have already benefited from this opportunity. The CRIST S.A. shipyard in Gdynia built leading edge jack-up vessels that are used to install offshore winds farms (OWF). A new ST^3 Offshore plant was built in Szczecin to make jacket foundations for OWFs, while other companies started specialising in steel structures and components of substations used for wind farms built in the North Sea. TELE-FONIKA Kable, a Polish cable manufacturer and global industry leader, has acquired JDR Cable Systems (Holdings) Ltd., thus becoming a major supplier of submarine bus and power cables for OWFs.

Foundation for Sustainable Energy (FNEZ) has been actively promoting offshore wind energy since 2009 as an example of a sustainable technology that respects social and environmental aspects of energy generation and brings clear economic benefits. In 2013, responding to the expectations of this emerging sector, FNEZ and EY – the global consulting expert – developed the „Program for the development of offshore energy and maritime industry in Poland" (the Program). In this document the overall potential of OWE was estimated for the first time in history. We also estimated generating costs, level of assistance expected by investors as well as economic benefits that this technology could bring if its development involved the Polish maritime industry. We indicated a reduction target for investment costs of 25% and for operating costs – 24% as a prerequisite for further development of this technology so that it could reach 6 GW by 2030.

Even though many experts deemed the goals listed in the Program ambitious but realistic, life had other plans. The world's largest providers of offshore technologies, along with many countries that were keen on developing offshore wind, committed to even higher cost reduction targets – below 100 £/MWh by 2020. Introduction of auction schemes as a leading model to determine the level of state assistance for renewable energy sources in the EU turned out to be a very effective tool supporting the achievement of this goal. These aggressive goals translated into technology leaps. Bigger construction vessels, larger and more efficient offshore turbines, innovation in connecting technologies, and above all more streamlined logistics of supplies and construction along with growing competitiveness led to an average price forecast of 75 €/MWh in subsequent EU auctions. Additionally, some positive investment decisions were made for projects beyond 2020 without any support.

The Polish energy industry and economy are facing enormous challenges. Aging coal-fired capacity, the need to introduce more restrictive norms to curb emissions, limited room to grow the domestic coal output, higher utilisation targets for RES looming on the horizon, exhausted potential to grow onshore renewable energy and significant delays in the development of nuclear energy. All these factors are compelling us to start a serious discussion on Poland's energy security in 2020-2030.

Offshore wind energy, which over the last 5 years has become mature and fully competitive from the point of view of technology and has shown considerable potential in the Polish marine areas, should be considered as one of the significant potential sources of energy for Poland. Especially given the wealth of positive experience and huge economic potential locked in our domestic offshore wind sector.

This is why FNEZ decided to update its original Program from 2013, using results of numerous studies performed recently and expertise accrued within the SMDI Advisory Group from the times when initial Polish OWF projects were developed.

This document is a summary of work that has been done so far and presents new estimates of the potential, costs and economic benefits represented by the offshore wind sector, considering existing progress and current market conditions.

We hope that our report will yet again stimulate a far-reaching discussion among industry players and politicians and that it will lead to a positive decision to develop the Polish offshore wind energy as an important tool to achieve energy security and an impulse to create a new Polish specialty – our own offshore wind industry.

Maciej Stryjecki

President

Foundation for Sustainable Energy

Key outcomes and conclusions

- **The real potential of Polish offshore wind is between 8 to 10 GW. The construction of the first OWF in Poland, with 600 MW, can start in 2022. The first OWFs can be connected to the grid in 2025. By the end of 2030 we may have approx. 4 GW built, while by 2035 it could be 8 GW.**

- **8 GW of offshore wind farms, in conjunction with parallel development of gas at the level of 4 - 5 GW and a cross border offshore transmission network with 1,5 - 2 GW capacity, can play a key role in providing energy security for Poland in the years 2025 - 2035, allowing for replacement of capacity deficits resulting from coal that is not compliant with BAT standards and securing the achievement of CO_2 reduction targets as well as required proportion of RES utilisation.**

- **Offshore wind farms in the Polish marine areas will operate approximately 8050 hours annually (91,9%), out of which 5800 hours annually will fall into the ranges that allow for full capacity (66,5%).**

- **Offshore wind farms with 8 GW capacity are able to meet approx. 20% of domestic power consumption.**

- **The price of energy generated by Polish OWFs (LCOE) should fall somewhere between 71 - 80 €/MWh in 2025 and 66 - 75 €/MWh in 2030, provided that investors will bear the costs leading to grid connection. If, however, the operator should bear the cost of grid construction, these prices would go to 57 - 65 €/MWh in 2025 and 53 - 60 €/MWh in 2030.**

- **Offshore wind farms in the South Baltic area can be installed mostly with supplies and services provided by the Polish offshore and maritime industries, while the offshore wind supply chain can become a key industrial specialization for Poland.**

- **Owing to the development of offshore wind energy, the Polish offshore wind sector can bring 77 000 jobs beyond 2025[1].**

- **Construction of OWFs in the Baltic Sea will be an important growth driver for Polish ports, among which Gdańsk, Gdynia, Szczecin and Świnoujście can become major construction centres for offshore wind farms in the South Baltic area, while Łeba, Ustka and Darłowo can turn into key service and maintenance centres for Polish OWFs.**

- **The Polish offshore industry, in partnership with the research centers, has a chance to become a ground for innovation, specialising in the development of cutting edge construction and maintenance vessels, substations, cables, and steel structures, which will drive further growth of the offshore sector globally.**

- **To be able to take advantage of the sector's potential, both from the point of view of energy and our economy, we need the following political decisions to be made urgently:**

    - **Adoption of an ambitious and bold political goal – 6 - 8 GW of OWFs to be built by the end of 2035,**

    - **Legislative changes in 2018, which introduces the following systemic solutions:**

[1] McKinsey&Company, 2016. Development of offshore wind energy in Poland. Perspectives and assessment of impact on the local economy"

        - **in 2019 – auctions that establish guaranteed energy price levels for 15 years for projects with granted environmental permits and connection contracts,**

        - **in 2020 – auctions specifying grid connection conditions, and guaranteed energy price levels for 10 years, for projects with granted valid location permits**

        - **in the areas designated for renewable energy in the Marine Spatial Plan for the Polish marine areas – defining of borders for new projects that have no valid location permits, and in 2021 – auction/tender with respect to location and grid connection conditions.**

    - **The grid operator needs to develop offshore transmission infrastructure, including transboundary connections that will serve as connection points for offshore wind farms on the eastern slope of the Slupsk Bank and the Middle Bank. Cross border offshore grids can be vital to allow for energy import into Poland in periods of heightened capacity deficit. Such projects could use EU funding.**

    - **Development of regulations and practices that will enable Polish companies to create the supply chain for OWFs built in the Polish marine areas. Development of program supporting investment and procurement in the Polish maritime industry that will encourage international investors who are looking to participate in Polish auctions for offshore wind.**

    - **Launching a broad educational program for future employees of the offshore sector, including both vocational and higher education.**

    - **In 2018 - 2020 launching public funds for the expansion of potential, manufacturing and logistics capabilities, research, development and implementation of the Polish offshore energy sector.**

- **The Program has been developed in line with Poland's development directions described in the National Strategy for Responsible Development and it is aligned with the Strategy's main objectives in such key areas as reindustrialization, innovative businesses, development of the SME sector, capital for growth, international expansion.**
- **If the abovementioned political and systemic decisions affecting the development of offshore energy in Polish marine areas will not be made, this technology will not cease to grow altogether in Poland, however, its economic and social potential will remain untapped. Following this scenario, one can expect projects with largest capacity of approx. 2 GW in years 2025 - 2035, and these projects will be executed after the technology has already become fully price competitive. It should be also expected, that due to the need to curb investment risks and costs, the supply chain for these projects will mostly involve technologies and services coming from established international players.**

1. Development potential of OWE in Polish maritime areas

The assessment of the potential of a given sector requires multi-criteria analysis and a variety of factors. For the purpose of the study, the potential of offshore wind energy in Polish maritime areas and the national maritime industry as a supply, logistics, service and service base for offshore power engineering was widely analysed. As a result, theoretical, technical and market potential of the development of offshore wind farms was indicated, thanks to which it was possible to set realistic objectives for this sector in the perspective of up to 2035.

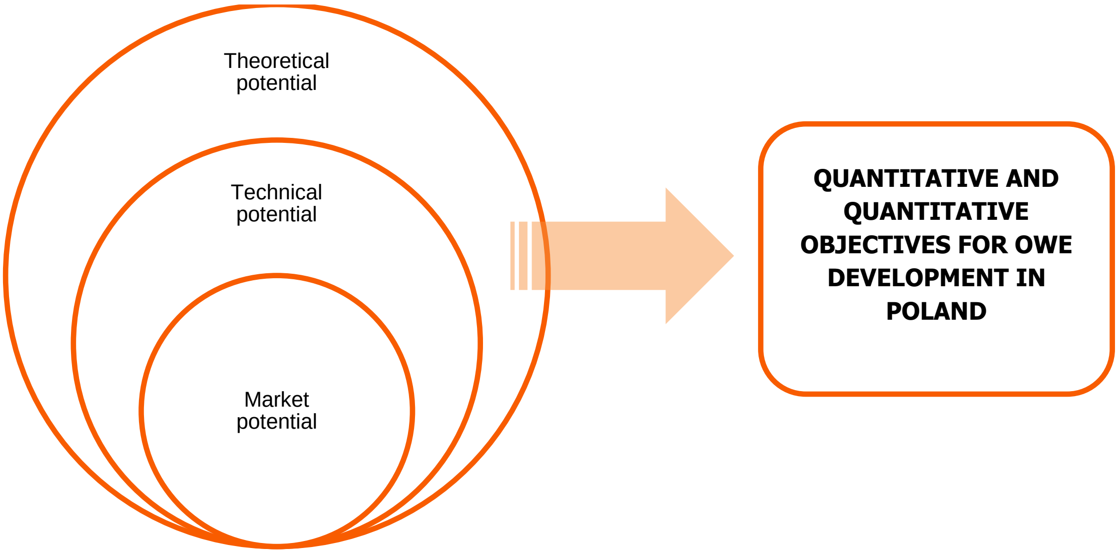

Figure 1 Plan for setting programme objectives

1.1. Theoretical potential

1.1.1. Localisation accessibility

Pursuant to the Act of 21 March 1991 *on Maritime Areas of the Republic of Poland and Maritime Administration* (Journal of Laws of 2017, item 2205; "UOM") amended in 2011, OWF may be located only in the Polish Exclusive Economic Zone. This means a minimum distance from the coastline of 12 nautical miles (approx. 22 km).

From an economic and technological point of view, the most convenient locations for OWF are shallow areas (due to foundation costs) and close to the shoreline (because of installation, maintenance and connection infrastructure costs). The choice of location should also take into consideration the existing forms of use of the maritime areas and the resulting limitations, that is:

- traditional sea routes and possible navigational difficulties,
- military areas,
- areas protected for environmental reasons (NATURA 2000),
- areas relevant to fisheries.

On 2 August 2016, the Director of the Maritime Office in Gdynia, together with the Director of the Maritime Office in Słupsk and the Director of the Maritime Office in Szczecin, announced that they had started to prepare a 1:200 000 scale Polish Maritime Areas Spatial Development Plan. Since then, in accordance with the provisions of the Act of 21 March 1991 *on Maritime Areas of the Republic of Poland and Maritime Administration*, works and consultations of the draft plan are underway, as a result of which a map with preferential functions of maritime areas has been prepared. "Obtaining renewable energy" is one of the preferred functions of Polish maritime areas in the exclusive economic zone. According to the authors of the plan, this function can be a basic (dominant) function in the areas with a total area of about 2,500 km^2.

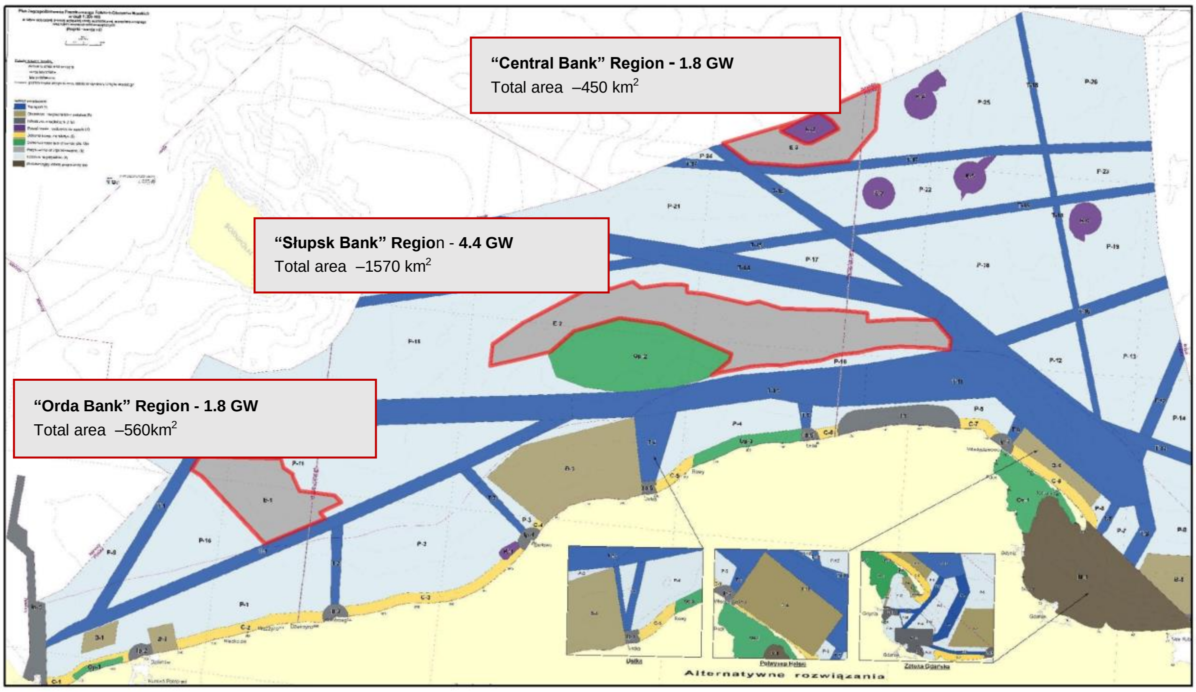

Figure 2 Map of potential locations designated for the location of wind farms in the exclusive economic zone (grey colour indicates areas designated for the development of offshore energy)[2]

1.1.2. Wind conditions, productivity

Wind resources are one of the main factors influencing the OWF productivity, i.e. the legitimacy of their construction and profitability. The preliminary assessment of wind conditions indicates that the area of the Polish economic zone is characterised by one of the greatest wind potential in the Baltic Sea. Analyses conducted by the Maritime Institute in Gdańsk indicate that the capacity of 1 MW of power in the Polish economic zone may be higher than the Baltic Sea area average[3].

For the purpose of this study, a case study "Wind Potential and Productivity of Selected Offshore Wind Farms in Polish Maritime Areas"[4] was prepared, based on wind measurement data from the Offshore FINO 2 measuring platform located in German EEZ, and on the onshore mast located 10 km from the city of Łeba in 2008 - 2009. Thanks to the use of professional mathematical models extrapolating FINO 2 data, the case study included calculations for three model projects representing groups of potential OWF locations in the area: Słupsk Bank, Central Bank and Odra Bank.

For each project the following analyses and modelling have been performed (for a 6 MW turbine in class (on the example of Repower 6M), for three variants of plant density in the farm area: 4 MW/km^2, 6 MW/km^2 and 8 MW/km^2):

- output of energy from the farm [MWh/a],
- efficiency level [%],
- average annual wind power [W/m^2],
- average annual wind energy potential [kWh/m^2a],
- relative and absolute frequency of hours per year depending on wind speed intervals and altitude [%],
- annual average turbine operating time and full power operation time [h, %],
- capacity factor [%].

[2] Maritime Office in Gdynia

[3] Maritime Institute in Gdańsk. 2011. Opportunities to use Polish maritime areas for the development of wind energy.

[4] Windhunter prognoza sp. z o.o. and WIND-consult Ingenieurgesellschaft für umweltschonende Energiewandlung mbH. 2012. Study of wind potential and productivity of selected offshore wind farms in Polish maritime areas. FNEZ - unpublished data.

Then the average capacity factor of a single turbine was calculated and for each of the three analysed variants of the installed capacity per 1 km^2.

The analyses results were verified with the results of the annual wind measurement for the 2013 - 2014 environmental impact assessment and the preliminary results of the professional wind measurement campaign conducted in 2017 for two Polish offshore wind farm projects: Polenergia Bałtyk III OWF, Polenergia Bałtyk II OWF.

The main wind direction in Polish maritime areas ("POM") is located in the western sector (from 255° to 285°) of the wind rose and its share in wind rose amounts to about 17%. The average annual wind speed at a height of 100 m is 10 m/s and at a height of 150 m – 10.46 m/s.

The frequency of hours per year is 150 m depending on wind speed intervals:

- >4 m/s – 7.8%,
- 4-8 m/s – 25.5%,
- 8-12 m/s – 31.1%,
- 12-25 m/s – 35.2%,
- >25 m/s – 0.4%.

The expected **operating time of the turbine**:

- year average – 91.9% [8054 h/a],
- full power – 66.5% [5828 h/a].

The capacity factor for a turbine of class 6 MW will be:

- single turbine – 53.9% [4721 h/a],
- density 4 MW/km^2 – 52.3% [4579 h/a],
- density 6 MW/km^2 – 47.3% [4142 h/a],
- density 8 MW/km^2 – 46.8% [4097 h/a],

Summing up, considering the available area of the Polish EEZ (2500 km^2 by 2030), verified wind conditions, OWF productivity forecasts, the theoretical potential of offshore wind farms in the Polish maritime areas has been defined in two categories:

- 20 GW with 82 TWh/a generation capacity[5] – with a maximum installed capacity scenario (8 MW/km^2 density),
- 15 GW with 62.1 TWh/a generation capacity – with an optimisation scenario (6 MW/km^2 density),
- 10 GW with 45.8 TWh/a generation capacity – with a maximum generation efficiency scenario (4 MW/km^2 density).

1.2. Technical potential

1.2.1. Possibility of connection to the grid

One of the most important factors influencing the development potential of offshore wind energy is the possibility of power evacuation from offshore areas and the introduction of generated energy into the power system. This problem became one of the most important factors holding back the development of offshore wind farm projects, due to the refusal of grid connection conditions for more investments, over 2.25 GW, which were granted to the first two OWF – Polenergia Baltic III and Baltica 3.

The connection possibilities of the National Power System are limited by the following factors:

- low NPS flexibility due to the predominance of coal generating units,
- low level of night-time energy demand, reaching 15.5 GW, with a technical minimum due to the regulatory capacity of 12 GW coal units,

[5] Terawatt hours per year.

- small share in the system of hydro-pumped power plants 1.5 GW,
- weak development of the transmission grid in Northern Poland, both in the west-east direction and mostly in the north–south direction,
- small number of large energy consumers in Northern Poland,
- poorly developed cross-border interconnections, as well as so-called "loop flows" from Northern Germany to south, to the Czech Republic and Austria, reducing the possibility of balancing the system through international energy transfer.

The assessment of the OWF real connection potential is further hampered by the fact that connection capacity has been blocked by a large number of connection conditions issued, especially for onshore wind power projects, mostly in Northern Poland (about 12 - 16 GW)[6].

However, it should be remembered that the assessment of the OWF connection potential should not be based on the current state of NPS, but it must consider factors that will shape its condition in the perspective of 2025 - 2035, in particular:

- projected increase in demand for energy, related to economic growth,
- power losses in the system because of phasing out old generation sources,
- significant delays in the implementation of the investment plan in the power industry regarding new capacities,
- planned investments in new transmission networks,
- projected increase in the share of flexible gas generation,
- development of energy storage technologies,
- development of maritime transmission systems in the Baltic Sea region.

During this analysis, it was assumed that further development of onshore wind energy will be significantly reduced, as a result of implemented systemic changes, limiting the possibility of locating new projects due to existing social and potential environmental conflicts. This will result in the release of at least a dozen or so gigawatts of potential connection power in Northern Poland. Even assuming that part of the released capacity is reserved for nuclear power plant projects to be located in the Baltic Sea coastal strip, **between 2025 and 2035 there should be a possibility of connection to the OWF generation grid of another 7 – 8 GW over and above the 2.25 GW agreed with the operator so far**. Yet, the structure of the energy mix in the domestic power system will have a decisive impact, especially the presence of flexible sources such as gas or pumped-storage. More on this subject can be found in chapter 1.2.2.

1.2.2. Prognosis of changes in the loss and increase of generation capacity in the system

The level of demand for electricity in the country and the ability of other technologies to meet demand is another key factor determining the possibility of development of offshore wind energy in Poland. The key form of demand is the peak moment, therefore, in the analyses of the current and future state of energy mix in Poland we should pay particular attention to the relation of electricity consumption at the peak moment against the amount of energy in the system.

According to PSE Operator[7], demand for peak capacity will increase by about 24% over current demand by 2030 and will reach about 32.7 GW in the winter peak. An additional, very important pressure on the ability to meet electricity demand will be triggered by the necessity to adjust Polish power industry to new, stricter emission standards (the so-called BAT Conclusions), which will come into force four years after the European Commission's

[6] Jagiellonian Institute. May 2015. Release the power of the Polish power engineering – Report on the proposal for the release of connection power for new wind power plants

[7] PSE Operator. 20 May 2016. Prognosis of peak demand for power in 2016-2036. Report on the proposal to release connection capacity for new wind power plants.

decision to use them, i.e. after 2021, and the necessity to decommission the oldest coal-fired boilers, which will surpass their service lifetime after 2020.

According to PSE, between 2020 and 2035, it will be necessary to phase out from 13.9 to 20.9 GW from the system, depending on the amount of modernisation of old coal-fired units that power plants will be able to carry out. During this period, about 5.8 GW of new capacity should be commissioned in investments that have already been started or for which investment decisions have been made. This scenario means that a shortfall of overcapacity is expected after 2022, rising to 13 GW between 2023 and 2035.

The operator points out that, depending on the adopted scenario, in order to maintain the energy security of the system, it is necessary to bring about an increase in installed capacity, over the investments already underway, in the following quantities (depending on the modernization capacity of existing units): by 2025 – 2.6 - 8.5 GW, by 2030 – 6.5 - 17.6 GW, by 2035 – 15.8 - 22.3 GW.

For the purposes of this Programme, FNEZ conducted its own model analyses of the changes that will take place in the fuel and generation structure of the Polish power system. The model considers the existing capacities in different categories and technologies, their viability, as well as planned and prognosed investments in new capacities[8]. The results of the 2012 analyses were updated in 2017, considering significant delays in the execution of several investments, including the nuclear energy development programme in Poland.

The conducted analyses considered the implementation of three offshore wind farm projects, with a total capacity of 2.25 GW, for which connection agreements have been signed and which are in the process of investment preparation: Polenergia Bałtyk III OWF, Polenergia Bałtyk II OWF (Investor: Polenergia S.A.) and Baltica 3 (Investor: PGE Energia Odnawialna S.A.).

Regarding the nuclear power development programme, it was assumed that even in the continuation scenario of the 2011 government programme, the first nuclear power plant would not be commissioned before the end of 2035.

The diagrams in figures 3 and 4 show the most important results, which are consistent with the PSE report.

The general conclusion is that in the years 2021–2030 it is necessary to commission about 9 GW of new capacities, in projects that have not yet been started and are not at an advanced stage of preparation. On the one hand, this is definitely a huge challenge for the Polish energy sector and the economy, and on the other hand, it is a great opportunity for the development of offshore wind energy, which systemic potential, in this context, can be estimated at not less than 10 GW, including 2.25 GW in projects already having connection agreements.

[8] PSE. November 2015. Development plan to meet current and future electricity demand for the years 2016-2025 of PSE. Information on generation resources of NPS (as of 30.11.2017)

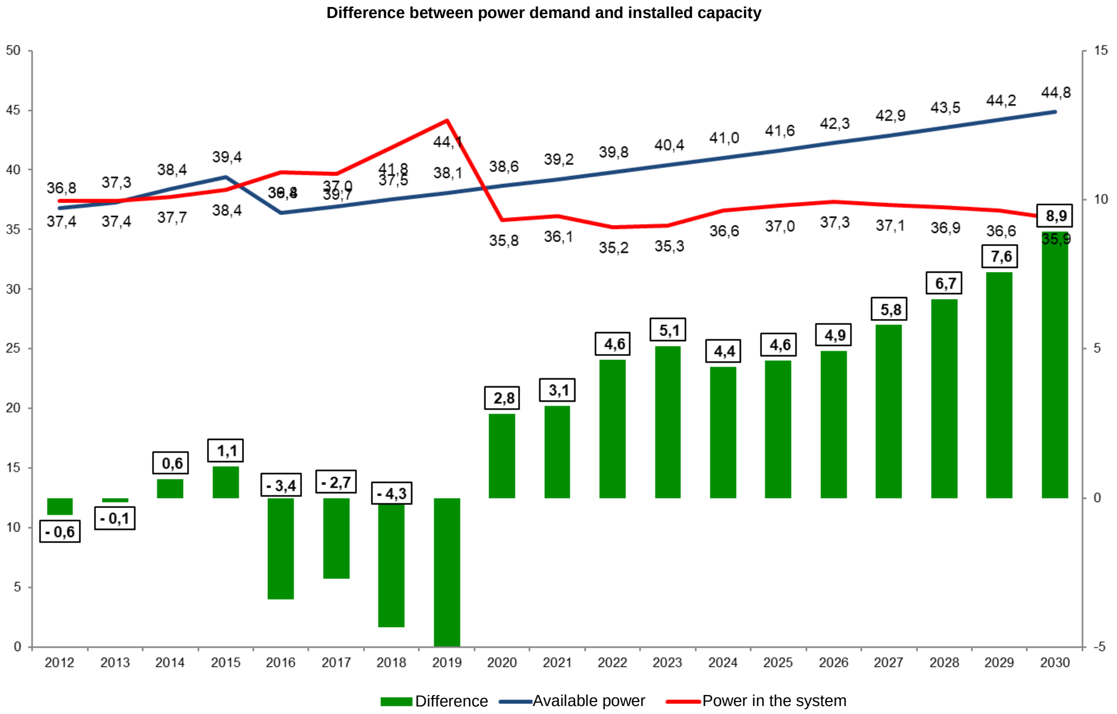

Figure 3 Power in the system – difference between power demand and installed capacity[9]

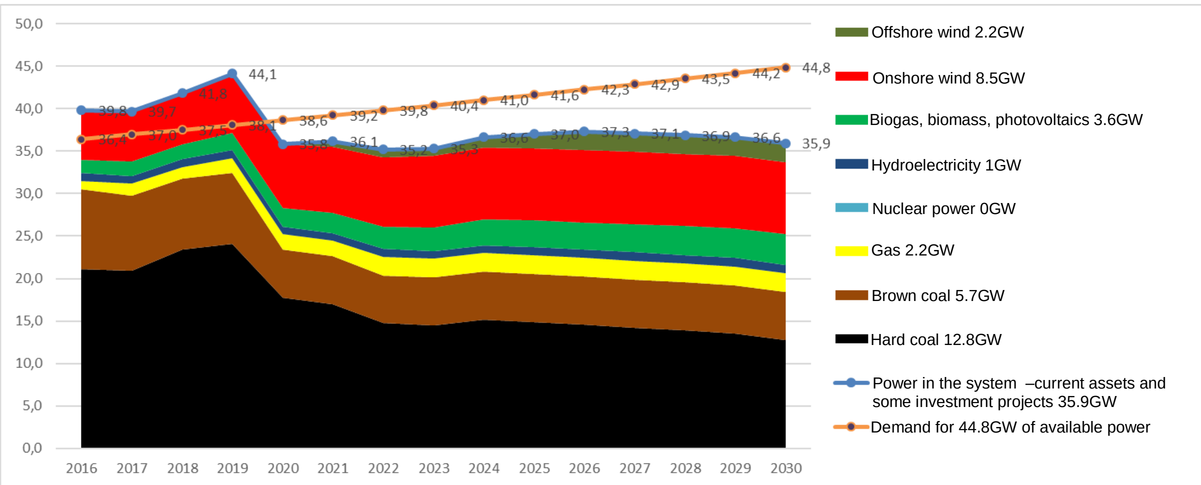

Figure 4 Power in the system – changes in the fuel structure, including commenced investments[10]

1.2.3. Collection and transmission of energy from OWF

Coordination of the connection of offshore wind farms to the NPS and the construction of offshore transmission networks will be an important element of the strategic development of OWE in Poland. No coordination will result in a radial connection of the projects, i.e. in a manner assuming the connection of each project individually. This will mean higher costs and opportunity costs for the power system. In case of a coordinated approach, it is possible to connect the OWF groups and next connect them to offshore storage stations, and transfer energy through common energy cables.

Looking at the experience abroad, it is clear that the countries intensively developing OWF technology place a strong emphasis on the coordination of project connection and planning of offshore grid development. There are several reasons for such an approach:

[9] FNEZ, Analysis of the energy balance in Poland in 2012-2030, Warsaw 2017
[10] FNEZ, Analysis of the energy balance in Poland in 2012-2030, Warsaw 2017

- Increasing the safety of OWF by increasing wind energy balancing capabilities,
- limited space in maritime areas – grouping (clustering) projects means fewer cables and more efficient use of space,
- limited possibilities of conducting cable infrastructure on land due to social and environmental conditions,
- reduction of project connection costs – common infrastructure,
- possibility of integration of OWF with cross-border interconnections,
- possibility to combine project groups and create maritime interconnections of the transmission network – increasing security of supply (connection redundancy).

Intensive work is currently underway in Europe to integrate offshore wind farms into maritime grids, such as the North Seas Countries' Offshore Grid Initiative (NSCOGI)[11] or the idea of creating a North Sea Wind Power Hub, an artificial island as a hub for offshore wind farms and an element of a cross-border grid connecting the UK, Denmark and Germany, among others. It should be noted that the first project integrated with the cross-border connection is currently underway in the Baltic Sea at the junction of the Exclusive Economic Zones of Denmark, Germany and Sweden.

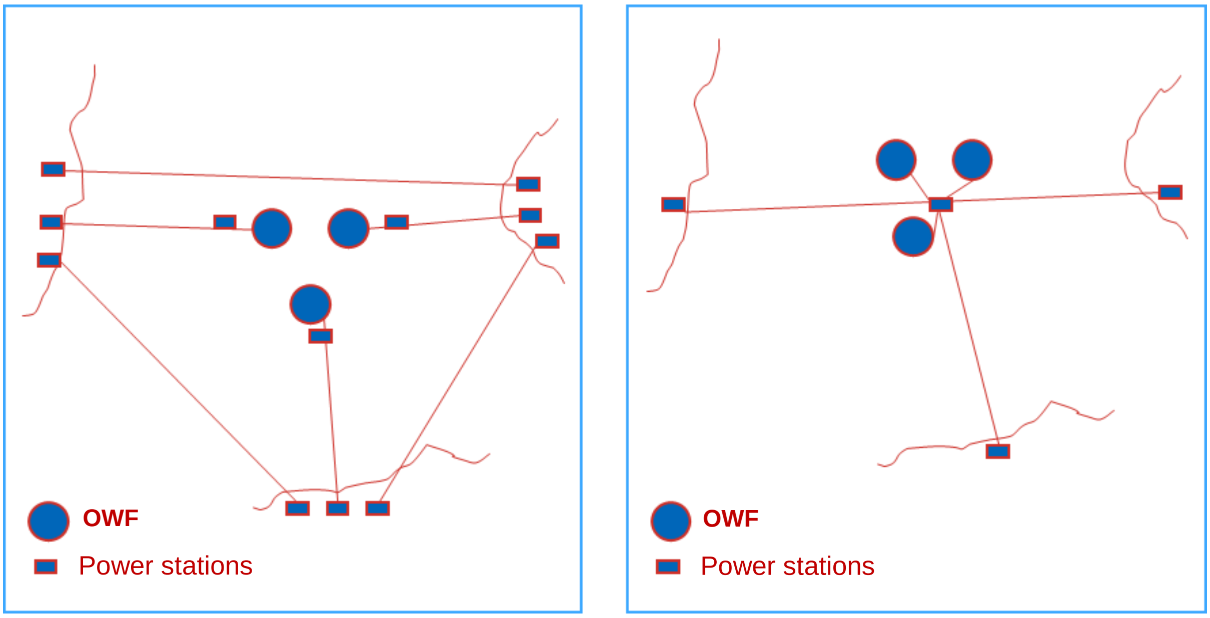

Figure 5 Comparison of the radial and integrated OWF connection model with cross-border connections12

In 2013 - 2015, FNEZ worked together with the SMDI Advisory Group on the concept of the national maritime spatial network called Marine Transmission Infrastructure (MTI). The aim of the work was to determine the course of potential infrastructure passages connecting three regions of potential development of OWE in Polish maritime areas. The following figure shows the results of conceptual work and agreements with the maritime administration.

[11] https://www.entsoe.eu/about-entso-e/system-development/the-north-seas-countries-offshore-grid-initiative-nscogi/Pages/default.aspx (access date: 19.01.2018)

[12] FNEZ, 2017

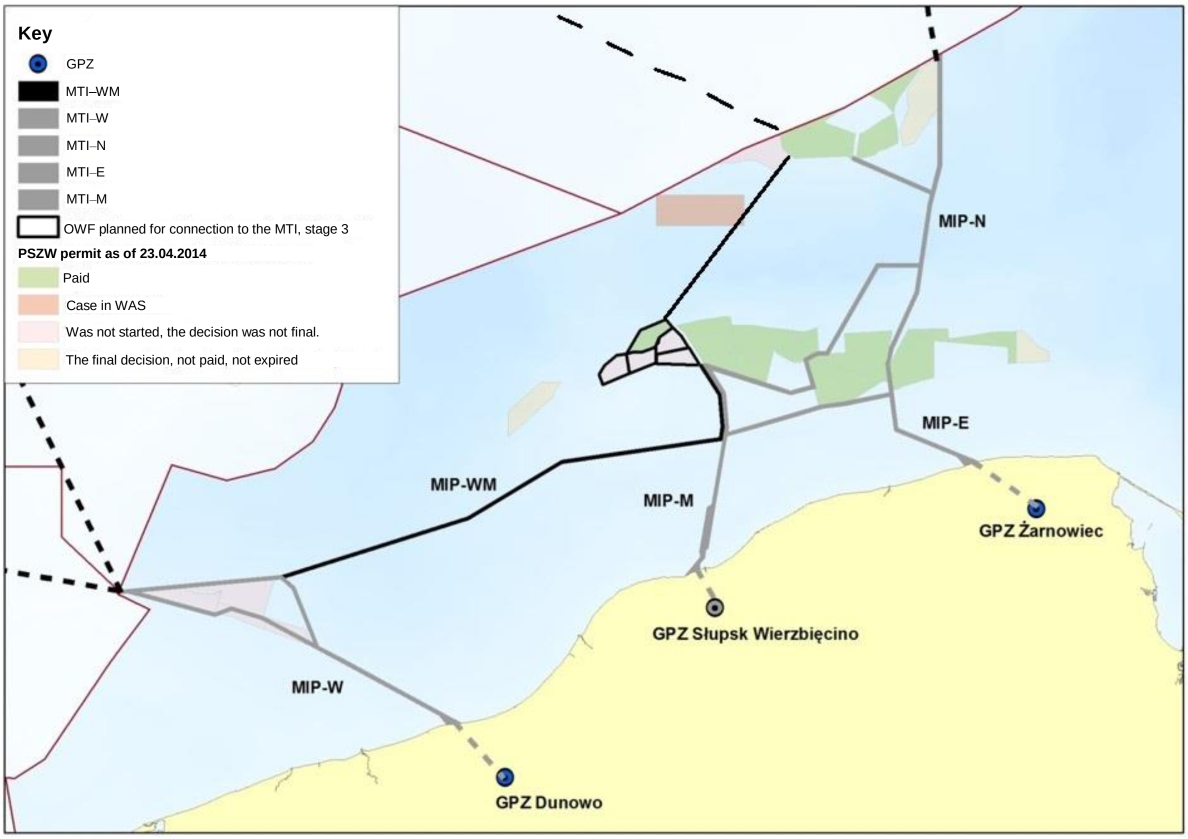

Figure 6 Concept of the route of the Marine Connection Infrastructure for offshore wind farms and cross-border interconnections in Polish maritime areas[13]

Based on preliminary results of the MTI project and experience from the North Sea Basin, a preliminary feasibility study is being developed within the Baltic InteGrid project[14] carried out by 14 organisations (including FNEZ) from 8 Baltic Sea Region countries for the cross-border interconnection between Poland and Sweden (with the possibility of connecting to Lithuania) integrated with offshore wind farms.

Analytical work on the study is still underway, but the first conclusions are already available today:

- development of OWE at a level >4 GW in the area of Słupsk Bank and Central Bank will not be possible without a coordinated approach,
- one of the main barriers will be the possibility of landing cable lines and leading them in the onshore part due to dense residential structure, high natural value of coastal areas and intensive development of coastal tourism; the integrated approach allows for a **3-fold** reduction in the number of cables needed,
- integration of OWF with transmission grids can bring about systemic savings, preliminary results show a cost reduction of about **EUR 3 billion**,
- cross-border electricity transmission capacity will be increased,
- intensive use of maritime space and a significant number of required submarine cables to connect the planned projects need the creation of infrastructure passages for the location of submarine cables and collective power stations (hubs) – infrastructure passages and locations of collective stations have been figured out based on spatial analysis,
- collective offshore power stations (hubs) at Słupsk Bank and Central Bank may serve as logistics bases for the Marine Search and Rescue Service.

[13] FNEZ, SMDI

[14] Integrated Baltic Offshore Wind Electricity Grid Development „Baltic InteGrid – "a project funded by the Baltic Sea Region INTERREG programme 2014-2020

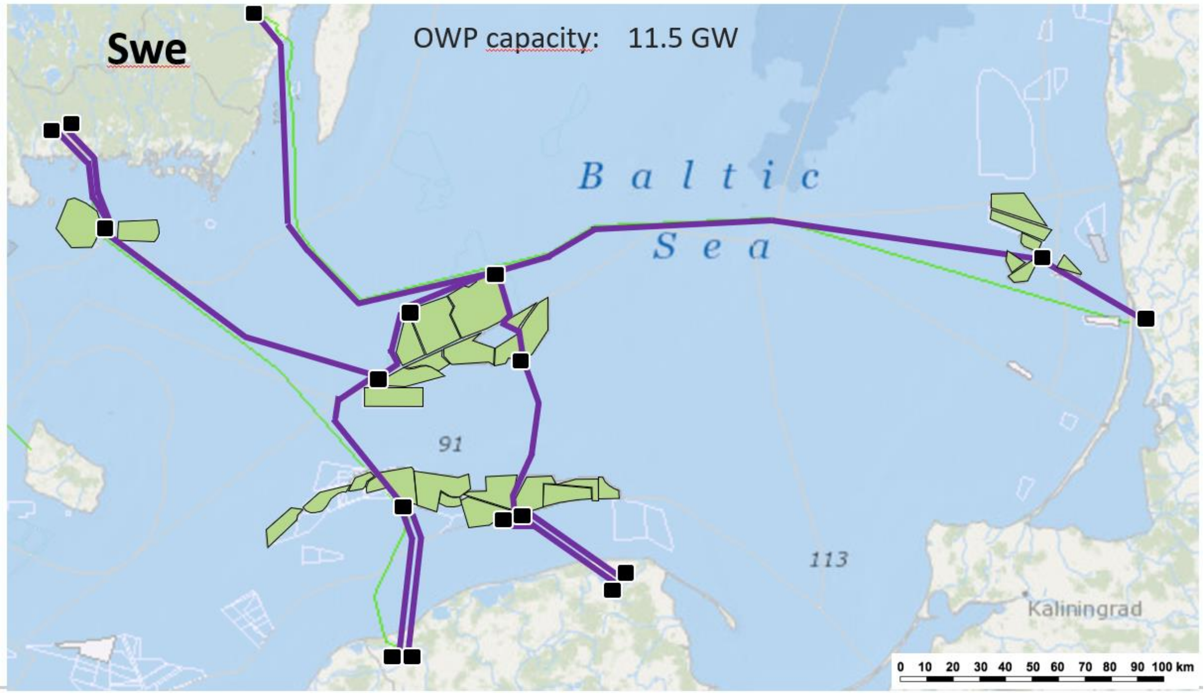

Figure 7 The concept of interconnection between Poland and Sweden (with the possibility of connection to Lithuania) integrated with the planned OWF (the map is for illustrative purposes only and does not reflect the actual cable routes)[15]

Currently in Poland, the responsibility for connecting OWF to the NPS lies with the investor, which means that the transmission grid operator has limited influence on the final shape of the connection and the possibility of creating synergies with other investments. This also means an increase in the risk of the investment and a growth of the costs of the projects themselves due to the need to build separate connections. There is also a problem of operation and ownership of the resulting infrastructure, which may be of strategic importance for the country's energy security, especially in the context of potential expansion into cross-border interconnections.

Analyses show the technical, economic, social and spatial feasibility of building maritime grids integrated with OWF. Nevertheless, the construction of such a grid requires a single entity responsible for the planning of transmission infrastructure, as well as integration of the interconnection into the grid development plan. The coordinating entity could be the transmission grid operator – PSE S.A.

Looking at the experience abroad, different models are available for strategic planning of the OWF grid connections. From the full responsibility of the transmission grid operator (German model) to indirect solutions where the OWF investor is responsible for the construction of the connection and is then obliged to resell it to the transmission grid operator (UK model). Whatever the final solution, an adequate level of coordination and planning at central level is necessary.

To sum up, the development of OWE with a capacity greater than 4 GW requires construction of:

- offshore grid with offshore power stations (hubs) on the Słupsk Bank and Central Bank, where the largest number of OWF projects is planned, and
- connections or cross-border interconnections (Sweden, Denmark, Lithuania) allowing for periodical import/export of energy, increasing the capacity of balancing the OWF energy, and system security through redundancy of transmission connections.

The decision on the assumption of the transmission grid development obligation with connection points in offshore areas by the transmission system operator will be the key issue influencing the further development of OWE in Poland. Such a solution will ensure the necessary coordination of OWF connections and will reduce the costs of offshore wind farm construction, thus shortening the period and reducing the amount of necessary support for such projects.

[15] Integrated Baltic Offshore Wind Electricity Grid Development „Baltic InteGrid" - a project funded by the Baltic Sea Region INTERREG programme 2014-2020

1.2.4. Role of offshore power industry in ensuring national energy security

As showed above, the greatest challenge for the Polish economy in the next decade will be to ensure that domestic electricity demand is met. At the beginning of the next decade at least a dozen or so giants of existing generation capacity will be shut down. These will be the oldest, non-compliant coal-fired units. The fundamental question arises as to what the gap in the power system will be filled with. Within a period of 4 - 5 years, it is not possible to make investments in new capacities at such a large scale in any technology. This means that Poland may have to import a large amount of energy, especially in seasonal and daily peak periods. But in order to import energy, it is necessary to have cross-border transmission infrastructure of sufficient capacity. The construction of offshore electricity connections with countries such as Denmark, Sweden and/or Lithuania may play a major role in this scope.

Dependence on energy imports may only be considered as a tool for periodical support of energy security, while building own generation sources. Here the question arises whether energy should be imported from countries where it has a lower price than in Poland, or on the contrary. The low price of imported energy will have the effect of lowering or keeping domestic prices at low levels, and this will result in unprofitable investments in new sources. On the other hand, it may reduce the burden on end users with the costs of investments in new sources, which is both pro-social and pro-economic. In this situation, however, it is necessary to set up other systems to support investments in new sources.

The second fundamental question is what generation technologies to invest in to ensure Poland's energy self-sufficiency in the long term. So far, the answer to this question has been obvious, because security has been provided by the national reserves of hard and brown coal. However, it has also become clear in recent years that this situation will not be sustained in the next decades, mainly due to the declining industrial reserves of coal. It seems not to be logical to construct new coal-fired power plants, contrary to the world megatrends, but first with the knowledge that in the next years this will mean dependence on fuel imports. Moreover, the preparation and construction of a coal-fired power plants takes several years, which means that new power plants would not have a chance to be built at the time of the greatest power shortages - between 2025 and 2030.

Nuclear power seems to be the alternative. It is a technology that produces energy without CO2 emissions, in a stable and safe way, providing ample power that can operate in the system's base. Nonetheless, the process of building nuclear power in Poland seems to be much delayed. Given the current state of development of the first nuclear power plant project, it must be assumed that it can be completed by 2035. Even if a final investment decision is made in this area, it will not solve the problem of the shortfall in capacity in the system between 2025 and 2035. For nuclear power to be a workable alternative to the phasing out of coal-fired power generation, nuclear power plant projects with a total capacity of not less than 6GW would have to be developed today, rather than one project with a capacity of 0.8 - 1 GW. Yet, there may be a problem with locations that ensure the safe and efficient operation of nuclear power plants for such a number of projects.

Development trends in the world energy sector may indicate that modernization of the Polish power industry will go in a completely different direction, based on technologies allowing to ensure energy security in individual and local, rather than national, perspective. The development of small energy sources, especially solar energy, combined with the technological revolution in the market of energy storage may mean that after 2030 the number of individual, dispersed energy sources, clusters and energy islands will definitely start to grow, which will significantly reduce the demand for energy from the system. However, Poland's spatial and climatic conditions, and most of all the very poor quality of outdated distribution infrastructure, constitute significant limitations for large-scale development here.

Natural gas is likely to be a very important source of energy in the next decade. Even though the hopes for rapid industrial development of national shale gas deposits have not been fulfilled, the decisive policy of diversification of gas import directions and development of the natural gas import, transmission and storage infrastructure makes it possible for gas-fired power plants to play a key role in ensuring the country's energy security. Maritime investments, such as the construction and expansion of the LNG terminal in Świnoujście and the construction of the "Baltic Pipe" Poland-Denmark-Norway gas interconnection, will be of primary importance. Execution of the investments under preparation will enable Poland to import gas from various directions for about 20 - 21 billion m3 per year. With the current domestic demand of about 16 billion m3, the remaining gas could supply 4 - 5 GW of power plants and gas-fired combined heat and power plants. Gas generation sources can be built within a few years, especially since many projects are ready. However, the problem is the price of gas, and thus the price of energy produced by gas sources. Nevertheless, it seems that the development of gas power generation is needed, which means that it is necessary to provide mechanisms for making this type of investment profitable. A key solution here may be diversification of gas sources, ensuring competition for supply and thus causing price pressure, as well as the power market, since gas sources are predisposed to act as system stabilisers due to the exceptionally high flexibility of production.

The development of gas generation, combined with the development of cross-border offshore grids, will create excellent conditions for the development of offshore wind energy. Considering that by 2030 4 GW may be put into operation in OWF and another 4 GW in the next five years, offshore wind energy may play a key role in ensuring Poland's energy security in the next two decades.

FNEZ conducted its own simulations of energy mix development in the years 2020 - 2030, in which it took into consideration many conditions for the implementation of investments in individual technologies. On their basis, the proposed energy mix was determined for the period between the current dominance of coal-fired power generation and its gradual, partial replacement by nuclear or dispersed power generation after 2040. Gas sources, offshore wind farms, renewable distributed energy and energy imports play a key role in this process.

Energy imports will be of primary importance between 2022 and 2026 and new cross-border links, including maritime connections with Denmark and/or Sweden, should be built by then. Also, in these years, new gas-fired combined heat and power plants with a total capacity of up to 4 - 5 GW should be commissioned, which in the period 2023 - 2027 would work as system sources, instead of decommissioned coal-fired power plants, and then reduce the load, increasing their back-up and stabilising role for the system. After 2027, offshore wind farms would become important sources of energy. The generation structure would be complemented by other dispersed renewable sources.
The results of the modelling are presented in the following diagrams.

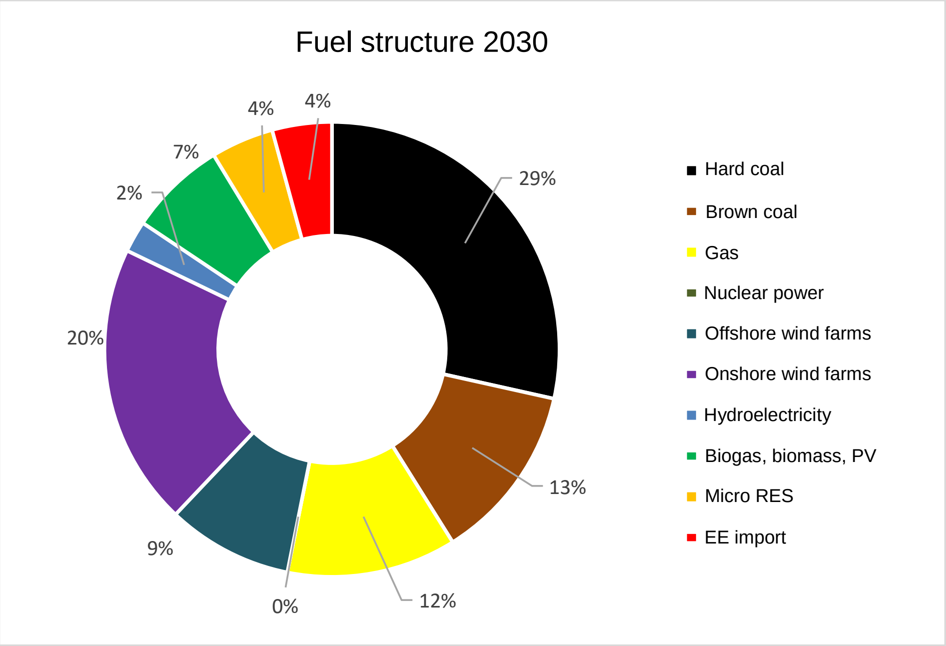

Figure 8 Forecast fuel structure of Poland in 2030[16]

[16] FNEZ, 2018 "Baltic Energy Programme for Poland" – unpublished material

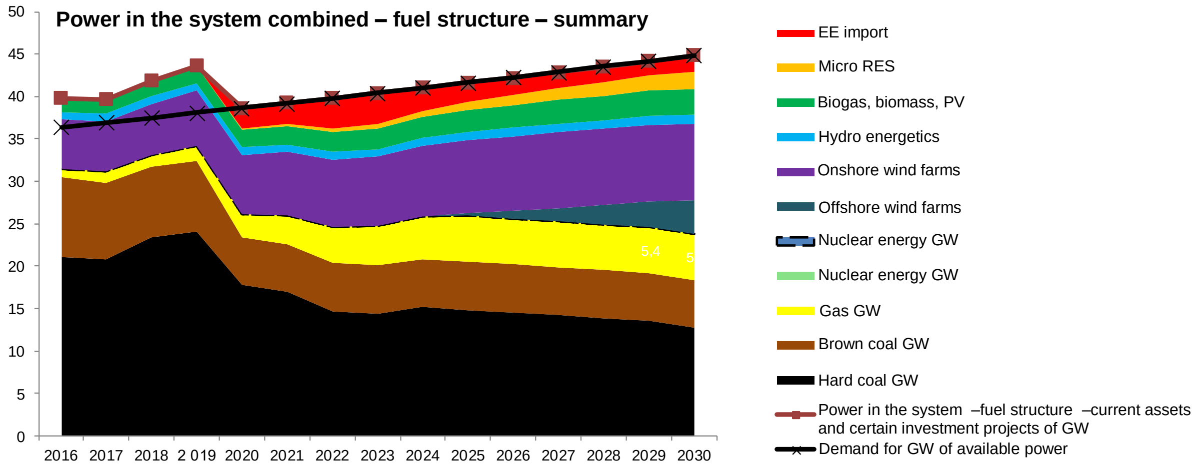

Figure 9 Forecast changes in Poland's fuel structure in the years 2016 - 2030[17]

1.2.5. Supply and logistics base

Ambitious plans of European countries envisage the development of OWF to the level of 70 GW by 2030 (according to Wind Europe), while according to the BNEF report the development of the global OWE market is estimated to reach the level of 115 GW by 2030[18]. Most projects are planned in the North Sea, but a large part of them also concern the Baltic Sea. According to EWEA statistics, about 20% of OWF, which have already obtained permits, is located in the Baltic Sea[19]. What is more, the total capacity of the planned OWF projects in the Baltic Sea (projects at various stages of implementation, from the conceptual phase to the permits obtained) is about 19 GW[20], excluding projects in Polish maritime areas.

Currently, the average size of the offshore wind turbine is 4.8 MW and most of the new projects are being built on 6 MW turbines. In 2016, generators with a unit capacity of 8 MW[21] were installed for the first time, and commercial turbines with a capacity of 9.5 MW[22] are now available. After 2020, however, it is planned to use turbines with a capacity of over 10 MW mainly, which are already in the test phase. As a result, potential demand can be estimated at around 8,000 wind power plants (generators, rotors, foundations, towers) together with other elements (offshore and onshore cabled, transformers) for the European market until 2030.

FNEZ carried out an analysis of the market potential of OWE in the South Baltic, within the framework of the Baltic InteGrid[23] project, which results indicate that between 9 and 15 GW could be installed in OWF until 2030. The chart below shows the supply chain needs for the Polish market and the neighbouring markets, thus competing for resources.

Table 1 Demand for supply of components of offshore wind farms in the South Baltic by 2030

Components	Low scenario – 8 GW	High scenario – 15 GW
Turbines	700	1400
Foundations	700	1400
Offshore transformer stations	30	40
Internal cables	2000 km	3750 km
Export cables	2800 km	4000 km

[17] FNEZ, 2018 "Baltic Energy Programme for Poland" – unpublished material
[18] BNEF. 2018 "2H 2017 Offshore Wind Market Outlook"
[19] EWEA. 2012. The European offshore wind industry – key trends and statistics 2012.
[20] Baltic Offshore Wind Energy Map. Baltic sea Transport, 6/2012, p.2 - 829.
[21] Wind Europe 2017. The European offshore wind industry, key trends and statistics 2016.
[22] Contractor data MHI Vestas Offshore Wind
[23] Integrated Baltic Offshore Wind Electricity Grid Development "Baltic InteGrid" – a project funded by the Baltic Sea Region INTERREG programme 2014-2020

Components	Low scenario – 8 GW	High scenario – 15 GW
Cable-laying vessels	4	6
Installation vessels	2	3
Service vessels	20	40

Source: FNEZ, 2017

Such ambitious plans will require adequate supply, logistics, maintenance and service facilities enabling the production of components, installation, maintenance and service of the target OWF. A key role will be played here by the plants of the maritime industry, including shipyards producing steel elements (foundations, towers, measurement masts, transformer covers) and seaports, which accompany the implementation of OWF at each stage. In practice, 3 types of ports can be distinguished by their role:

- **Production ports** – where plants producing large OWF components such as foundations, towers, nacelles, blades, etc. are located. Production facilities are most often located in seaports because of the significant size of components and the final offshore installation of these components,
- **Construction ports** – as a direct logistic base for OWF projects, in which components are assembled and prepared for offshore installations. The assembled elements are loaded onto installation vessels directly in construction ports and transported to the OWF area where they are installed. It is possible to combine production and construction port functions,
- **Maintenance and service ports** – from which OWF daily services and maintenance are carried out. These ports are mostly characterised by significant traffic of small vessels or helicopters, therefore the distance to the serviced OWF is particularly important.

A very important factor in the development of the service and logistics facilities for the Polish OWF will be the proximity from their location, among other things. Thanks to the organization of the so-called "supply chain" based on the national production of components of offshore power plants, such as foundations, towers, turbines and cables, which have logistic bases in short distances from the areas where the construction will be carried out, it is possible to significantly reduce the costs of the construction itself. Both the cost of maritime transport and the time for downtimes associated with the need to take weather conditions into account are of immense importance.

Another crucial factor, which is helpful to planning the development of offshore wind energy in Poland, is the experience of the Polish offshore energy industry, which in 2013 - 2018 underwent intensive development.

There are currently several dozen companies on the Polish market, specialising in the production of components of offshore wind farms in almost all stages of the supply chain:

- preparation and development of OWF projects
  - SMDI Doradztwo Inwestycyjne Sp. z o.o.
- delivery of turbines and towers
  - No turbine manufacturer
  - GE – rotor blade manufacturer
  - GSG Towers Sp. z o.o. – manufacturer of wind towers
- construction and service of OWF construction and maintenance vessels
  - CRIST S.A.
  - Stocznia Remontowa NAUTA S.A.
- offshore foundations and structures
  - Energomontaż-Północ Gdynia S.A. [EPG]
  - Energop
  - GSG Towers Sp. z o.o.
  - Morska Stocznia Remontowa „Gryfia "S.A.

        - ST3 Offshore Sp. z o.o.
        - Szczeciński Park Przemysłowy Sp. z o.o.
        - Vistal Offshore Sp. z o.o. (Vistal Gdynia S.A.)
        - ZAMET Industry / Mostostal Chojnice
    - underwater cables
        - TELE-FONIKA Kable S.A.
    - offshore transformer stations
        - ABB Sp. z o.o.
        - ZAMET Industry
        - Energomontaż-Północ Gdynia S.A. [EPG]
        - Consortium: GSG Towers Sp. z o.o., Activ Sp. z o.o., Ciecholewski-Wentylacje, Enamor, Famor, Lotos Serwis, MPL Techma, Protea
    - additional services
        - Global Maritime Sp. z o.o. Poland
        - Morska Agencja Gdynia Sp. z o.o.
        - SCAT –Security Consulting and Training
        - Szczeciński Park Przemysłowy Sp. z o.o.
        - StoGda Ship Design Engineering
        - MEWO S.A.
        - MKM Offshore

In 2016, FNEZ took part in the SWOT analysis of the Polish port facilities for the construction, operation and service of offshore wind farms. Its results show that all four ports: Gdańsk, Gdynia Szczecin and Świnoujście have good or very good conditions to function as construction ports for OWF. Łeba, Ustka, Władysławowo and Darłowo have good or sufficient conditions to function as operation and service ports.

With proper implementation of the expansion and modernisation of Polish ports, they may fulfil both the role of production and construction ports. In case of the latter, assuming typical port capacity of 100 turbines/year[24], it can be calculated that large sea ports in Poland allow the engineering and installation of up to 400 turbines/year. Between 2020 and 2030 Polish ports can theoretically handle the construction of up to 4,000 offshore wind turbines, so port logistics is not a factor limiting the possibility of implementation of 10 GW OWF scenario in Polish maritime areas.

The analysis of supply chain potential for the Polish OWF carried out by the SMDI Advisory Group in 2017 also indicates that there are no barriers limiting the technical potential estimated at 10 GW in terms of supply chain organisation. Nearly 100 companies from all over the world, offering together a full range of supplies and services during the OWF preparation and construction process, expressed their interest in participating in the development of supply chain for Polish projects. At the same time, 25% of the analysed companies came from Poland. However, a significant doubt arises as to how many components allowing for the construction of a complete wind farm can be produced, stored and delivered to the site at the same time for a larger number of projects in 2025–2030. Restrictions in this respect may have a significant impact on the possibility of achieving high targets in 2030, as further elaborated in 4.

1.2.6. Human resources

In the offshore wind energy sector, it is possible to identify the need for qualified personnel in the following areas:

[24] Department of Energy and Climate Change. 2009. UK Ports for the Offshore Wind Industry: Time to Act. p. 15.

- **Shipyards** – construction of new special vessels for the transport and installation of offshore wind farms, maintenance of tower production lines, foundations and other steel structures for the construction and operation of offshore wind farms,
- **Ports** – logistic, transshipment and transport services for the construction, operation and service of offshore wind farms,
- **Warehouses** – storage, warehousing of generators, towers and foundations, crane handling, communication with ports and shipyards,
- **Cables** – production, storage, transportation, laying,
- **Equipment and subassemblies of offshore power plants** – design and construction of equipment and subassemblies,
- **Project preparation and maintenance** – marine environment research, management of administrative procedures, design, risk assessment, safety analysis, security, standardisation, supply chain management, construction supervision, project preparation, construction and operation management, service,
- **Science** – creation of inexpensive, effective marine technologies in the scope of building and servicing the process of preparing, constructing and servicing offshore wind farms, participation in the performance of environmental pre-execution analyses and post-execution monitoring of the marine environment,
- **Education** – implementation and execution of training programmes for employees of shipbuilding, cable, construction, service and maintenance companies at the level of vocational and higher education,
- **Tourism** – promotion of OWF as a tourist attraction, organization of cruises to offshore wind farms,
- **Insurance, financing** – specialized investment services in the financial and insurance sectors, risk analysis, audits, financial engineering,
- **Security** – establishment and management of supervision and monitoring systems for installations.

According to the conducted analyses, it can be concluded that the OWF sector may have a significant impact on the labour market in Poland, especially during the investment phase. Comparative data from the UK market show that at the time of OWE construction, over 17 jobs (equivalents of full-time jobs) result from every 1 MW of capacity in the OWE and related sectors. In the operating phase it is estimated that with each MW of capacity, about 0,5-1 equivalent of full-time job of the OWE and intermediate sectors is directly related.

Based on the results of the analyses carried out by EY[25] and own analyses, it was estimated that in case of 6 GW projects in the investment and operational phase, by 2030 a total of approximately 24.8 thousand additional permanent jobs may be created on average annually in the offshore wind energy sector, directly related to the preparation and implementation of the OWF projects.

According to McKinsey&Company[26], the development of offshore wind energy in Poland at the level of 6 GW may create 77,000 new jobs in sectors directly and indirectly related to the maritime industry.

In order to assess in detail, the scale of the impact of offshore wind energy on the development of the labour market in Poland, it is necessary to consider also the operational phase of the installation (the 2050 - 2060 perspective). Based on estimates, the average annual level of employment resulting from the OWF development may reach even about 5.1 thousand jobs, assuming the implementation of 6 GW projects (based on data from 2013).

[25] EY. 2013. Offshore wind energy – analysis of the benefits for the Polish economy and development conditions.

[26] McKinsey&Company. 2016. Offshore wind energy industry development in Poland Prospects and evaluation of the impact on the local economy

Of all sectors related to the development of offshore wind energy, by far the largest number of jobs can be created in the shipbuilding, electrical machinery, cable and maritime construction sectors.

However, the human resources base may also be a key factor limiting, and certainly slowing down, the development of offshore wind energy in Poland. If we assume that employment in the Polish maritime industry in 2015[27] amounted to about 65 thousand people (excluding the market of fishing and fish processing), assuming that about 25% of this group of employees could be involved in the preparation and implementation of offshore wind energy projects, the background of the OWE sector could count on about 16.5 thousand employees. Considering statistics, it would mean the possibility to handle investments with a capacity of about 1 GW. The 10 GW capacity programme would therefore require at least 5 - 6 times higher employment, assuming that the investment programme is spread over time. On the one hand, it gives an employment impulse which is extremely important for the development of the Polish industry, on the other hand, it would be necessary to launch intensive training and education programmes in vocational and higher education, the effects of which were significantly delayed in time.

Poland has well-developed educational and research and development facilities for the maritime industry sector, and thus the potential to provide personnel for the needs of the offshore power industry. In this respect, the following public education centres have been identified, which can provide qualified staff in the OWF sector, subject to appropriate adjustment of scientific programmes. They can educate at the same time about 30,000 students in fields of study that are particularly important for the industry, such as: navigation, mechanics and machine building, electrical engineering, electronics and communication, mechatronics, transport, production management and engineering, technical physics, automation and robotics, construction, ocean engineering, energetics, investments and industrial implementations. Schools:

- Polish Naval Academy in Gdynia,
- Maritime Academy of Gdynia,
- Maritime University of Szczecin,
- Pomeranian Academy in Słupsk,
- Technical University of Gdańsk,
- Koszalin University of Technology,
- University of Gdansk,
- University of Szczecin,
- West Pomeranian University of Technology.

In view of the fact that the education process, but also the process of adapting training and educational programmes, is relatively lengthy and takes a minimum of 5 - 6 years (bachelor and master degree courses, additional specialised training and adaptation of academic courses and training to the market demand), in order to prevent deficiencies that could have a serious negative impact on the development of the offshore wind energy sector, further measures are required to ensure the training and education of engineers and technicians. These measures should be developed by industry, universities and politicians.

To sum up, taking into account: the possibility of connecting new generation capacities to the grid, the structure of the power system and the projected demand for electricity, the capacity of supply and logistics facilities and human resources, it is possible to estimate the technical potential of OWF development in Poland at the level of 10 GW, however, with execution spread over a period of time up to at least 2035.

[27] GUS. 2016. Statistics Yearbook of Maritime Economy 2016

1.3. Market potential

The theoretical and technical potential is further limited by market conditions, which indicate the real potential for the development of OWE in Poland, i.e. one which may translate into investment decisions. Factors limiting technical potential include:

- social factors – potential conflicts with other users of maritime areas,
- environmental factors – potential significant impacts on the marine environment,
- economic factors – competitiveness in relation to other technologies and acceptability of investment costs,
- regulatory factors – credibility and stability of the industry's policy and regulatory environment.

1.3.1. Social and environmental conditions

The results of the first environmental impact assessments, public consultations and works on the maritime spatial development plan indicate that on areas indicated as preferable areas for the development of OWE, in order to avoid significant social and environmental pressure, it will be necessary to:

- introduce buffers restricting wind turbine construction near shipping routes (about 2 nautical miles),
- leave corridors between larger built-up areas allowing for safe and unhindered movement of fishermen between important fisheries and ports (1.5 - 3 km),
- consider the restriction of power plant development on the main routes of birds' migration (4 - 8 km),
- move wind farm boundaries away from the winter areas of sea birds protected by the Natura 2000 network,
- carry out post-execution monitoring of OWF projects – to do so, it may be justified to develop a central OWF monitoring system based on a network of measurement and research platforms on each of Bank, modelled on FINO platforms and included in the marine waters monitoring programme. Platforms could also be part of research and development infrastructure and national defence system.

Experience abroad, including that of the Baltic Sea projects, makes it possible to assume that some of the areas covered by location permits may not favour the location of the power plant due to unfavourable geological conditions.

The possibility to land export cables connecting projects to the NPS will also be an important spatial factor that may have a significant impact on the limitation of the potential of the Polish OWE. Analysing both environmental and social spatial conditions in marine areas, in the coastal zone and in the areas between the sea shore and potential grid connection points, it can be concluded that it will not be possible to radially connect more projects. Development of OWF at a level greater than 4 GW will require the creation of a common connection infrastructure for several projects. This issue is presented in detail in chapter 1.2.3.

The above factors characterise each of the potential areas of offshore wind energy development in the Polish maritime areas differently:

- Region I – the north and east slope of the Słupsk Bank (about 1570 km^2) – on the one hand it is a region located closest to potential construction and service ports, and it is characterized by good connection capabilities and relatively low depth. Nevertheless, a key limitation of this region is the immediate vicinity of the Natura 2000 area "Słupsk Bank", which is an important winter area for sea birds in the Baltic Sea. The area is also located on the routes of fishing vessels' movements between ports and the most important fishing areas in Słupsk Furnace. It is therefore essential in this area to:
  - ensure that the location of wind power plants is well separated from the shallowest areas intensively used by wintering sea birds that are subject to Natura 2000 protection,
  - provide migration corridors for birds migrating to and from winter areas,
  - ensure the free passage of fishing vessels between ports and important fisheries.
- Region II – the southern slope of the Central Bank (about 450 km^2) – this area is characterised by the best wind conditions, but it is significantly distant from the shore, which increases the costs of connection, construction and project management. Nevertheless, this area does not pose a significant risk of social and environmental conflicts, which allows for planning a higher density of wind power plants.

- Region III – the north-eastern slope of Odra Bank (about 560 km^2) – the area relatively close to potential construction ports in Szczecin and Świnoujście, with the intensively developing production facilities of OWF components. However, the region's potential is limited by intensive fishing and potential hydrocarbon resources in the seabed. Connection conditions on land may also be problematic.

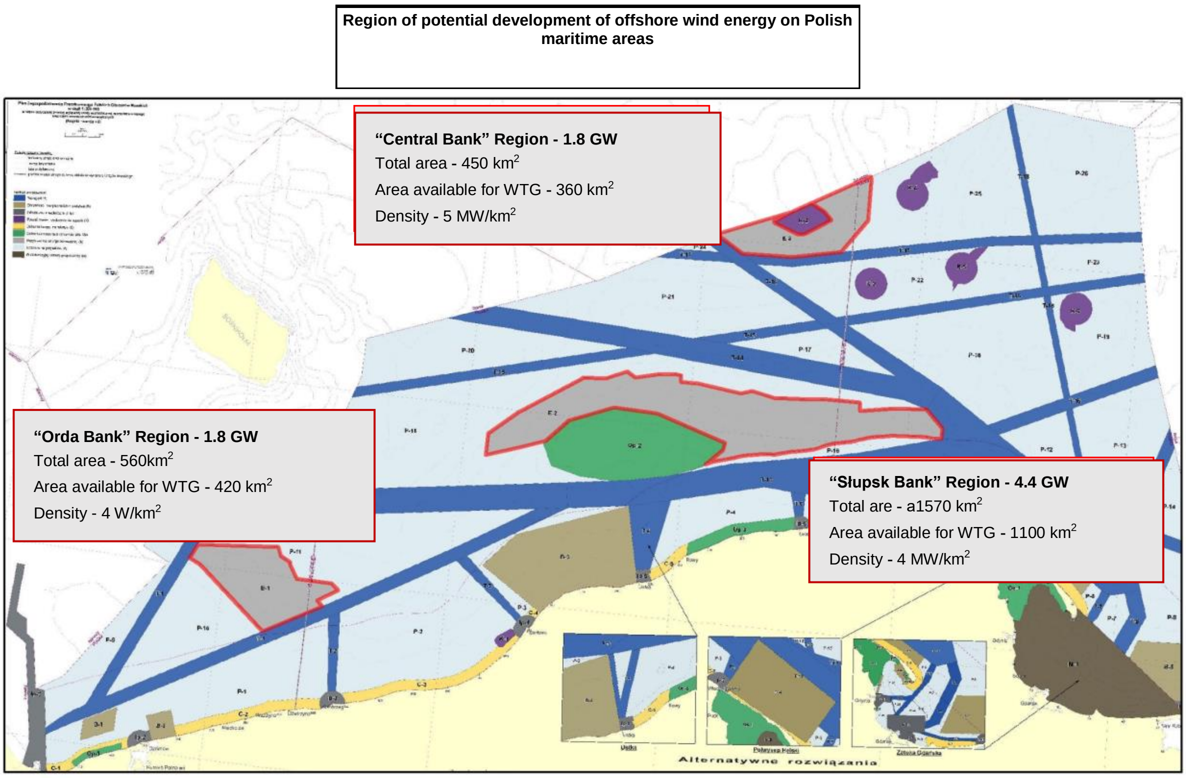

Figure 10 Map of regions of potential development of offshore wind energy on Polish maritime areas[28]

Table 2 Impact of spatial conditions on the market potential of OWE[29]

Region	Area available [km^2]	Reduction factor [%]	"Market" area	Density [MW/km^2]	Available capacity [MW]
Słupsk Bank	1570	30	1100	4	**4400**
Central Bank	450	20	360	5	**1800**
Orda Bank	560	25	420	4	**1800**
Total	2,580		1,880		**8,000**

Considering the characteristics of the areas of potential development of OWF in the Polish EEZ, it should be assumed that they will be used by the market on the level not higher than 8GW.

1.3.2. Price conditions

Offshore wind power industry has been going through a technological revolution for several years, resulting in a significant reduction of investment and operating costs, allowing to reduce the average LCOE energy price from 150 – 160 €/MWh for projects implemented in 2015 to 65 – 100 €/MWh in 2020.

The year 2017 was a breakthrough year, when the results of auctions organised for new offshore wind farm projects in the EU countries indicated an expected level of energy production costs by OWF in the range of 60 – 90 €/MWh.

[28] Maritime Office in Gdynia
[29] FNEZ, 2017

Table 3 Results of selected auctions for offshore wind farms[30]

Project	Kriegers Flak	Borssele 1/2	Borssele 3/4	The Gode Wind 3	West / Borkum Riffgrund West2
Auction results [€/MWh]	49.90	72.70	54.50	60	No support (wholesale price)
+25% connection cost	62.37	90.87	68.12	75	-

It should be noted that several auctions ended with a result indicating that there was no need for additional support for OWF. Investors however stress that the implementation of the OWF projects in 2020 - 2025 without support will be possible if several conditions are met:

- costs of constructing farm connections do not burden the investor,
- projects are developed in mature markets with organised construction, supply, service and maintenance facilities,
- projects will be based on turbines with a unit capacity exceeding 12 MW,
- manufacturers' announcements of further reduction of components costs and OWF construction logistics will be made true.

The density of offshore wind turbine installations is very important for the ultimate efficiency of the entire farm. On the one hand, the denser location of the power plant provides more power installed in the area, while on the other hand, too little distance between turbines disrupts the flow of wind (aerodynamic shadow effect) and thus decreases the efficiency of individual power plants and shortens their lifetime due to the increase of turbulence of air masses. An essential element is also the costs of installation of turbines, which are inversely proportional to the size of the installed turbine. The higher the installed turbine capacity, the lower the cost per 1 MW. Increasing the size of the turbines, however, requires more spacing between the turbines due to larger rotor sizes and increased air mass flow disturbances.

The determination of the optimum power density per area therefore requires that many factors mentioned above needs to be taken into account. After comparing the different options (4, 6 and 8 MW/km^2) the optimal value for individual projects seems to be about 6 MW/km^2. Option of 4 MW/km^2 is characterised by a higher efficiency but lower absolute energy production value (quantity of MWh per area unit), which is not optimal from the investor's point of view due to area limitations of the permits issued. The 8 MW/km^2 option was also considered, which is characterised by a few percent lower efficiency but higher absolute production[31]. Final decisions concerning the power density on the farm's area will be made by investors, and the final financial effect and auction results, which determine the level of energy price will certainly be a very important factor influencing these decisions. **Nonetheless, while determining the final potential of OWF for the needs of the Programme, a conservative 4 MW power density assumption was adopted for the Słupsk Bank and Odra Bank and 5 MW for Central Bank**, due to the necessity of taking into account all factors limiting the use of maritime space in a given area, as referred to in Chapter 1.1.1, in the final, combined calculation.

For the Programme, the financial analysis of potential OWF projects in Polish maritime areas was updated, which resulted in determining the expected LCOE price of energy. The analysis took into consideration current and projected investment (CAPEX) and operational costs (OPEX), results of productivity analysis, as well as expected cost reductions due to the learning curve. The main external source of data was the Danish Energy Agency's August 2016 report "Technology Data for Energy Plants" as it was based on information from one of the most developed offshore energy markets in the world.

The results of the calculations, in different options, are presented in the chart below:

[30] offshorewind.biz

[31] Windhunter prognoza sp. z o.o. and WIND-consult Ingenieurgesellschaft für umweltschonende Energiewandlung mbH. 2012. Study of wind potential and productivity of selected offshore wind farms in Polish maritime areas. FNEZ – unpublished data.

Table 4 LCOE options[32]

Density [MW/km²]	Capacity factor	Useful life	Return on capital	LCOE 2025 [PLN/MWh]	LCOE 2030 [PLN/MWh]
4	52.3	25	12	306.63	280.09
4	52.3	30	11	277.51	253.51
6	47.3	25	12	313.78	280.09
6	47.3	30	11	283.93	253.51
8	46.8	25	12	314.51	280.09
8	46.8	30	11	284.58	253.51
average				**296.8 [74.2]**	**266.8 [66.7]**

In the assessment of market potential, two main factors influencing investment decisions were considered, i.e. the competitiveness of a given technology in relation to other, alternative, and average energy prices.

The achievement of competitiveness level by OWF, understood as the cost of generating energy not higher than in other, alternative technologies, is possible in Poland in 2020, as shown in the chart below.

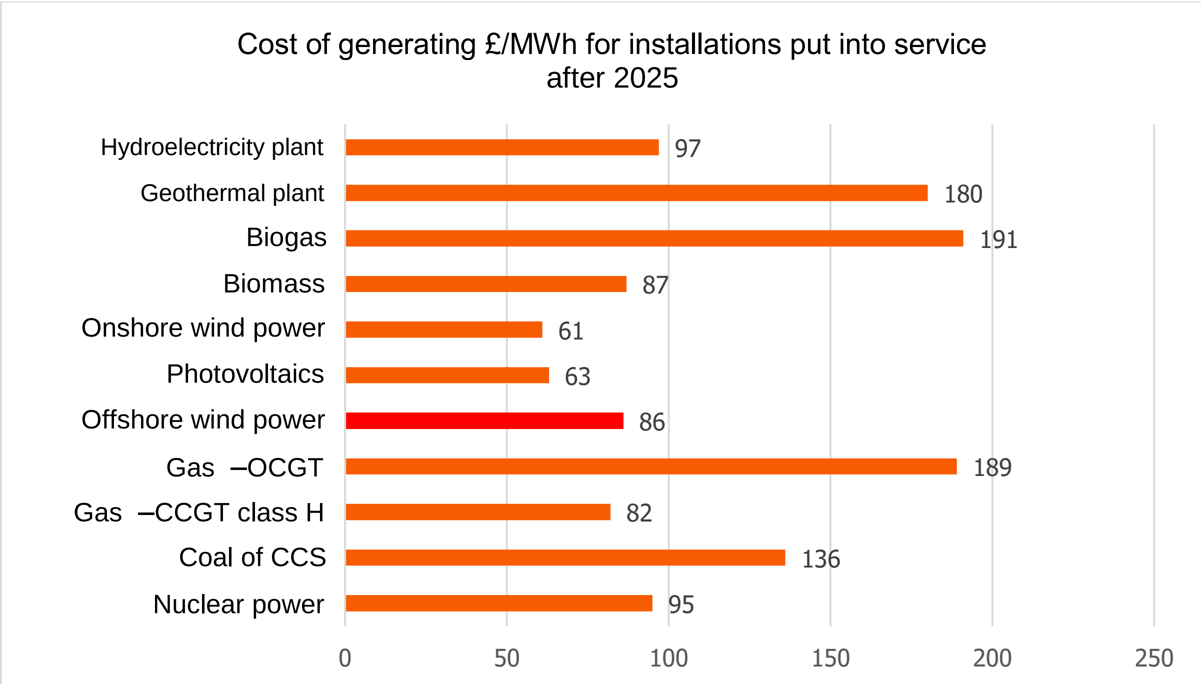

Diagram 1 Comparison of prices per generation technology – British market forecast[33]

On the other hand, it is difficult to estimate the moment when OWF reaches the level of profitability, allowing for the execution of investments without support, i.e. at the energy production price no higher than its average market price, due to the lack of reliable forecasts of energy price increases. In recent years, there has been a continuing trend of low energy prices. Nevertheless, considering the investment needs of the Polish energy sector, as well as the real risk of a capacity shortage in the years 2022 - 2023, the assumption of higher than in recent years energy price growth dynamics does not seem to be a methodological error. For the Project, two paths of energy price forecasts were considered: low growth (with a continuing tendency not to include the necessary investment costs in the energy price) and investment growth (with consideration of the need to invest in new capacities), but the path with low energy prices was taken as the base. The results presented in the diagrams below show that the profitability of the OWF projects without additional support can be achieved, depending on the efficiency of the project and the cost of construction of the entire connection to the onshore point and charging the investor, only

[32] FNEZ, 2017
[33] Crown Estate, Department for Business, Energy & Industrial Strategy, 2016, Electricity Generation Costs

in case of taking over the costs of construction of the connection by the operator. For less productive wind farms this could happen around 2030 and for the most productive wind farms around 2026.

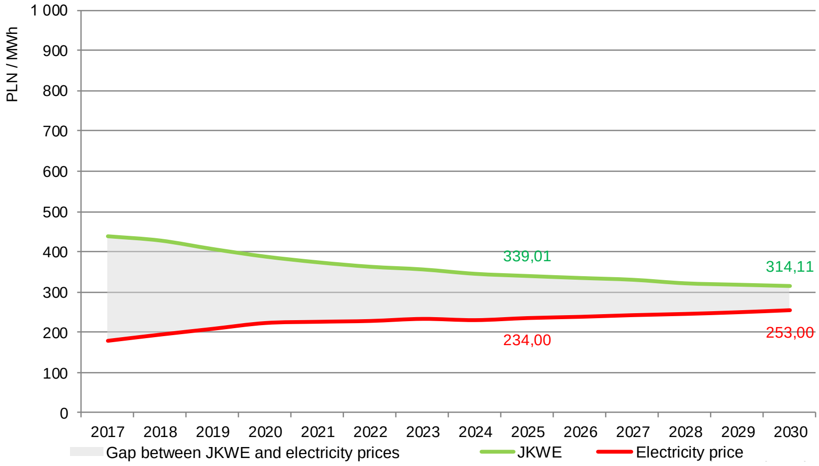

Diagram 2 Ratio of the cost per unit of OWF energy generation (JKWE) against energy price: Option I: OWF low efficiency, with connection cost on the investor's side[34]

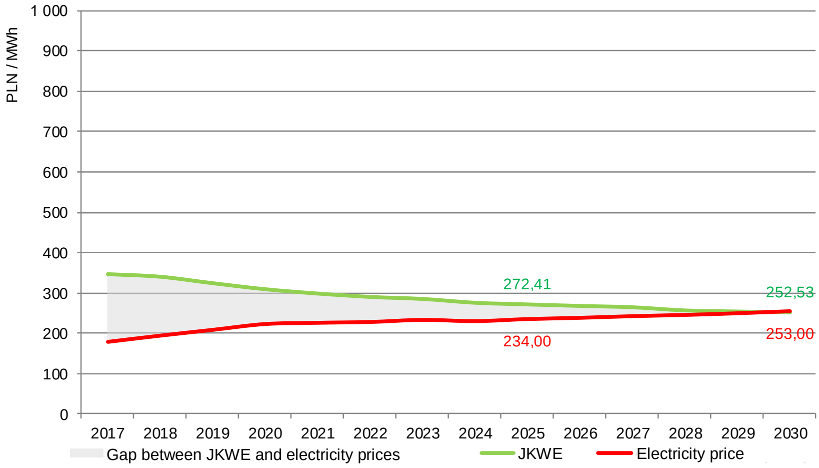

Diagram 3 Ratio of the cost per unit of OWF energy generation (JKWE) against energy price: Option II: OWF low efficiency, without connection cost on the investor's side[35]

Taking the above into consideration, it can be concluded that after 2020 offshore wind farms will become an attractive alternative for investors in Poland, which, in view of the expected significant capacity shortfalls, may cause a great interest in making decisions to prepare investments in this technology. However, investment decisions will depend on the existing support system making it possible to cover the difference between the average price of energy and its generation cost. Such mechanisms may be either the capacity market or auctions specifying the guaranteed price of energy generated from renewable sources. If offshore wind energy is not allowed to use the above-mentioned support schemes for energy investments, the moment of making an investment decision will be reaching the level of energy production costs no higher than the average energy price level.

Achieving investment profitability will be vitally influenced by a possible decision concerning the construction of offshore grids, including cross-border interconnections, by the transmission operator, which could reduce the investment costs by up to 25% and have a major impact on the competitiveness of offshore wind energy. This issue is discussed in more detail in the chapter 1.2.3.

[34] Assuming 25 years of operation, 47.3% capacity factor, 6 MW/km^2 density, assumed return on capital 11%, CAPEX'2025 8.6 million PLN/MW (includes connection), fixed operating costs 220,000 PLN/MW, Euro exchange rate 4.2 PLN.
[35] Assuming 25 years of operation, 47.3% capacity factor, 6 MW/km^2 density, assumed return on capital 11%, CAPEX'2025 6.4 million PLN/MW (contains connection), fixed operating costs 220,000 PLN/MW, Euro exchange rate 4.2 PLN.

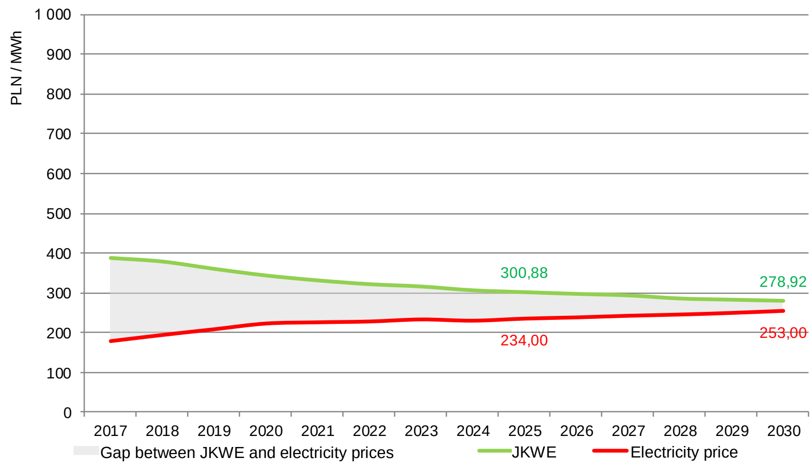

Diagram 4 Ratio of the cost per unit of OWF energy generation (JKWE) against energy price: Option III: OWF high efficiency, with connection cost on the investor's side[36]

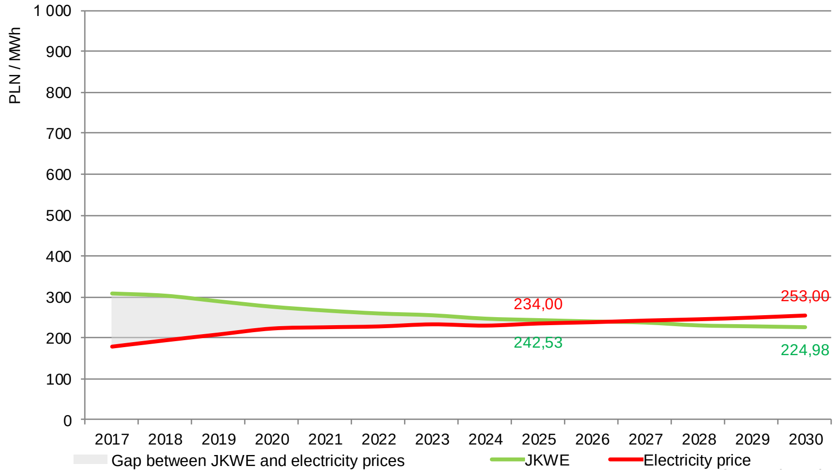

Diagram 5 Ratio of the cost per unit of OWF energy generation (JKWE) against energy price: Option IV: OWF high efficiency, without connection cost on the investor's side[37]

To sum up, it can be concluded that price conditions will mainly affect the timing of investment decisions. Very dynamic development of offshore wind farm technologies, resulting in an equally dynamic reduction of costs, confronted with the need to create new capacities in the Polish power system and the existing potential of Polish maritime areas, entitles us to claim that offshore wind energy will certainly develop in Poland. It is only political decisions that determine when this development will take place. With the support of the state launched in 2018 (admission to auctions or power market, establishment of grid connection points at sea), the first offshore wind farms are likely to be put into operation after 2023, and without support - after 2027. This will once again determine the final capacity that can be achieved by 2030 or 2035.

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[36] Assuming 30 years of operation, 52.3% capacity factor, 4 MW/km^2 density, assumed return on capital 11%, CAPEX'2025 8.6 million PLN/MW (contains connection), fixed operating costs 220,000 PLN/MW, Euro exchange rate 4.2 PLN.
[37] Assuming 30 years of operation, 52.3% capacity factor, 4 MW/km^2 density, assumed return on capital 11%, CAPEX'2025 6.4 million PLN (without connection), fixed operating costs 220,000 PLN, Euro exchange rate 4.2 PLN.

1.3.3. Organisational conditions

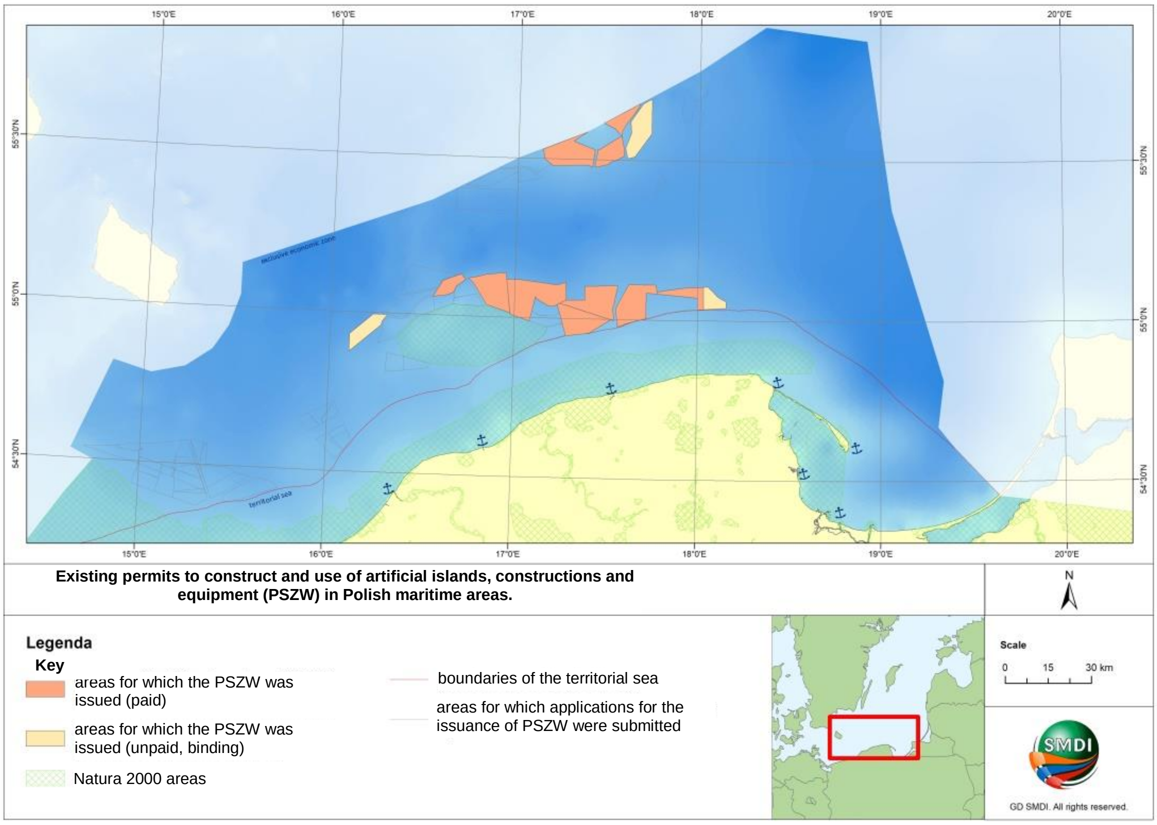
Current state of offshore wind energy industry development in Poland

In 2012 - 2017, a number of preparatory activities were carried out to develop offshore wind farm projects. Most of them concerned the identification of location conditions for individual projects as part of the procedures for agreeing location for the erection of artificial islands and offshore structures. At the time, more than 60 formal administrative procedures were carried out in this scope, out of which about 20 were followed by positive agreements.

The formal and legal state of preparation of individual projects at the beginning of 2018 is as follows:

- 9 legally valid location decisions for OWF projects of about 8 GW of total capacity,
- legally valid location decisions for export cables, enabling power generation from 6 projects with a total capacity of about 6GW,
- environmental studies performed for 3 projects with a capacity of about 3.5 GW,
- 2 legally valid decisions on environmental conditions for 2 OWF projects with a total capacity of 2.4 GW,
- signed connection agreements for 2.25 GW with connection dates for 2026 (1200 MW) and 2030 (1050 MW).

Figure 11 Map of planned OWF investments within the exclusive economic zone of Poland[38]



[38] SMDI

The OWF projects being prepared in Poland can be divided into 3 main groups:

- Group I – projects which will have environmental decisions and connection agreements at the end of 2018,
- Group II – projects which have legally valid PSZW, but which do not have connection conditions,
- Group III – projects which were prepared and obtained a positive location agreement, which was not subsequently paid for and expired, as well as projects which have not been prepared so far, but the boundaries of which can be defined in the areas designated in the plan for the development of maritime areas for development of offshore energy.

Political and regulatory conditions

Considering the different degree of preparation of OWF projects in Poland, the development of each of the three groups of projects should be planned based on regulations adapted to a given group of projects, allowing for meeting the conditions necessary to enable the projects in each group to develop further. The conditions necessary for making investment decisions on the continuation of project development are as follows:

- A stable and predictable legal framework, allowing the project to develop fully in line with the deadlines and conditions laid down in subsequent permits and administrative decisions,
- Possibility to obtain income to ensure profitability of the investment,
- The execution of the investment, including access to the location, the possibility of connection to the network, the possibility of organizing the construction and logistics facilities.

It should be emphasized that as of now there is no system environment in Poland that meets the above-mentioned conditions. The key barriers are uncertainty as to the timing and volume of auctions determining the level of energy prices for RES generators and the validity periods of individual permits and consents, not adjusted to the investment process, which the investor must obtain before starting the construction of OWF. For projects that do not have connection conditions, there is no mechanism for determining the prospect of obtaining them.

In the absence of legislative solutions aimed at creating conditions for investment decisions in each of the three groups of projects, it will not be possible to use the potential of 8 GW. If no significant new legislative decisions dedicated to the II and III Groups will be made, the development of offshore wind energy in Poland is likely to end with projects that have signed connection agreements. These projects could take part in an auction, if it is organised and considers the specificities of offshore projects, so that after the auction has been successfully completed, investors can make investment decisions that will trigger the design and organisation of the supply chain. The second possible option is to make investment decisions only after these projects have achieved full market competitiveness and implement them without systemic support. This however means that by 2035 the potential of about 2.2 GW would have been used. It should be stressed that this scenario would require legal protection of these projects against the expiry of the permits obtained.

However, since the objective of this programme is to indicate the possibilities of achieving the largest possible sustainable development of offshore wind energy in Poland, the scenarios for construction of up to 8 GW in OWE will be analysed later.

In terms of creating the regulatory environment for offshore wind energy, the following conditions for individual project groups must be met:

- for Group I – obtaining a guarantee of the purchase price for energy in the period of 15 years. The amount of the energy price may be determined in an auction, on terms similar to those currently applicable to RES and allow projects with environmental decisions and connection agreements to take part,
- for Group II – obtaining the conditions of connection to the grid and a guarantee of the energy price in the period up to 2035. The connection conditions and energy price should be set in a modified auction system where projects with paid location permits could take part,
- for Group III – obtaining location agreement and conditions of connection, which would take place in tenders organised based on new regulations, like the regulations on exploration and production licences for hydrocarbons in maritime areas, for projects with boundaries defined by the maritime administration.

Appropriate legislative amendments should be adopted on dates allowing for the organisation of auctions for Group I projects in 2019, the organisation of Group II auctions in 2020 and tenders for Group III in 2021.

Schedule of OWF project preparation

The preparation and construction of an offshore wind farm project in Poland, under the current formal and legal conditions, takes not less than 13 years, assuming the stability of the political and regulatory environment. This process can be divided into the following stages:

- Localisation and environmental stage – includes: procedures on localisation permits, environmental studies and analyses, environmental impact assessment, ending with obtaining a valid decision on environmental conditions. This stage can be completed theoretically in about 3 years,
- Design stage – includes: wind measurements, productivity analysis, preparation and agreement of the technical concept, geotechnical research, execution and agreement of the construction design, obtaining a building permit. This stage can be completed in 4 years,
- Supply chain stage – includes: supply market analysis, financial engineering, investment decision, contracting, production and delivery of offshore wind farm components and connections. This stage can last about 3 years,
- Construction stage – covers construction logistics preparation, construction, commissioning, putting into service. This stage can last about 3 years.

As the market develops, experiences are gained, and supply and logistics facilities are organised, the project preparation time should be reduced to about 10 years.

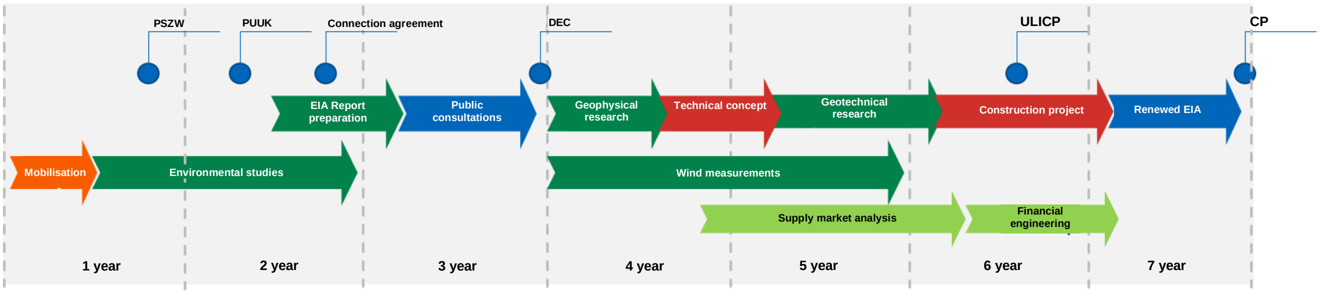


Figure 12 Schematic schedule for the OWF preparation process in Poland[39]

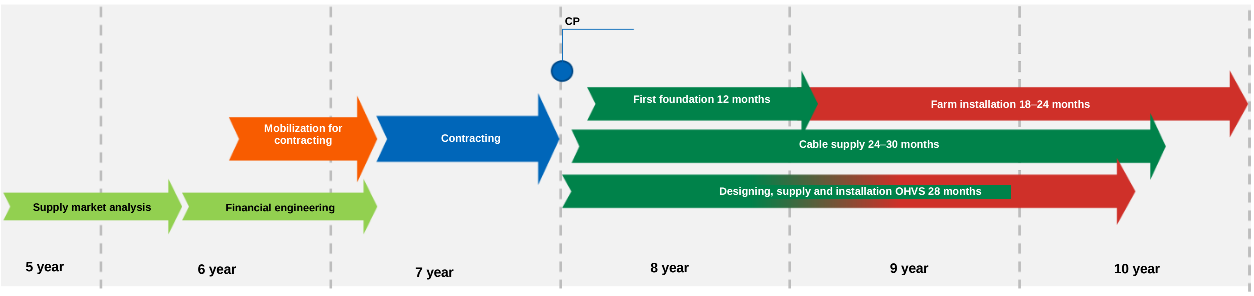


Figure 13 Schematic schedule for the supply chain creation[40]

Systemic conditions for the preparation and execution of the offshore wind farm project in Poland are presented in more detail in Chapter 3.

[39,40] FNEZ, 2017

Market development schedule

To be able to install 8 GW of capacity in Polish maritime areas by 2030, it would be necessary to carry out simultaneously many preparatory and construction activities for a large number of projects. It would also be necessary to bring about an enormous volume of construction work between 2027 and 2030, allowing for the commissioning of 2 to 2.4 GW of new capacity each year. To make this possible, two very strong production and construction centres in Gdańsk–Gdynia and Szczecin–Świnoujście would have to be established in 2019 - 2027, each of which would be able to handle the supply and construction of OWF of about 1 GW in parallel for three regions. This scenario would therefore require appropriate policy decisions, which would translate into investments in production and logistics facilities.

Meeting the above conditions in 2019 - 2021 would allow for implementation of 8 GW of OWE in Poland by 2030. However, such a scenario seems to be purely theoretical, also because of the low probability of meeting human resources needs before 2027 and achieving such high efficiency of the Polish offshore power industry. Handling such many projects in a short time would also be likely to encounter logistical problems and cause too high cumulative environmental and maritime safety impacts. The diagram of the OWE market organization schedule is presented in the figure below.

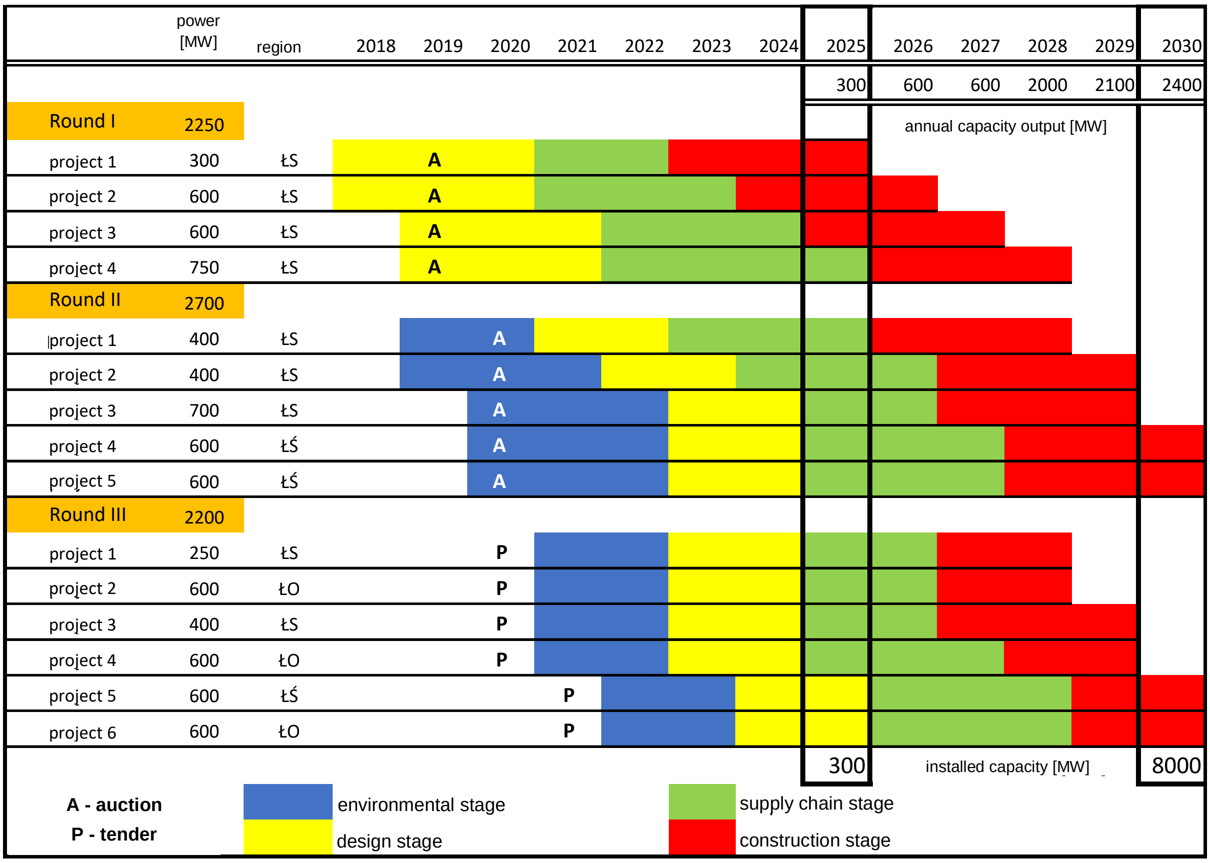


Figure 14 Schematic schedule of OWE development in Poland – scenario "8 GW in 2030" (ŁS – Słupsk Bank region, ŁO – Odra Bank region, ŁŚ – Central Bank region)[40]

Another, very important factor limiting the possibility of simultaneously building several projects in the close vicinity, thus undermining the feasibility of the above scenario, will be the cumulative environmental impacts, especially at the foundation stage (the accumulation of noise while piling foundations may have a significant impact on fish and marine mammals), as well as the impact of increased traffic of construction vessels on the safety of navigation.

Considering the above conditions, it is necessary to undertake actions increasing environmental safety and social development of offshore wind energy:

[40] FNEZ, 2017

- Planning the parallel implementation of projects in different regions, to minimize the accumulation of their negative environmental impacts and excessive competition for execution and logistic resources, at the same time using economies of scale as an important factor influencing the development of the infrastructure and its competitiveness,
- Maintaining continuity and succession in the preparation of further groups of projects, to maintain an optimal level of employment in the domestic production and implementation sector for as long as possible and to minimise the risk of running out of execution resources to other foreign markets.

Such a distribution of the implementation of individual projects would avoid the most significant cumulative impacts on the environment, because despite the high investment intensity during the same periods, construction works would be carried out at the same time in significantly distant maritime areas.

Sustainable and yet more realistic scenario of the development of OWF in Poland assumes a long-term deployment of 8 GW OWF in Polish maritime areas. In this scenario, as shown in the figure below, it would be possible to reach the level of 4 GW installed capacity in MEW by the end of 2030, and another 4 GW by the end of 2035.

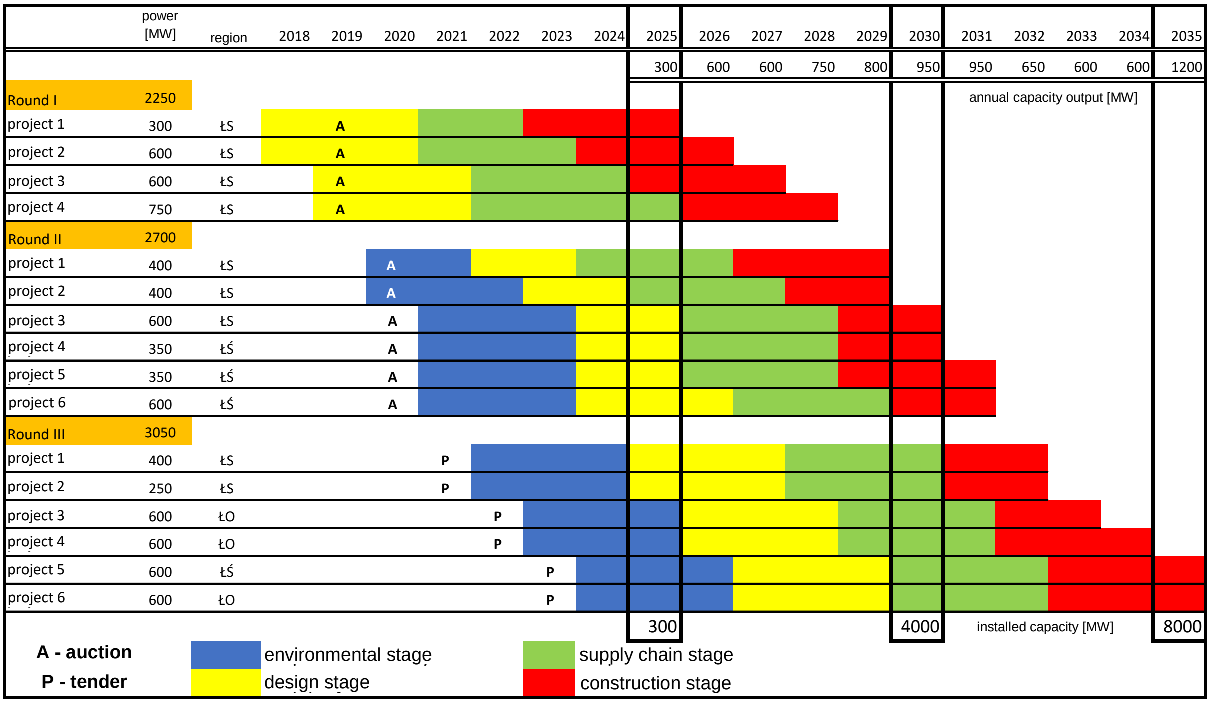


Figure 15 Schematic schedule of OWE development in Poland – balanced scenario "8 GW in 2035" (ŁS – Słupsk Bank region, ŁO – Odra Bank region, ŁŚ – Central Bank region)[41]

This scenario seems preferable, for the following reasons:

- It ensures the sustainable development of the domestic production and logistic base for the construction of further OWF projects, considering other production tasks set for the Polish maritime industry,
- It allows for the development of offshore wind energy in Poland without undue burdens from the support system, since most projects will be able to be implemented on market terms strictly,
- It allows for the gradual development of national staff and companies in the sector, which reduces the risk of searching for suppliers and companies providing services to Polish projects abroad,
- It allows to create and maintain the export potential of Polish industry to other Baltic markets (e.g. Sweden, Lithuania, Estonia), which are likely to develop after 2030,
- It gives time for the development of offshore transmission infrastructure, which will reduce investment costs in OWF and increase Poland's energy security,

[41] FNEZ, 2017

- It minimizes the risk of occurrence of significant negative environmental impacts and social conflicts related to the accumulation of impacts at the stage of construction of a larger number of OWF,
- It gives more time to prepare and implement new system regulations for the third round of projects.

1.4. Summary

The real market potential of offshore wind energy in Poland is 8 to 10 GW. The construction of the first OWF in Poland, with a capacity of about 600 MW, may commence around 2022 - 2023 and the first power plants will be put into operation in 2025. By the end of 2030, without causing excessive competition with other tasks of the Polish maritime industry and without social and environmental conflicts, 4 GW may be built, and another 4 GW by the end of 2035.

Offshore wind farms with a total capacity of 8 GW can satisfy about 20% of domestic electricity demand, significantly affecting the possibility of achieving a noticeable reduction of CO_2 emissions and increasing domestic use of renewable energy sources.

Wind power plants in Polish offshore areas will operate for about 8,050 hours a year (91.9%), of which about 5,800 hours a year in the wind speed range enabling full capacity to be reached (66.5%), providing stable electricity supplies to 14 million households.

The price of energy generated by Polish offshore wind farms (LCOE) should be within the range of 71.6 - 80.7 €/MWh in 2025 and 66.6 - 74.8 €/MWh in 2030, if the charges for grid connection on the investor side are maintained. If the operator were to take over the costs of building the offshore grid, these prices would be 57 - 64.9 €/MWh in 2025 and 53.3 - 60.1 €/MWh respectively in 2030.

Offshore wind farms in the South Baltic may be implemented with a dominant share of supplies and services provided by the Polish offshore power industry, and the supply chain for energy investments at sea may become an important Polish export specialisation.

Employed in the Polish offshore energy industry, related to the development of offshore wind energy, may be 77,000 employees after 2025, yet it is necessary to urgently develop and implement educational programmes for vocational and higher education institutions covering component production and support for the development and implementation of offshore wind farm projects.

The construction of OWF in the Baltic Sea will be an important stimulus for the development of Polish ports, where Gdańsk, Gdynia, Szczecin and Świnoujście may become the main construction centres for offshore energy in the South Baltic, and Łeba, Ustka and Darłowo – important operation and service centres for Polish offshore wind farms.

2. Compliance of the Programme with policies and strategies

The programme's assumptions and objectives are part of the European Union's key strategy papers, policies and implementation programmes, which set out plans and strategies for the development of the energy sector. This is because of the convergence between the development of offshore wind and maritime industries and the EU and international development directions, social, economic and environmental policy objectives, while maintaining the principle of sustainable development in harmony with and with respect for environmental protection requirements.

The implementation of the Programme meets the objectives adopted by the European Commission in 2016 as part of the "Clean Energy for All Europeans" package, the so-called winter package, climate and energy objectives in the area of increasing energy efficiency, increasing the use of energy from renewable sources, reducing CO_2 emissions and ensuring energy security.

At the national level, the Programme is consistent with political and strategic documents and programmes and may contribute to the achievement of Poland's energy policy objectives in scope of power generation development, diversification of sources and directions, energy security and development of transmission grids. Moreover, it responds to national assumptions for the development of renewable energy sources and environmental protection.

The Programme provides an opportunity for the development of port and service facilities, contributing to the achievement of the objectives of the Maritime Policy and the strategy for port development.

First of all, the Programme is prepared in accordance with the directions of Poland's development as set out in the Strategy for Responsible Development and forms the implementation of its main objectives in the following key areas:

- **Reindustrialisation** – by making the maritime industry more dynamic and competitive on European and world markets. Offshore energy will open opportunities for the construction of new production plants, increase the demand for copper, steel and concrete, influencing the development of the metallurgical and cement industries,
- **Innovativeness of companies** – thanks to the fact that Polish companies are in line with the development trend of the offshore wind energy sector and remain an industrial partner on the European market. Setting ambitious national development goals for the industry also means stepping up the development of national research centres, increasing innovation and competitiveness.
- **Development of small and medium businesses** – implementation of new energy investments means a demand for participation of companies providing services for the preparation, implementation and then service of investments. This opens potential for the development of new entrepreneurship, job creation and innovation.
- **Capital for development** – due to the attractiveness of offshore wind farm projects for financing institutions and attracting foreign investment capital. Implementation of the Programme will enable domestic market participants to connect with large foreign industry investors, who will contribute capital and know-how to the country.
- **Foreign expansion** – thanks to the development of the domestic maritime industry through the development of investments in the maritime sector, increased specialisation and competition on the European market. The Programme enables the creation of a strong service and scientific implementation base, which opens the potential for servicing neighbouring markets and covering the Baltic Sea market.

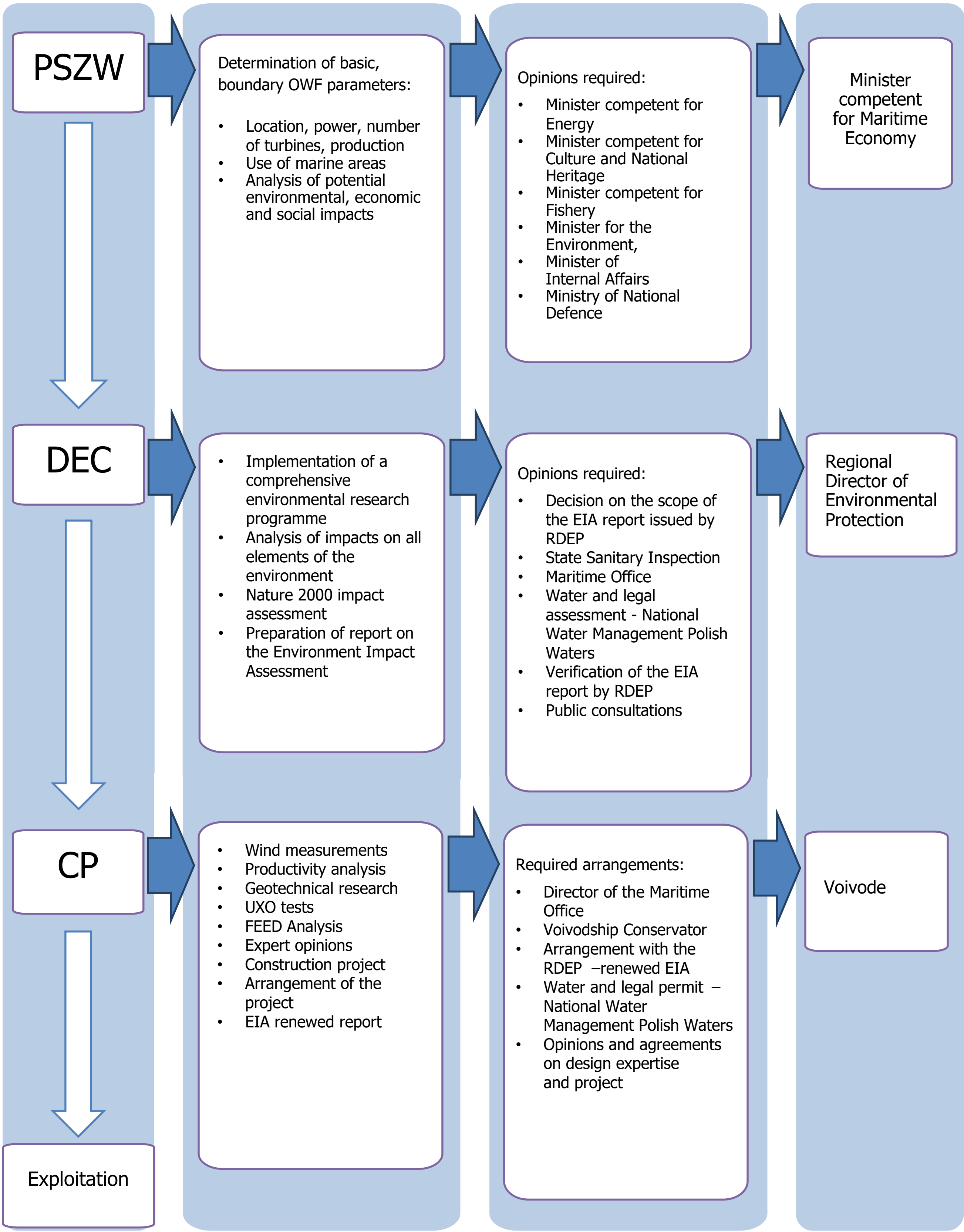
3. Regulatory environment

The process of obtaining decisions, opinions and arrangements of the administration bodies necessary to perform further tasks has a significant impact on the schedule of offshore wind energy projects. It is enough to mention that from the moment of obtaining a decision on environmental conditions to issue a building permit, it is necessary to obtain over a dozen of agreements, opinions and decisions, at least several of which are issued under the procedures not regulated by the provisions of the Code of Administrative Procedure.

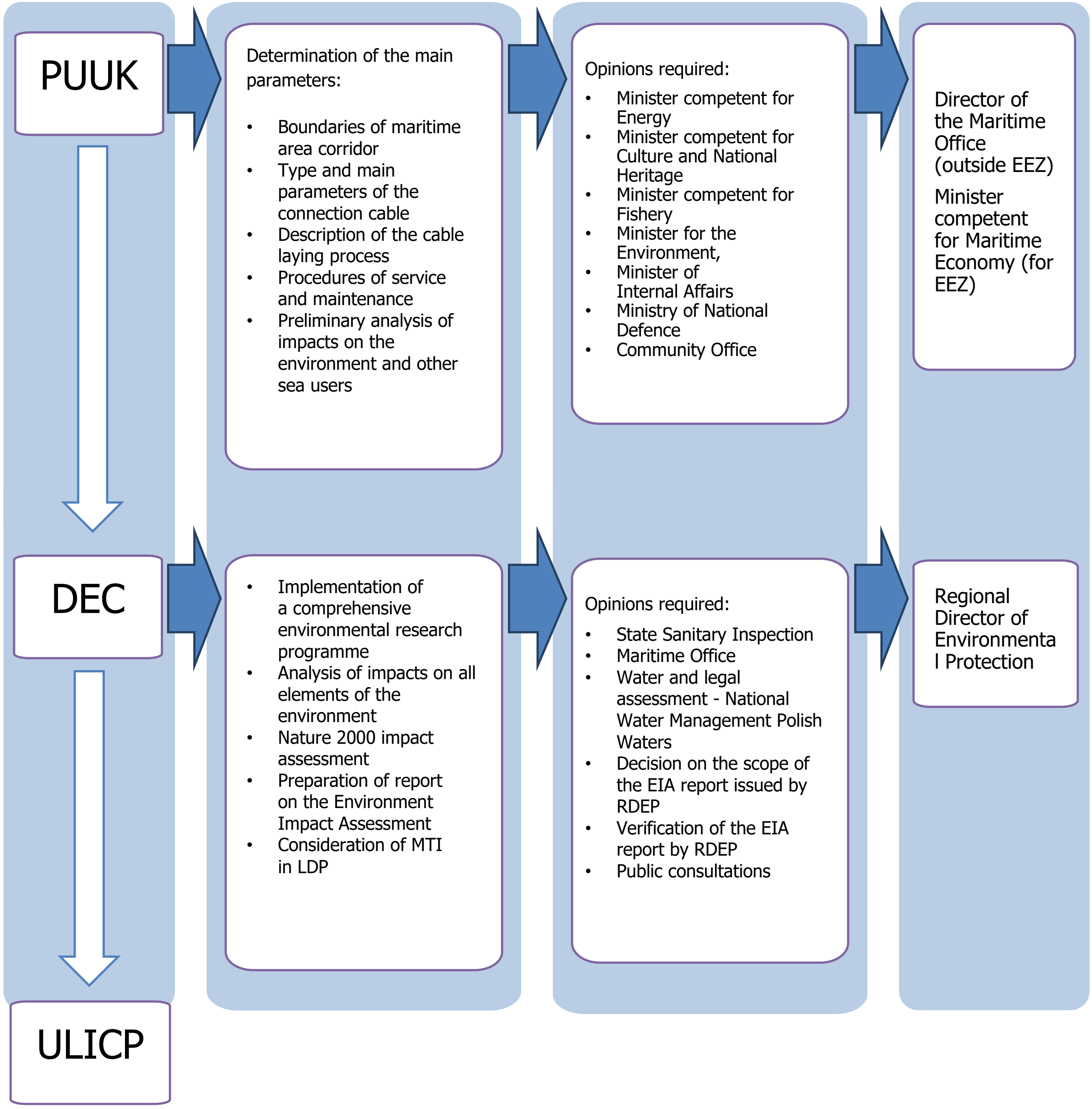
Below is presented in a schematic way of the relation between the most important administrative decisions required to obtain an offshore wind farm for the project, starting from the permit to erect and use artificial islands, constructions and equipment in Polish maritime areas, and ending with the building permit. The diagram also shows the most important steps of the investor to obtain the required decisions and consents, the authority responsible for issuing the decision and the degree of involvement of other competent authorities in the decision-making process.

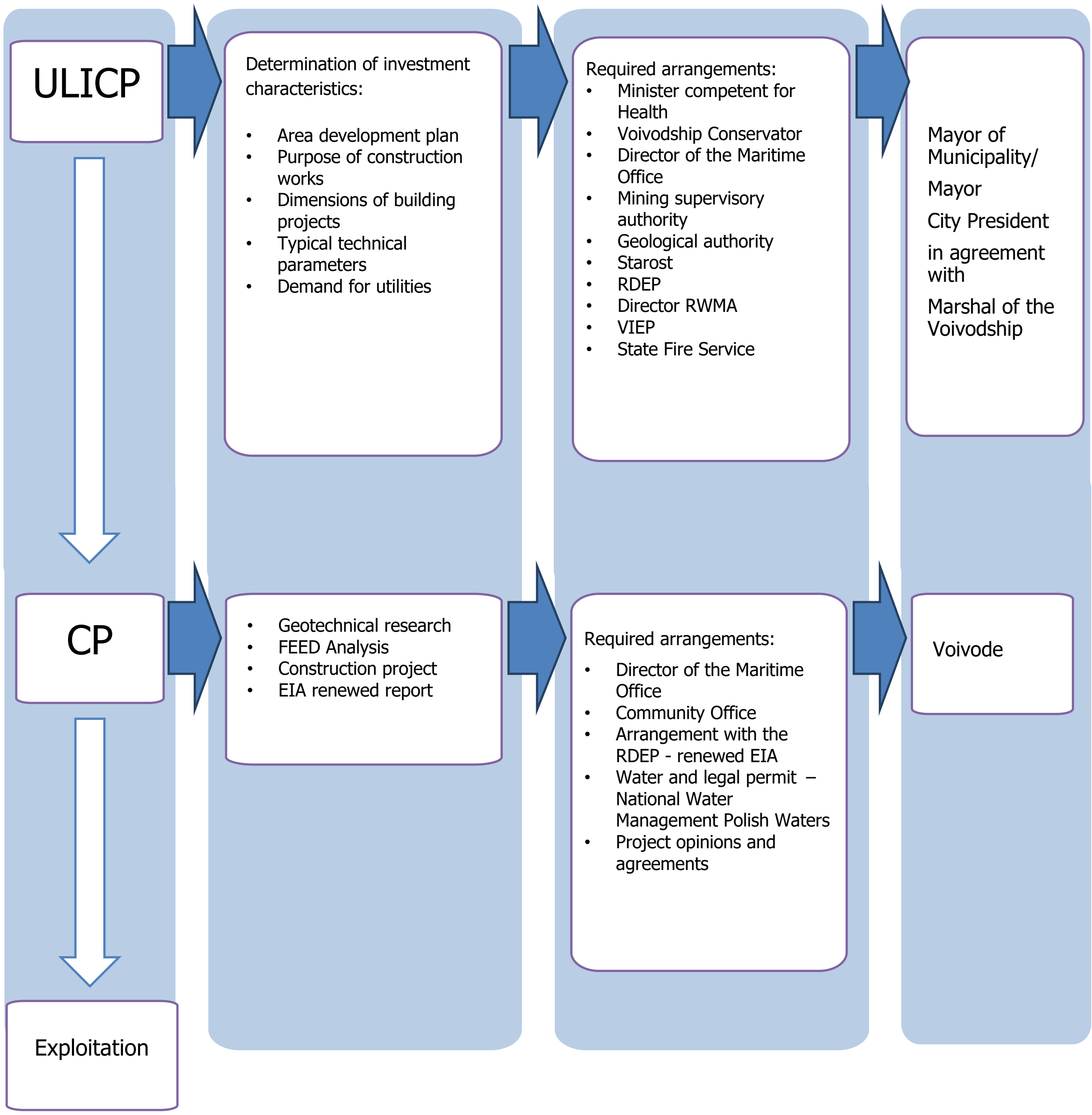
The legal framework for the implementation and operation of offshore wind farm projects in Poland is defined by many laws and regulations. One of the most important from the point of view of the investment is the Act of 20 February 2015 on *Renewable Energy Sources* ("RES Act") with executive regulations to this Act.

Scheme of issuing basic administrative decisions for an offshore wind farm (OWF)



Scheme of issuing basic administrative decisions for transmission infrastructure




ULICP
Determination of investment characteristics:
Area development plan
Purpose of construction works
Dimensions of building projects
Typical technical parameters
Demand for utilities
Required arrangements:
Minister competent for Health
Voivodship Conservator
Director of the Maritime Office
Mining supervisory authority
Geological authority
Starost
RDEP
Director RWMA
VIEP
State Fire Service
Mayor of Municipality/
Mayor
City President
in agreement with
Marshal of the Voivodship
CP
Geotechnical research
FEED Analysis
Construction project
EIA renewed report
Required arrangements:
Director of the Maritime Office
Community Office
Arrangement with the RDEP - renewed EIA
Water and legal permit – National Water Management Polish Waters
Project opinions and agreements
Voivode
Exploitation

4. Risk and barrier analysis

Analysis of the market potential of offshore wind energy in Poland confirms that the development of this sector in Poland is justified at the level of up to 8 GW and should lead to significant economic, social and environmental benefits.

Despite this, there are still no grounds for making binding investment decisions on the construction of OWF in Poland, due to too high investment risk caused by existing barriers, among others.

Key risk factors and barriers to further development of the most advanced projects (I Group - projects with location and environmental permits and connection agreements) are as follows:

- lack or instability of political decisions on the future shape of the Polish power industry;
- lack of binding declarations on the desired national energy mix,
- instability of the support system for renewable energy sources, variability of political support for the development of offshore wind energy,
- lack of predictability as to when auctions will be organised in which offshore wind farms can take part,
- rules for allowing OWF to take part in auctions that do not take into account the specificities of the investment process,
- excessive complexity and lengthy administrative procedures, uncorrelated to the periods of validity of individual licences,
- increasing risk of expiry of location permits (PSZW) issued in 2012 - 2014 due to suspension or delays in project preparation,
- no system of incentives for cooperation between OWF investors and the operator in the expansion of offshore grids, creation of OWF energy storage and balancing systems,
- ordering the OWF owner to pay the full costs of connecting OWF to the grid at a point on land,
- failure to include production for the domestic offshore energy market as one of the priority directions of development of the Polish industry in the country's economic policy.

Key risk factors in the further development of Group II projects (projects with valid location permits) are (above the risk factors and barriers specified earlier):

- lack of certainty as to the possibility of obtaining connection conditions,
- no legal regulations guaranteeing the possibility of developing an OWF project without the risk of expiring location permits validity if there are no conditions for connection to the grid.

Key barriers to further development of Group III projects (new projects without valid location permits) are (above the risk factors specified above):

- suspension of administrative procedures for the issuing of location permits until the works on the maritime development plan have been completed;
- ongoing work on the maritime development plan - no detailed provisions of the plan and decisions on infrastructure corridors;
- lack of mechanisms for granting/selecting location together with the conditions for connection to the grid.

5. Implementation programme

To ensure the development of offshore wind energy in Polish maritime areas up to 8 GW by 2035, the following political and legal measures are proposed.

- **Defining targets for the development of offshore wind energy and maritime industry at 4 GW by 2030 and 8 GW by 2035 in government strategy documents** as a tool for achieving the following objectives:
    - meeting the obligations to increase the use of RES by 2030 and 2040,
    - meeting the obligations to reduce CO_2 emissions,
    - increasing diversification of energy sources in the energy mix after 2025, especially in the context of the need to reduce the use of coal units that do not meet BAT standards,
    - reindustrialisation and modernisation of the Polish maritime industry,
    - creation of Polish export specialisations in the offshore energy industry.
- **Developing and adopting the act on investments in offshore wind energy or making appropriate changes to the RES Act,** allowing for the organization of development of the offshore wind energy market in three rounds:
    - Round I
        - dedicated for projects which, at the time of entry into force of the Act, have valid location permits, decisions on environmental conditions and conditions of connection to the grid,
        - investors meeting the conditions set out in the Act could participate in the auction to determine the price of energy produced by OWF (the differential mechanism principle) guaranteed for 15 years. The price level of the guaranteed energy sale would be determined by a mechanism of exerting pressure on the price level as a result of determining the price range in relation to the lowest price offered, calculated as "x" PLN per MWh in relation to the lowest bid submitted in the auction. In the case of submitting an offer with an energy price higher than the lowest price plus a specified x% - the bidder would not receive support. This mechanism would allow the entire volume of energy from all projects developed on the market to be covered by support, at the level determined by the most competitive offers,
        - The auction deadline would have to be announced at least 12 months in advance and should not be organised later than by the end of 2019.
    - Round II
        - dedicated for projects which, at the time of entry into force of the Act, have valid location permits,
        - investors meeting the conditions set out in the Act could take part in the auction to determine the price of energy produced by OWF guaranteed for 10 years. The energy price would be determined on the same basis as in Round I,
        - the successful bidders would have the conditions for connection to the grid guaranteed. The investor would be responsible for the construction of the connection in accordance with the connection terms and conditions drawn up on the basis of the grid development plan,
        - The auction deadline would have to be announced at least 24 months in advance and should not be organised later than by the end of 2020.
    - Round III
        - dedicated for projects without location permits, but located in areas designated in the spatial development plan of Polish maritime areas for the development of offshore wind energy,
        - investors could take part in a tender for an area designated by the maritime administration with a specified target wind farm capacity,

      - winning the tender would ensure that conditions of connection to the grid for this power are obtained. The tenders would not guarantee the sale price of energy and would be intended for projects implemented without additional support,
      - the tender deadline should be announced 12 months in advance. The first tenders should be organised in 2020.

- **Making the decision to build offshore grids, including cross-border interconnections between Poland-Sweden and Poland-Sweden-Lithuania, integrated with offshore connection points for wind farms in the area of Słupsk Bank and Central Bank, as well as interconnections of Poland-Denmark, integrated with projects in the area of Odra Bank.**
- **Preparation and implementation of a strategy for the development of the Polish offshore energy industry,** including production and logistics centres, as well as service and maintenance centres, including:
    - creation or development of special economic zones around domestic port centres,
    - modernisation of ports and accompanying transport and storage infrastructure,
    - development of auction criteria maximising the use of domestic local content,
    - offset programs for foreign investors who want to take part in auctions and tenders for offshore wind farms without the participation of Polish partners, consisting in negotiating investment and procurement commitments within the supply chain in the Polish offshore power industry,
    - extension of the existing and construction of new production plants of offshore wind farms construction components,
    - launching funding programmes for scientific research, development and implementation centres, ensuring cooperation of industry and science for the development of innovativeness of the Polish offshore energy industry.

6. List of Figures

7. List of Charts

8. List of Diagrams

Notes

Notes

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