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# STRUCTURAL ANALYSIS OF THE OFFSHORE WIND INNOVATION SYSTEM IN POLAND

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Jakub Sawulski♦

## Abstract

The paper is a the preliminary evaluation of the offshore wind innovation system in Poland. The analysis is based on the Technology Innovation System concept. The paper includes the two first steps of the procedure: the structural analysis and the technology stage of development analysis. We found that, although there are not any offshore wind farms in Poland yet, Polish industry has broad experience in implementing offshore wind projects and can cover a large part of the offshore wind farm investment. However, knowledge area is not a strong point of the innovation system. Also the institutional (political) uncertainty, as well as inadequate public system of support for RES, may be significant barriers for the development of the technology. So far, the Baltic Sea has remained weakly explored in terms of offshore wind deployment. Poland, with its large sea space and good wind and soil conditions, may play a pivotal role in kick-starting the offshore market in this area.

Keywords: offshore wind, innovation system, TIS

JEL: Q42, Q55, O31, O33

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♦ Institute for Structural Research, Warsaw, and the Poznań University of Economics and Business, Poznań. E-mail: jakub.sawulski@ibs.org.pl.

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# Introduction

In the coming decades, Poland will have to make a significant effort to meet its energy needs and maintain energy security. The existing coal plants, which are a key element of the current power system, are outdated. Between 2020 and 2035, installations accounting for about 50% of the power generation are intended to be closed, and most of the remaining units need to be modernized. By 2050, only 5 GW from existing installations will still be in use, while the maximum demand is estimated to about 40 GW (NIK 2015). Some problems with meeting energy needs already emerged in the summer of 2015, when temporary administrative restrictions on energy consumption were introduced due to the unexpected shortage of power.

In response to the problem, it is planned to launch new coal and gas power plants providing almost 6 GW until 2020. However, the future needs for modernization and the creation of energy infrastructure (especially after 2022) will be much higher (PSE 2015; PSE 2016). To meet the long-term national energy demand, as well as EU climate policy goals, there is a need to also invest in other energy sources, including renewable energy. Yet, the development opportunities for the most widespread technologies of obtaining energy from renewable sources have been considerably limited by public authorities. The law regulating the requirements for building new wind farms almost fully excludes building new onshore wind farms, and the new auction system with specific technological baskets (both regulations effective from July 2016) is not preferable for photovoltaics (Antosiewicz et al. 2016). Moreover, the technologies promoted by the act on renewable energy sources (primarily biogas and biomass) do not have enough capacity potential to solve the future energy policy problems (KPRM 2015). The energy security plans include building a nuclear power plant, but due to factors such as high investment costs, low social acceptance and the lack of a clear political decision, its construction is still subject to high uncertainty (NIK 2015).

In this context, offshore wind technology should be considered as one of the main alternatives for the Polish power sector. Since the beginning of the 21st century, the technology has experienced rapid growth, especially in European countries with access to the North Sea (Longa 2015). The Baltic Sea is also being explored, mainly by Denmark and Germany, but its potential is still largely unused. Poland – with its long coastline and high needs for power sector investments – is considered to play a pivotal role in kick-starting the Baltic Sea offshore market (Kruger 2016).

The literature in the field of innovation is dominated by a statement, that introducing innovations is a collective activity and takes place within the context of a wider system, which is usually called an “innovation system” or “innovation ecosystem” (Hekkert et al. 2011). In this concept, technological development and change are the outcome of an innovation system. Therefore, to shape the innovation process it is crucial to understand how the innovation system is built and how it functions – what are the societal subsystems, actors and institutions contributing to the emergence or production of innovation, and what kind of communication and interaction foster or hamper innovation (Hekkert et al. 2007).

This article is the first part of the larger project aiming at the evaluation of the innovation system for offshore wind technology in Poland. We analyse the conditions for potential offshore wind deployment, both in terms of the share in the Polish energy system and the benefits and threats for the whole economy (in particular the business sector). We use the Technological Innovation System (TIS) approach developed by Bergek et al. (2008) and Hekkert et al. (2011), who provide manuals containing instructions and explanations on the TIS analysis, as well as by Luo et al. (2012), which is the example of well-prepared offshore wind innovation analysis for four European countries – Denmark, Germany, the Netherlands and the United Kingdom.

This paper consists of the two first steps of the TIS procedure – the structural analysis and the technology stage of development analysis. The structural analysis is about mapping the main components of the innovation system: actors, networks and institutions. Defining the technology stage of development is necessary as the evaluation of the innovation system should be different depending on the maturity of the technology. The analyses have been based on wide research covering reports, publications, law acts and internet sources, as well as e-mail correspondence with stakeholders (mainly business representatives). The issues presented in this paper will be the basis for the second part of the TIS procedure, including a series of interviews with actors (stakeholders) involved in the field of offshore wind in Poland. This will allow the identification of innovation system functions and system failures, and in the end the formulation of some policy implications.

# 1. Structural analysis

## 1.1. Actors

### 1.1.1 Governmental agencies

The role of the government in offshore wind TIS broadly concerns the development and administration of legislation, permissions procedures and providing consent (Luo et al. 2012). The Ministry of Energy is the body responsible for determining the general direction of energy policy in Poland, in particular preparing the long-term energy policy strategy and arranging the proposals for legal reforms (together with parliament bodies). However, the Ministry of Energy is not directly engaged in the permission procedure for offshore wind projects. The procedure consists of four main stages – the location decision, connection agreement, environmental decision and building permit. A wide range of public institutions are involved in these steps (table 1).

Table 1. Overview of governmental bodies relevant for offshore wind

| Institution | Responsibility |
|---|---|
| Ministry of Energy | Designing the energy policy |
| Ministry of Maritime Economy and Inland Navigation | Location decisions for wind farms; location decisions for submarine cables in exclusive economic zone |
| Local authorities | Location decisions for onshore cables; building permits |
| Maritime Offices | Location decisions for submarine cables outside the exclusive economic zone |
| Regional Directorates for Environmental Protection | Decisions on environmental conditions |
| Energy Regulatory Office | Auctions for RES; concessions for producing RES energy |
| PSE S.A. (Polish Transmission System Operator) | Grid connection terms and connection agreement |

*Source: own elaboration.*

The location decision for a wind farm is issued by Minister of Maritime Economy, assisted by six other ministers, who prepare their own opinions. Separate location decisions also need to be obtained for submarine and onshore cables. They are issued by the Minister of Maritime Economy, maritime offices and local authorities. The investor is obliged to meet the connection conditions and sign a connection agreement with the national transmission system operator – PSE S.A. (a state-owned company). One of the key milestones is obtaining environmental permission, which is issued by the director of the appropriate Regional Directorate for Environmental Protection. The decision is preceded by the investor carrying out extensive environmental studies and preparing the Environmental Impact Assessment Report. The last step is obtaining the building permits for wind farms and connection infrastructure. The decision is issued by local governors (regional government representatives), who rely on previously obtained permits and investment projects. Before the energy starts to be produced, a concession needs to be obtained to produce energy from RE sources. This concession is issued by the Energy Regulatory Office, which is also responsible for organising auctions for RE generation.

### 1.1.2 Knowledge institutes

As of June 2017, the number of publications from Poland relating to the offshore wind topic on the Web of Science database amounted to 55 (table 2). It is rather low in comparison to other EU countries. The total number of publications from three EU countries with highest offshore wind deployment – Denmark, Germany and United Kingdom – amounted to 2586 (862 on average). The quality of Polish research papers is also unsatisfactory – the average number of citations per item reached 3.7, while in the other aforementioned countries it was 11.2. However, it should be taken into account that the whole research sector in Poland is rather underdeveloped in terms of publications in well-established journals. The number of all publications from Poland in the Web of Science database is almost 5 times lower than from Germany, while the total country population is about half.

The Polish Academy of Sciences (PAS) is the leading organisation in publications about offshore wind. The PAS consists of a number of institutes, of which the most important in the context of offshore wind deployment in Poland are: the Institute of Oceanology in Sopot, the Institute of Geophysics in Warsaw, the Institute of Fluid-Flow Machinery in Gdańsk, the Institute of Hydroengineering in Gdańsk and the Institute of Geological Sciences in Warsaw. The first two organisations are members of a research consortium which received the status of Leading National Research Centre for 2014-2018 (there are only 5 consortia with this status for that period in Poland). Other important public research institutes (which are not part of PAS) which provide research in areas potentially appropriate for offshore wind are: the Polish Geological Institute, the Institute of Meteorology and Water Management, the Institute of Power Engineering (all with main offices located in Warsaw), the Maritime Institute in Gdańsk and the National Marine Fisheries Research Institute in Gdynia. These organizations provide research facilities for some important steps in the development of offshore wind in Poland, in particular environmental research and seabed exploration. The role of the Maritime Institute is especially worth highlighting, as this institution has been largely engaged in almost all permission procedures initiated so far.

Research in offshore wind is also conducted by academic authors. The leading organisation in this case is the Gdańsk University of Technology, in particular the Faculty of Ocean Engineering and Ship Technology. The Faculty also publishes the Polish Maritime Research journal (impact factor in 2016 – 0.776), which covers research in engineering, computing and technology, which could have applications in the domain of maritime economy.

Table 2. Overview of publications occurring in Web of Science database with *offshore wind* as topic indication and *Poland* as country indication

| Year of publication | | | |
|---|---|---|---|
| Year | No. of publications | Year | No. of publications |
| 2012 | 5 | 2016 | 7 |
| 2013 | 6 | 2017 | 6 |
| 2014 | 4 | Other | 17 |
| 2015 | 10 | Total | 55 |
| Most represented organisations* | | | |
| Organisation name | | | No. of publications |
| Polish Academy of Sciences | | | 16 |
| Gdańsk University of Technology | | | 10 |
| Warsaw University of Technology | | | 5 |
| University of Gdańsk | | | 4 |
| Most represented authors* | | | |
| Author | Affiliation | | No. of publications |
| Dymarski Paweł | Gdańsk University of Technology | | 4 |
| Zieliński Tymon | Polish Academy of Sciences | | 4 |
| Dymarski Czesław | Gdańsk University of Technology | | 3 |
| Kahsin Maciej | Gdańsk University of Technology | | 3 |
| Żywicki Jędrzej | Gdańsk University of Technology | | 3 |
| Most represented research areas* | | | |
| Research area | | | No. of publications |
| Engineering | | | 31 |
| Energy fuels | | | 9 |
| Oceanography | | | 8 |
| Geology | | | 5 |
| Computer science | | | 5 |

** More than one organization, author and research area may be assigned to one article.*

*Source: own elaboration based on the Web of Science database (accessed: 27.06.2017).*

A special kind of actor in knowledge area about offshore wind is the CTO – Ship Design and Research Centre. It is a state-owned company, which provides vessel model studies, as well as research, design and certification services, in particular for the shipbuilding industry.

An analysis of the abstracts and keywords of publications occurring in the Web of Science database provides the information about the main directions of research in offshore wind in Poland. There is a set of publications, prepared mainly by the team of the Gdańsk University of Technology, covering computer simulations and strength analyses of scaled laboratory models of offshore wind turbines support structures, in particular foundations and TLP platforms. The resistance of such structures to loads due to waves is one of the most studied topics. There are also some papers on the characteristics of marine power grids and plant connection infrastructure. Similarly to observations made by Luo et al. (2012) for Denmark, Germany, the Netherlands and the United Kingdom, a large part of the offshore wind literature in Poland concentrates on how to fit the technology into specific environmental and geographical conditions, rather than on the technology itself.

### 1.1.3 Educational organisations

There are no academic programmes in Poland which specialise in the particular needs of the offshore wind sector. However, there is a wide range of faculties, which have the potential to create such types of courses, in case of significant increase in market demand for these qualifications. The academic courses related to marine sciences (i.e. engineering, transport, geology, navigation) are concentrated in the Pomeranian region. These faculties cover over 12,500 students and the locations of the universities coincide with the potential locations of offshore wind construction seaports (see subsection 1.1.4). There are also a number of courses offered by higher education institutions in Poland in fields such as power engineering, mechanical engineering, environment and geology, and a growing number of programmes on renewable energy sources (table 3).

Table 3. Overview of higher education institutions and courses potentially relevant for offshore wind

| By university | | |
|---|---|---|
| Selected universities | Selected faculties | Number of students 2016/2017 (approx.) |
| Gdynia Maritime University | Faculty of Marine Electrical Engineering | 1000 |
| | Faculty of Marine Engineering | 1100 |
| | Faculty of Navigation | 1800 |
| Maritime University of Szczecin | Faculty of Economics and Transport Engineering | 1100 |
| | Faculty of Marine Engineering | 800 |
| | Faculty of Navigation | 1800 |
| Gdańsk University of Technology | Faculty of Ocean Engineering and Ship Technology | 1900 |
| West Pomeranian University of Technology Szczecin | Faculty of Maritime Technology and Transport | 400 |
| University of Gdańsk | Faculty of Oceanography and Geography | 1300 |
| University of Szczecin | Faculty of Geosciences (including Institute of Marine Sciences) | 450 |
| Polish Naval Academy | Faculty of Mechanical and Electrical Engineering | 300 |
| | Faculty of Navigation and Naval Weapons | 600 |
| By field of study | | |
| Field of study | | No. of universities offering a course in the given field |
| Environment (engineering, protection, management) | | 68 |
| Geology | | 13 |
| Mechanical engineering | | 43 |
| Oceanography | | 2 |
| Ocean engineering | | 3 |
| Power engineering | | 27 |
| Renewable energy sources | | 14 |

*Source: own elaboration based on government data on faculties and fields of study in the higher education system in Poland, available at: www.wybierzstudia.nauka.gov.pl (accessed 26.06.2017).*

Since 2012 is has been possible to obtain the title of Technician of Renewable Energy Equipment and Systems at a vocational pillar of education in Poland. Therefore, many vocational schools have opened courses in this field. Acquiring a certificate of competence in this profession is preceded by a four-year period of training combined with professional practice. A two-stage state exam is the final element of the course. Program graduates are competent in the assembly and operation of RES installations. Moreover, educational organisations located in the Pomeranian region also offer a broad spectrum of vocational courses in marine studies. The courses are mainly dedicated to the shipbuilding industry, i.e. ship mechanics, ship building, port operation and maritime navigation. The vocational educational organisations prepare students either for getting a job immediately after finishing school, or for starting their academic education with an extended level of knowledge in a particular area.

### 1.1.4 Industrial actors

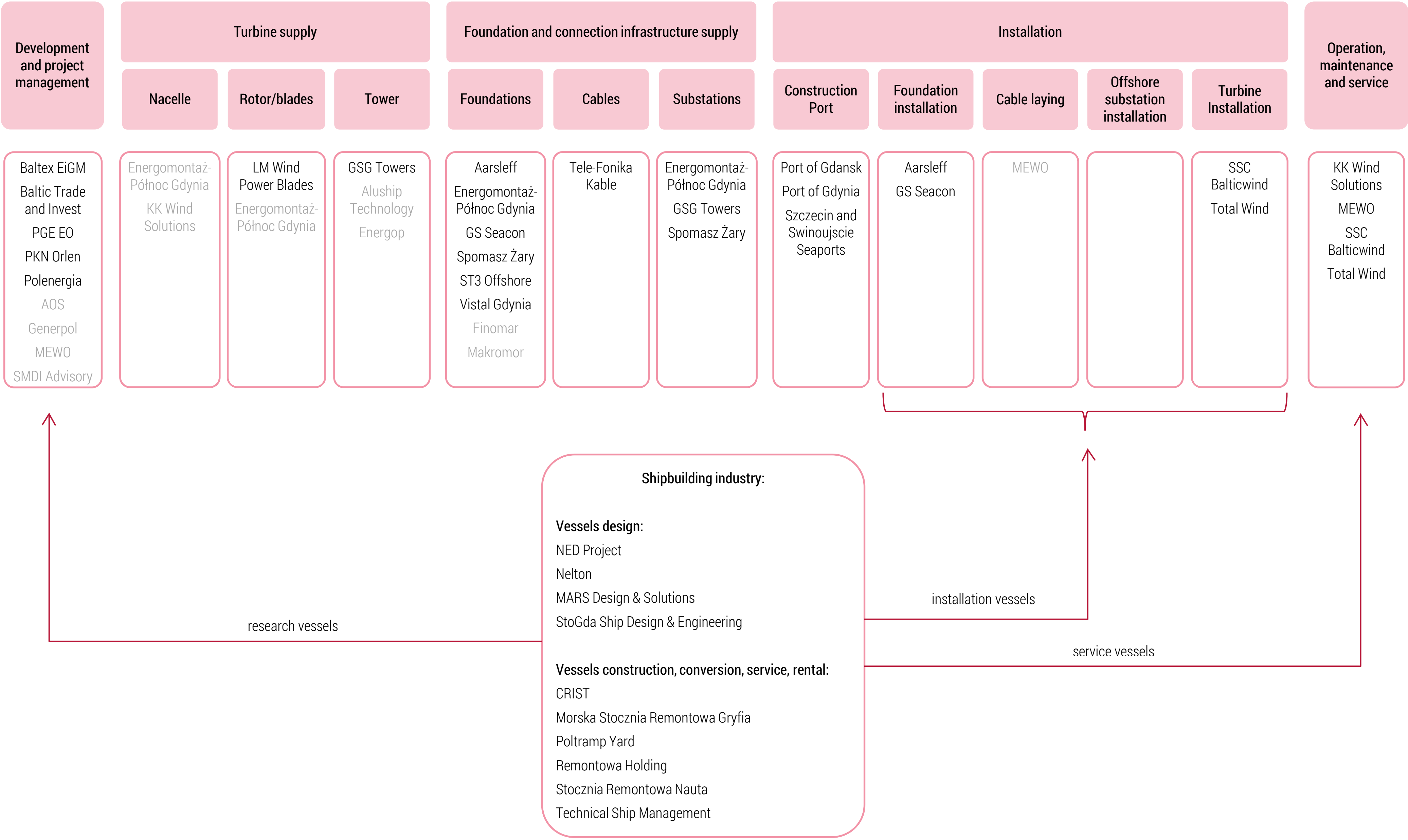
The key industrial actors involved into offshore wind system in Poland are presented in scheme 1. The actors were divided into main value chain steps. The scheme covers the most important companies in the Polish value chain, primarily those who had already taken part in offshore wind investments in other countries. In the case of multinational corporations, the company has only been classified to the Polish value chain if its subsidiary is located in Poland, and only to the stages of the value chain, which can be covered by this Polish branch.

Although there is no offshore wind farm located in Poland, Polish industry can cover a large part of the offshore wind farm investment. So far, activity in this area shows that the large state-owned companies – PKN Orlen and PGE EO, as well as the privately-owned Polenergia, should probably be the most important investors and project developers. There are also at least a few significant players on the global offshore wind market, with their businesses located in Poland, i.e.: GSG Towers, Energomontaż-Północ Gdynia, ST3 Offshore, GS Seacon, Aarsleff and Spomasz Żary. These companies mainly specialise in the supply of foundations, towers and substations. Their portfolio is filled by many projects realisations, in particular for offshore wind farms located on the Baltic and North Sea. Moreover, Tele-Fonika Kable is one of the largest European cables producer, whose cables have been largely used in offshore wind investments worldwide. There are also companies (AOS, MEWO, SMDI Advisory Group, SSC Balticwind), which have experience in dealing with administrative procedures and preparing environmental documentation for offshore wind farms.

The strength of the Polish offshore wind value chain is a well-developed shipbuilding industry. Offshore wind sector requires specialised vessels for environmental and geological research, transport and installation of wind farm components and wind farms service. The construction and repair of ships and boats industry in Poland includes over 5000 enterprises (of which about 80 employ more than 50 workers), and employs almost 30 thousand workers (2015 data) (GUS 2016). Polish shipbuilding companies offer a few models of vessels dedicated for offshore wind farms investments, which have already been used in offshore wind projects worldwide. Also Polish seaports seem to be sufficiently developed for offshore wind deployment.

However, the nacelle production and some stages of the installation activities are the parts of the Polish offshore wind value chain which are somewhat underdeveloped. Also, the production of rotors and blades is not sufficient, with only one blade manufacturer: the LM Wind Power subsidiary. The O&M and service stage of the value chain is covered mainly by a few subsidiaries of multinational corporations, although it should develop in parallel with the deployment of technology.

Scheme 1. Polish industrial actors potentially involved in national offshore wind projects along the value chain




*A gray font means that the company may potentially take part in the specified stage of value chain as a sub-supplier.*
*Source: own elaboration.*

It is worth noting that the range of sub-suppliers, not mentioned in the value chain scheme, could also be important factor for offshore wind deployment in Poland. Poland has large steel producers (i.e. ISD Huta Częstochowa), and offshore wind deployment could become the largest steel-consumption project in recent decades (Purta et al. 2016). Moreover, Polish KGHM is one of the world's largest copper producers, which is primarily used to produce cables for offshore wind installations.

Given the outlined factors and taking into account the investment costs in each phase of the value chain, at least 50% of the offshore wind farm investment costs can be covered by Polish value chain at this moment (Purta et al. 2016). This share can rise up to 70%, assuming the value chain develops in parallel with technology. Still, nacelle, rotor and blade supply collectively account for about one-third of investment costs, and these elements will probably be mostly imported.

### 1.1.5 Support organisations

The high costs of offshore wind investments make the availability of external financing one of the key issues for the development of this technology in Poland. BGK – the Polish state-owned development bank – should be one of the main capital providers, since it is usually involved in large infrastructure projects in Poland (in the energy sector as well). Also, the European Investment Bank (EIB) may be interested in Polish offshore wind projects, as it has already taken part in financing offshore wind deployment in other countries (especially through the European Fund for Strategic Investments – a joint initiative of the EIB and the European Commission). The probability of obtaining financing at EU's institutional structures may be particularly high for regional marine grid connection projects, covering all EU countries with access to Baltic Sea (see also subsection 1.3). Such projects may receive the status of projects of common interest (PCIs) and become part of an integrated EU energy market.

Financial and non-financial assistance for industrial projects is offered by the Polish Entrepreneurship Development Agency and the Industrial Development Agency. Similar activities are also carried out by regional institutions, i.e. the Pomerania Development Agency (coordinator of the 'Invest in Pomerania' initiative) and the Pomeranian Regional Development Agency. These institutions provide access to investment areas, consultation and information services and professional support in obtaining EU funds and other financial support, and also offer their own financial instruments dedicated mainly to small and medium-sized enterprises.

Other important actors for offshore wind in Poland are non-governmental organisations, which care about promoting and lobbying for this technology spread, and also put forward regulatory proposals in that area. There are at least four such organisations: The Foundation for Sustainable Energy, Institute for Renewable Energy, Polish Offshore Wind Energy Society and Polish Wind Energy Association. Their activity is substantially important at the current stage of technology development in Poland and given the high political uncertainty related to whole energy sector (see sections 1.3 and 2).

## 1.2. Networks

The most important industrial network in the Polish offshore wind sector is the MARS Shipyards & Offshore group of companies. It includes two shipyards – MSR Gryfia and SR Nauta, two companies which specialise in the manufacturing of offshore constructions – Energomontaż-Północ Gdynia and Energop, as well as a marine and offshore design office – MARS Design & Solutions. The owner of the group is MARS Fund, which is managed by the MS Investment Funds Society, a subsidiary of the PGZ - Polish Armaments Group. PGZ is a company, whose sole shareholder is the State Treasury, therefore the companies forming MARS Shipyards & Offshore group can be viewed as state-owned. At the beginning of 2017 the group expanded, as MARS Fund purchased the Szczecin Industrial Park, which covers the area of the former Szczecin Shipyard. Moreover, the Fund holds significant, but non-controlling, shares in the CRIST Shipyard and $ST^3$ Offshore. The companies gathered around MARS Fund represent a substantial part of the technical potential of Polish industry, that may participate in offshore wind technology deployment in Poland.

The Polish Offshore Energy Industry Alliance is an agreement signed by 30 companies from the maritime, steel and electrical industry, representing, among others, the shipbuilding, metallurgy and cable design sectors. The aim of the Alliance is to provide support for the development of the offshore wind energy sector in Poland, which mainly translates into lobbying activities. The initiator and coordinator of the Alliance is the Polish Offshore Wind Energy Society, which gathers a set of offshore wind actors. A similar function, albeit dedicated to the whole offshore sector, is also performed by the Polish Chamber of Maritime Commerce. Another important form of cooperation between companies is merging into clusters. There are at least three important formalised clusters in Polish offshore sector: the Westpomeranian Maritime Cluster, Polish Maritime Cluster and North-South Logistics & Transport Cluster. They cover, in particular, companies related to the shipbuilding industry, as this is the main area of interest of the offshore business sector in the Pomerania region (as indicated in section 1.1.4).

Table 4. Formalised knowledge cooperatives in areas relevant for offshore wind

| Name | Members | Mission |
|---|---|---|
| MORECKO | CTO – Ship Design and Research Centre<br>Gdańsk University of Technology<br>Institute of Fluid-Flow Machinery (PAS)<br>Institute of Oceanology (PAS)<br>Maritime Institute<br>Pomeranian Special Economic Zone | Integration of activities of consortium partners in offshore wind energy sector in order to achieve synergies and developing research programs in cooperation with the private sector. |
| PolMar | Gdańsk University of Technology<br>Institute of Meteorology and Water Management<br>Institute of Oceanology (PAS)<br>Maritime Institute<br>National Marine Fisheries Research Institute<br>Polish Geological Institute | Consolidation of scientific, organizational and financial capacities of consortium members, to conduct large research projects in the field of marine research, exploration and exploitation of marine resources, protection and sustainable development of marine environment and the dissemination of knowledge about the sea. |
| POMCERT | Gdańsk University of Technology<br>Medical University of Gdańsk<br>University of Gdańsk | Integration of specialists in the broadly-understood environmental sciences and technology and environmental engineering. Developing joint research programs. |

*Source: own elaboration based on: Maritime Institute (2014) and information from cooperatives web sites.*

Scientific collaboration within the Polish offshore wind innovation system is relatively high. According to the data from Web of Science database, the average number of authors per publication is 3.7, the share of co-authored publications is 80%, while the share of internationally co-authored papers is 42%. In similar analysis for Denmark, Germany, the Netherlands and the United Kingdom for 1990-2010, these numbers amounted to 1.8, 46% and 17% respectively. An especially important issue for offshore wind technology deployment in Poland is the well-developed international collaboration, as there is still a great need for knowledge absorption in that area. However, an analysis of the publications also showed some deficiencies in terms of cooperation between scientists and the business sector, since there were only 4 publications identified with a company representative as a co-author.

There are a few formalised knowledge cooperatives, which may be important for future offshore wind deployment in Poland (table 4). PolMar and POMCERT are consortia of research centres, which concentrate more generally on research in areas related to maritime issues, while MORCEKO's (the Maritime Centre for Eco-Energy and Eco-Systems) activities are dedicated specifically to offshore wind. The main area of interest of scientists engaged in the latter initiative are support structures for offshore wind turbines (i.e. the consortium has realised a research project on the technical, geological and environmental aspects of the optimal choice of the type of support structure for wind turbine in Polish maritime areas, financed by the National Centre for Research and Development).

## 1.3. Institutions

In 2015, the share of energy from renewable sources in the gross final consumption of energy in Poland reached 11.8% (Eurostat 2017). The Polish obligation according to the EU Directive on national renewable energy targets, has been set to 15% by 2020, and even 15.85% according to the National Action Plan. The probability of this being achieved is assessed as rather low (Schnell 2016, Janeiro and Resch 2017). Assuming that the current conditions for RES deployment (i.e. support policies are in place and have been announced for the period 2017–2020) will continue, the share of renewables in the final energy consumption is forecasted to range between 10.0% and 13.8% in 2020 (Janeiro and Resch 2017). However, it is worth noting that Poland made a significant progress in RES deployment since joining the EU in 2004. The installed capacity of renewable energy sources has increased from 1.2 GW in 2005 to 8.2 GW in 2016 (Energy Regulatory Office 2017).

The energy sector in Poland is struggling with a high level of uncertainty about the energy policy goals, legal framework and system of support. The key document for the sector is the "State energy policy", which contains an assessment of the implementation of the previous document, and lays down a forecast for a period not shorter than 20 years. The document should be adopted every four years. Despite this, the currently valid "State energy policy up to 2030" is dated 2009. The stakeholders are still waiting for the final version of a new strategy, namely the "State energy policy up to 2050", whose proposals have been changed several times. It is also the key issue for offshore wind, since the current government's position toward this technology deployment in Poland remains unknown. The strategy up to 2030 assumed some offshore wind deployment, however, the government ruling since the election in 2015 seems to be less favourable for RES. The high uncertainty level and the lack of political agreement over the desirable direction for the development of the Polish energy system is indicated as an important problem for the whole sector, and is crucial also for offshore wind (Rosicki 2015, Antosiewicz et al. 2016).

In 2016, after years of public discussions and several proposals on the optimal support scheme for RE generation, Poland replaced the system based on certificates of origin (valid since 2005) with an auction system. New regulations introduced 7 categories ('baskets') of installations, under which investors are competing for support.

The categories refer to several criteria, i.e. the installed electrical capacity factor, volume of $CO_2$ emissions, legal and organizational form of business activity, and the natural resources used to produce energy (Act on RES 2016, Janicka et al. 2017). There is no strict technological division, so different technologies can compete in most of the baskets. Also, none of the baskets is dedicated specifically for offshore wind. The most appropriate category for this technology is the basket for installations with a capacity higher than 3504 MWh/MW/year and $CO_2$ emissions lower than 100 kg/MWh. However, in this basket, offshore wind has to compete with other technologies such as hydro power plants.

Moreover, the requirements for participation in the auction include holding a building permit, which is particularly severe for offshore wind, as in this case, a significant part of the investment costs are incurred before the building permit is obtained (i.e. the environmental research). The difficulties in investment planning may also stem from the short timeframe between the announcement of the auctions and their occurrence. The auction allocations for a current year are announced by the end of November of the previous year, and there is no obligation to hold auctions for all the baskets each year. In the case of offshore wind, the installations that win an auction must begin producing electricity within 72 months of the closing date of the auction (Act on RES 2016).

From a more general perspective, it is worth noting that auctions do not seem to be a proper system to support technologies like offshore wind in Poland, at an early stage of their development (see section 2). In the event that there are no strictly defined technology-specific baskets, this system of support is preferable mainly for mature (the cheapest) technologies (del Rio and Linares 2014). On the one hand, in the categories currently defined in Poland, offshore wind has little chance to compete with other technologies based on price. On the other hand, a separate technological basket for offshore wind would be pointless due to the lack of sufficient competition.

Under the Act on Sea Areas of Poland and maritime administration, offshore wind farms are only allowed to be positioned in the exclusive economic zone, which covers an area of about 22,500 $km^2$. This means that the minimum distance of offshore wind farms from the coast amounts to around 22 km. In terms of the connection to the national power transmission system, offshore wind farm installations are treated in the same way as other technologies. Thus, investors are required to build the connection infrastructure at their own cost, both on land and sea (Maritime Institute 2016). Moreover, the northern segment of the national power grid is rather poorly developed. In the event of significant offshore wind deployment, it may be beneficial to introduce the concepts of marine network, enabling the collective connection of all Polish offshore wind farms to the national power grid, as well as the connection with power grids of other countries. There are already at least two existing concepts of this kind of network developed in Poland (Marine Power Grid and Baltic Rail) and at least one international initiative in progress (Baltic InteGrid) (Stryjecki et al. 2013, IEA 2016, Maritime Institute 2016).

## 2. Stage of development

Hekkert et al. (2011) distinguishes 5 phases of technology development in TIS analysis: pre-development, development, take-off, acceleration and stabilisation. So far, no wind farms or their prototypes have been built in the Polish sea areas, therefore the technology phase of development should be assessed as pre-development. As of June 2017, environmental permission has been granted for two offshore wind projects, both with a maximum capacity of 1.2 GW. The owner of these permissions is Polenergia. The next crucial step is obtaining building permits. In the first stage, the investor plans to develop 600 MW on each farm, and the expected year of starting energy production is 2022 and 2025 (Polenergia 2017a, Polenergia 2017b). Moreover, since 2011, governmental bodies have issued almost 40 location decisions for offshore wind farms. However, only 14 of them are still valid (as per June 2017) and only 9 of them have been paid by investors. Two connection agreements have also been signed – for 1.2 GW by Polenergia and 1.1 GW by PGE EO (FNEZ 2017).

Offshore wind technology in Poland is underdeveloped in terms of patent applications. There are only two patents recorded in Espacenet (European Patent Office database) with offshore wind as a keyword and Poland as the applicant country. Both refer to a method of embedding (foundation of) an offshore wind farm. One of the applicants is a business sector representative (Vistal Gdynia) and one is an individual. A similar analysis for Denmark gives 75 records in Espacenet database, for Germany – 325, and for the United Kingdom – 96.

Although offshore wind technology in Poland is in the pre-development phase, it is already in the acceleration phase worldwide. The global installed capacity of offshore wind amounted to 12.1 GW by the end of 2015, while in 2006 it was less than 1 GW. It is expected that the total offshore wind capacity will exceed 40 GW by 2020 and 84 GW by 2024 (WEC 2016). The technological progress due to learning by doing effect and innovation is driving costs of the technology down. The levelized cost of electricity (LCOE) from offshore wind averaged about USD 240/MWh in 2001, and had fallen to approximately USD 170/MWh by the end of 2015. A further decline of the LCOE is expected in the future, due to both technological progress and non-technological factors (site choices, market scale, competition, reduction in financial risk), to USD 95/MWh by 2030 and USD 74/MWh by 2045 (IRENA 2016).

So far, most of the installations are located in European countries, which is advantageous from the Polish perspective, as it gives great possibilities for technology absorption. The market, including the wide range of suppliers, is well-developed especially in Denmark (1.3 GW capacity installed by the end of 2015), Germany (3.1 GW) and the United Kingdom (5.1 GW), which together accounted for almost 80% of global capacity installed by the end of 2015 (WEC 2016). Installations in the North Sea are most widespread – they accounted for 69% of the capacity installed in Europe in 2015, whereas the Baltic Sea accounted for only 13%. The rapid growth of European market will still continue – by 2020 the total installed capacity will more than double in comparison to the 2015 level. The North Sea is also considered to remain the main region for offshore deployment in Europe in the future (EWEA 2016, WindEurope 2017). However, Poland is recognised as playing a pivotal role in kick-starting the offshore market on the Baltic Sea (Kruger 2016).

Table 5. Potential sea space for offshore wind deployment in Poland

| Localisation rating | Distance to land | Depth of seabed | Potential area | Share in potential area | Potential power generation | Dedicated phase of technology deployment |
|---|---|---|---|---|---|---|
| Optimal | <40 km | <30 m | 260 $km^2$ | 20% | 1560 MW | early stage |
| Moderate | <50 km | <40 m | 640 $km^2$ | 50% | 3840 MW | middle stage |
| Rather poor | >50 km | >30 m | 380 $km^2$ | 30% | 2280 MW | late stage |

*Source: own elaboration based on: Stryjecki et al. (2013).*

The long coastal line, as well as good wind and seabed conditions, translate into high assessments of the potential of the Polish sea area in the context of the development of offshore wind technology. Due to legal regulations and environmental limitations (large fragments of Polish sea waters are included in the NATURA 2000 network), 3,600 $km^2$ of Polish sea space is deemed to be available for building offshore wind farms. Given the economic issues resulting from the depth of the seabed and distance from land (at current global technological capabilities), the area is limited to about 2,000 $km^2$. On the assumption of 6 $MW/km^2$, that turns into a theoretical potential of 12 GW. However, also taking into account possible conflicts in using the sea area (i.e. concerning localisation and environmental permits) and the geological uncertainty, the estimated area suitable for offshore wind farms amounts to 1,300 $km^2$, 20% of which is assessed as optimal, 50% as moderate and 30% as rather poor (table 5). On the assumption of 6 $MW/km^2$, the estimated sea space translates into 7.7 GW potential power generation (Stryjecki et al. 2013). However, that potential may be increased due to future technological progress and innovation (IRENA 2016).

The analysis of the wind strength in Polish sea space potentially dedicated for offshore wind shows, that the conditions for placing offshore wind farms are good. The average wind speed amounts to 9-10 m/s (depending on height of measurement), and the efficiency of energy production should exceed 40% (up to 54% in the best-case scenario). By comparison, the average wind speed on the North Sea is between 8.5 and 11.5 m/s, while the efficiency indicator amounts to approximately 41% (Stryjecki 2013; Maritime Institute 2016). Moreover, geological studies show that the soil conditions for building maritime structures in the Baltic Sea are mainly good or sufficient, which suggests that seabed characteristics should not be an important limitation for offshore wind farms foundations (Coufal and Kaszubowski 2008, 2014, Maritime Institute 2016).

## Summary

In the coming decades, the energy sector in Poland will require significant investment to cover its growing energy needs. It is necessary not only to renovate the outdated existing coal plants, but also make greater use of other energy sources. Offshore wind farms seem to be one of the most suitable options to consider, as Poland has good access to the Baltic Sea and the technology is experiencing rapid growth worldwide.

The aim of the study is to evaluate the innovation system for offshore wind technology in Poland, based on the Technology Innovation System concept. This paper is the first part of the analysis, covering the structural analysis and the technology stage of development analysis. The issues presented in this paper will be the basis for the second part of the TIS procedure, which includes functional analysis, identifying system failures and formulating policy implications.

Although there are not any offshore wind farms located in Poland yet, Polish industry has broad experience in implementing offshore wind projects (mainly in the North Sea and the Baltic Sea) and can cover a large part of the offshore wind farm investment. The industry is well-developed especially in the manufacture of support structures (foundations, towers, substations). Also, the large presence of companies in the ship and boat construction and maintenance industry is a strength, as offshore wind farm projects require specialised vessels. However, the value chain is rather underdeveloped in terms of nacelle, rotor and blade production, and these elements account for a large part of the investment costs.

Knowledge area cannot be considered a strong point of the innovation system, however. The number of scientific publications and patents in offshore wind is low in comparison to other countries. The directions of research correlate to the industry specialisations – the most common subjects of research are the construction of support structures and their resistance to specific conditions.

The permissions and consent for the deployment of offshore wind installations is well-defined in Polish law. However, the whole procedure is dispersed between many different public institutions. Existing educational organisations should provide the appropriate supply of qualifications for offshore wind deployment. Likewise, the support organisations should ensure sufficient services – mainly financial and lobbying – if needed.

There are some networks which represent the interests of offshore wind actors externally, as well as cluster forms of cooperation. Scientific collaboration within the Polish offshore wind innovation system is also high. However, the scientific connections between knowledge and industry representatives (e.g. joint publications or patent applications) are somewhat rare.

The energy sector in Poland is struggling with a high level of uncertainty about energy policy goals, the legal framework and system of support. The institutional (political) uncertainty is also crucial for offshore wind. The auction system for RE does not seem to be a proper system of support for technologies in the early stage of development. On the other hand, the emerging concepts of marine network, enabling the collective connection of all Polish offshore wind farms to the national power grid, as well as connecting with the power grids of other countries, may potentially be a perspective issue.

Offshore wind technology in Poland is in the pre-development phase. So far, no wind farms or prototypes thereof have been built in the Polish sea areas. However, the technology is gaining momentum in neighbouring countries, especially in Denmark, Germany, and the United Kingdom. That is advantageous from the Polish perspective, as it offers great opportunities for technology absorption. Poland is especially important for the technology acceleration on the Baltic Sea, as so far, this area has remained weakly explored in terms of offshore wind deployment. The potential power generation in the Polish sea space is estimated at almost 8 GW (based on cautious assumptions). The wind and soil conditions are assessed as no worse than in the North Sea, where the technology is experiencing rapid growth.

## References

Act on Renewable Energy Sources (2015). [Online] Available at: http://isap.sejm.gov.pl/Download;jsessionid=5B95EEF84BCD94E424CCDD1355A1C36A?id=WDU20150000478&type=3 [Accessed: 26 May 2017].

Antosiewicz, M., Sawulski, J., Szpor., A., Witajewski-Baltvilks, J. (2016). Poland: Coal and Renewable Energy Sources. Deliverable for the Horizon2020 project „TRANSrisk".

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, vol. 37, issue 3, pp. 407–429.

del Rio, P., Linares, P. (2014). Back to the future? Rethinking auctions for renewable electricity support. Renewable and Sustainable Energy Reviews, 35(2014), pp. 42–56.

Energy Regulatory Office (2017). Moc zainstalowana. [Online] Available at: https://www.ure.gov.pl/pl/rynki-energii/energia-elektryczna/odnawialne-zrodla-ener/potencjal-krajowy-oze/5753,Moc-zainstalowana-MW.html [Accessed 31th May 2017].

Eurostat (2017). Renewable energy in the EU. Eurostat News Release, 43/2017.

EWEA (2016). The European offshore wind industry – key trends and statistics 2015. European Wind Energy Association.

FNEZ (2017). Komentarz Fundacji na rzecz Energetyki Zrównoważonej do stanowiska Ministra Energii w odpowiedzi na interpelację poselską. Foundation for Sustainable Energy. [Online] Available at: http://www.fnez.pl/fnez,article,0,5,963,komentarze-fundacji-na-rzecz-energetyki-zrownowazonej-do-stanowiska-ministra-energii-w-odpowiedzi-na-interpelacje-poselska.html [Accessed: 11th July 2017].

GUS (2016). Statistical yearbook of maritime economy. Central Statistical Office of Poland.

Hekkert, M., Suurs, R., Negro, S., Kuhlmann, S., Smits, R. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change, vol. 74, issue 4, pp. 413–432.

Hekkert, M., Negro, S., Heimeriks, G., Harmsen, R. (2011). Technological Innovation System Analysis. A manual for analyst. Utrecht University.

IEA (2016). Introduction to the Baltic InteGrid Project. Industrial Electrical Engineering and Automation. [Online] Available at: http://www.iea.lth.se/research/projects/17_BalticIntegrid.pdf [Accessed 1st June 2017].

IRENA (2016). Innovation Outlook: Offshore Wind. International Renewable Energy Agency.

Janeiro, L., Resch, G. (2017). 2020 Renewable Energy Target Realisation Forecast for Poland. Final Report. Ecofys.

Janicka, A., Puacz, P., Zys, B. (2017). New support scheme for renewable energy sources in Poland – results of first auction published. Clifford Chance Briefing Note.

KPRM (2015). Model optymalnego miksu energetycznego dla Polski do roku 2060. The Chancellery of the Prime Minister.

Kaszubowski, L. J., Coufal R. (2008). Preliminary engineering-geological division of the Baltic Sea bottom (Polish part) in the light of geological maps of the Baltic and seismoacoustic research. 11th Baltic Geotechnical Conference.

Kaszubowski, L. J., Coufal R. (2014). Wytrzymałość na ścinanie i ściskanie gruntów polskiego Bałtyku na głębokości 10 i 20 m poniżej dna morskiego, Przegląd Geologiczny, vol. 62, no. 10/2.

Kruger, K. (2016). The Baltic Sea – the next offshore wind market?. Bloomberg New Energy Finance, 19 December.

Longa, F. (2015). Global RES-E developments and technological learning. Towards 2030, Issue Paper No. 12.

Luo, L., Lacal-Arantegui, R., Wieczorek, A.J., Negro, S.O., Harmsen, R., Heimeriks, G.J., Hekkert, M.P. (2012). A Systemic Assessment of the European Offshore Wind Innovation. JRC Scientific and Policy Reports.

Maritime Institute (2016). Study of Conditions of Spatial Development of Polish Sea Areas.

NIK (2015). Zapewnienie mocy wytwórczych w elektroenergetyce konwencjonalnej. Supreme Audit Office.

Polenergia (2017a). Morska farma wiatrowa Polenergia Bałtyk II. [Online] Available at: http://www.baltyk2.pl/projekt/ [Accessed: 11th July 2017].

Polenergia (2017b). Morska farma wiatrowa Polenergia Bałtyk III. [Online] Available at: http://www.baltyk3.pl/projekt/ [Accessed: 11th July 2017].

PSE (2015). Plan rozwoju w zakresie zaspokojenia obecnego i przyszłego zapotrzebowania na energię elektryczną na lata 2016–2025. Polskie Sieci Elektroenergetyczne.

PSE (2016). Prognoza pokrycia zapotrzebowania szczytowego na moc w latach 2016–2035. Polskie Sieci Elektroenergetyczne.

Purta, M., Marciniak, T., Rozenbaum, K. (2016). Developing offshore wind power in Poland. Outlook and assessment of local economic impact. McKinsey&Company.

Rosicki, R. (2015). The energy policy of Poland up to 2050 – a critical analysis. Środkowoeuropejskie Studia Polityczne, No. 1, pp. 51–62.

Schnell, Ch. (2016). Achievment of the RES target for 2020. Analysis of the current situation and a forecast. SOLIVAN.

Stryjecki, M., Wójcik, M., Sokołowski, J., Biegaj, J., Bojanowska, B., Gabryś, A. (2013). Program rozwoju morskiej energetyki i przemysłu morskiego w Polsce. Foundation for Sustainable Energy, EY.

WEC (2016). World Energy Resources – Wind 2016. World Energy Council.

WindEurope (2017). The European offshore wind industry. Key trends and statistics 2016.

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