

Impact of key factors on expected development of onshore wind energy sector in Poland and development scenarios

Izabela Wielewska³, Karol Tucki^{1,*}, Anna Bącznyk², and Magda Trzaska¹

¹Warsaw University of Life Sciences, Department of Production Organization and Engineering, Nowoursynowska Street 164, 02-787 Warsaw, Poland

²Warsaw University of Life Sciences, Department of Hydraulic Engineering, Nowoursynowska Street 159, 02-776 Warsaw, Poland

³UTP University of Science and Technology in Bydgoszcz, Department of Agronomy, Fordońska Street 430, 85-790 Bydgoszcz, Poland

Abstract. The aim of the paper was to analyse the wind power market in Poland by reviewing the factors that shape and influence its current state and the possible development prospects. The paper was focused on legislative, environmental, manufacturing, sociocultural and economic factors. Barriers to the development of onshore wind power market and the expected development of wind energy in Poland in the years 2017-2020 were identified and measured based on a survey. The review of individual factors and the study performed present that legislative barriers and the introduction of the 'distance act' are factors with the biggest influence on the current stagnation of onshore wind energy sector. A review of the recommendations concerning the distance (from protected areas and housing) required to build wind farms set forth in literature shows that Poland is the only country with such harsh restrictions. With its good environmental conditions and technical capacities, Poland can become a European leader in the production of energy from wind. The only barrier is the legislative environment and political instability on the national level. Without improvements in this sector, there is no chance for new wind projects, as these factors are crucial for development of this type of energy.

1 Introduction

In the times of gradually diminishing resources of fossil fuels and a growing energy demand, renewable power seems to be a lifebelt for the global economy and the natural environment. Pursuant to directive of the European Parliament and of the Council no. 2009/28/CE [1-4], Poland was obligated to reach at least a 15% share of energy from renewable sources in gross final consumption of energy. Nevertheless, hard bituminous coal and lignite remain the main sources of energy in Poland, with the respective shares of 50% and 31.4% in the overall production of energy [5].

Wind energy is an important factor for Poland in the process of pursuing the EU's objective. Onshore wind power allows to obtain 5824 MW (69%) of the total of 8538 MW (as at 30.09.2017) [6] of installed capacity of RES. The economically and environmentally justified share of onshore wind power in the Polish energy market is estimated to amount to 10 GW, compared to today's 5.8 GW of installed capacity of onshore wind energy.

The onshore wind energy sector, developing dynamically since 2001, is now in stagnation caused by the implementation of new and amendments of the currently applicable legal deeds. The biggest of the barriers encountered so far is the Act of 20 May 2016 on investments in wind power stations, commonly known as

the 'distance act'. The provisions that are especially important for the sectors apply to:

- 1) Restrictions concerning distance between wind turbines and occupied buildings/nature conservation areas,
- 2) Increase of the real property tax base,
- 3) Identification of wind farm location exclusively based on a local zoning plan.

The tragic situation of wind power is further enhanced by the current condition of the market of green certificates, i.e. negotiable certificates of origin confirming that electrical energy has been produced from renewable energy sources. The scale of oversupply estimated by PSEW (Polish Wind Energy Association) is the largest ever, with the price of green certificates being drastically low [7,8]. Trying to minimise or mitigate the problem, the Polish government introduced new amendments to the act on renewable sources of energy. The crucial changes in the renewed Act signed on 14 April 2017 apply to determination of the substitution fee, which now depends on market prices of certificates of origin [9]. Originally established at the level of PLN 300.03, it is now calculated based on 125% of the annual average weighted price of property rights in the previous calendar year. The act entered into force without prior consultations, and met with fierce criticism of representatives of the sector [10-15]. All these actions make the achievement of the objective set to Poland

* Corresponding author: karol_tucki@sggw.pl

impossible (a 15% share of energy from renewable sources in gross final consumption of energy) [16-20].

Poland has good wind conditions [21,22], but in order to be able to use them, it needs to create sustainable conditions for its development [23-25], in particular, by introducing stable legislation which is a standard in other countries [26-28].

The aim of the article is to present the current status of wind energy, indicate the significance of key factors for the prospects of its development and choose the most plausible development scenario.

2 Methodology

Two research techniques were used to achieve the objectives, i.e.: a survey conducted in February 2017 among employees directly employed in the wind energy field; and analysis, as part of which individual properties and incidents were identified and their relationship with the whole were described. Additionally, the research encompassed an overview of available scientific literature including legal deeds, technical articles, reports and studies. The survey, entitled "Analysis of development of wind energy in Poland", was sent to companies rendering services or delivering products for the purpose of wind energy production. 30 out of the 100 surveys sent were collected. The surveys were filled in by companies specialising in:

- environmental consultancy,
- noise measurements and monitoring for the existent and planned wind farms,
- electric power generation from renewable energy sources and provision of regulatory system services (PGE Energia Odnawialna S.A., a Polish state power company).

Relying on experts' knowledge and the literature available, 23 factors were distinguished with potential significance for the slowdown of wind energy in Poland [29-37]. The factors were divided into 5 groups (table 1) and the division was used as a basis for the Ishikawa diagram [38], with the aim to facilitate expert assessment of individual criteria. The groups of factors listed in table 1 were used as 2nd order objectives. Acting in accordance with the Ishikawa diagram principle, it was assumed that the impact of all groups of factors equals 100% (same as the impact of individual factors within the group). This principle was applied by the experts, who performed their assessment by breaking the 100% down into individual factors and showing their significance. The experts assessed the significance of individual factor groups and individual factors in the group [38]. Then, the consensus of expert opinions was analysed [38]. For this purpose, the concordance coefficient θ was calculated, based on formula (1):

$$\Theta = \frac{12 S}{N_E^2 (b^3 - b)} \quad (1)$$

where:

S - sum of squares of factual deviations of rank values,
 N_E - number of experts, b - number of factors assessed.

To find out whether the consensus of expert opinions was not accidental, the χ^2 criterion was used, expressed by formula (2):

$$\chi^2 = \frac{S}{\frac{1}{12} N_E b(b+1) - \frac{1}{b-1} \sum_{i=1}^{N_E} T_i} \quad (2)$$

where: T_i - similar rank coefficient.

If the χ^2 value was higher than the tabular value χ^{2tab} , and the concordance coefficient differed significantly from zero, the consensus of expert opinions was considered not accidental. Additionally, consensus of opinions was also assessed with the use of the coefficient of variation V , calculated based on formula (3):

$$V_j = \frac{g_j}{m_j} 100\% \quad (2)$$

where: g_j - standard deviation, m_j - arithmetic mean of expert assessments.

Another method used in the study was the scenario method. The scenarios selected were supposed to facilitate expert assessment of the likelihood of application of individual wind power development prospects for the years 2017-2020. The respondents' task was to break down 100% of the 1st order elements into 2nd order factors with potential influence on the emergence and significance of 1st order barriers. The scenarios were as follows:

- significant cuts in all investments,
- increased number of turbines with less dynamic increase in installed capacities than before, despite the restrictions introduced by the distance act,
- increased number of household installations and offshore wind farms and reduced number of onshore wind farms with tall towers.

Table 1. 1st and 2nd order barriers which may potentially favour the freezing of wind power development in Poland.

Parameter symbol	Barriers
C21	Legal (legislative) barriers
C211	Restrictions introduced by legal regulations concerning the conditions, location and construction of wind power stations (including, among others, minimum distance between the wind power station and residential properties/combined use buildings/protected nature/ pilot forest complexes)
C212	Restrictions imposed by the local zoning plan; weak laws concerning spatial planning
C213	Stability of state and local government
C214	Lack of political motivation to support wind power; i.e. complicated procedures and long waiting time for permits required in order to build wind turbines, inadequate attention paid in the Polish power strategy and development concepts to the development of wind power
C215	Risks connected with the implementation of bidding system

Table 1: continuation.

C22	Economic barriers
C221	Relatively high costs of production of wind energy when compared to conventional energy
C222	High investment costs of implementation of new technologies that need to be incurred at the start
C223	Economic standing of the country (gross domestic product, inflation, unemployment rate, etc.)
C224	Interest rates and availability of credit facilities
C225	Inadequate possibilities to obtain subsidies from EU green funds
C23	Manufacturing and technological barriers
C231	Inadequately developed power grid for power reception from wind devices
C232	Obsolete grid infrastructure
C233	Difficulties pertaining to the planning and prediction of available capacity and volumes of power produced from wind power stations, resulting from dependency of the parameters on meteorological conditions
C234	Necessity to store some of the power generated at wind power stations as back-up power
C24	Sociocultural barriers
C241	Conflicts with ecological circles. No methods to avoid conflicts with ecological circles
C242	Ecological awareness of the society: wind power is perceived negatively - conflicts with local communities
C243	No interest in employment in wind power sectors
C244	Inadequate education on wind power at schools
C25	Environmental barriers
C251	Adverse wind conditions in areas available for the execution of wind energy projects
C252	Environmental risks related to wind power (farms' impact on birds and bats)
C253	Hazards to anthropological environment posed by wind power (noise emission, flicker effect, shadow cast by turbines, magnetic field emission, impact on value of the nearby properties)
C254	Limited area available to install wind power stations due to the existence of National Parks, Nature Reserves, Nature 2000 Areas, Ramsar (wetland) Areas, eco-corridors, Landscape Parks, Protected Landscape Areas, Natural and Landscape Complexes, ecological sites and natural monuments
C255	Negative perception of the impact of wind power stations on landscape

3 Results

Before the survey results were presented, the Act of 20 May 2016 on investments in wind power stations had been thoroughly analysed, as it has for some time had major impact on the condition of the sector. The document sets forth conditions and requirements of/for location of wind power stations within the vicinity of

existent or planned residential premises. The Act introduced major restrictions, in particular, when it comes to minimum distance between wind turbines and occupied buildings and nature conservation areas, and the possibility to choose investment site exclusively based on local zoning plans (LZP). Poland is the only European state with such restrictive distance requirements [39-41]. Figure 1 and table 1 show selected EU states and their regulations concerning the restrictions and recommendations pertaining to distance between wind power stations and residential buildings.

Because of the restrictions introduced, there are currently no investors interested in the performance of new wind farm projects. In addition, all projects which are currently at the procedural stage needed to obtain a building permit have been withheld, which means that huge amounts of money spent on agreements with owners of the lands leased, tests carried out etc., have been lost. The already erected farms and previous investors are afraid that they may go bankrupt because of the raised taxes or decreasing prices of certificates of origin.



Fig. 1. Minimum distances of wind power stations from residential buildings in selected countries; blue: recommendations, red - requirements [author's own work based on [41].

Table 2. Minimum distances of wind power stations from residential buildings in selected countries [41].

Country	Distance
Poland	Distance equal to or bigger than ten times the height of the wind power plant measured from the ground level to the highest point of the structure, including technical elements, such as rotor and blades
Denmark	Distance from buildings must be equal to or bigger than four times the height of the wind power station ; Distance from major roads and railroad rails must at least be equal to the overall height of the wind turbine. Additionally, the distance also depends on the noise level.
Germany	Recommendations: <ul style="list-style-type: none"> Saara: 550-850 m from residential properties, Thuringia: 1000 m from residential properties and recreational or historical sites,

Table 2: continuation.

Germany	<ul style="list-style-type: none"> Rhineland-Palatinate: 400 m from individual detached houses, 1000 m from residential areas, Bremen: 200-500 m from residential properties, Schleswig-Holstein: 300 m from areas with 1 to 4 residential properties, 500 m from rural areas, 1000 m from cities and holiday resorts. <p>Legal requirements:</p> <ul style="list-style-type: none"> Lower Saxony/Saxony: 1000 m from residential properties Hamburg: 300 m from individual residential properties, 500 m from residential areas, 50-100 m from the nearest roads, railways, telecom networks, transformers, real estate boundaries, 200-500 m from forests, wetlands, stand off areas of birds and bats and other protected areas.
England:	No recommendations or legal requirements.
Scotland:	Recommendations: Area within 2 km from cities and villages; the assessment is performed <i>in concreto</i> depending on geographical conditions and visual factors, which is why the distance is usually smaller (500-1000 m), but can also be extended. Wind power stations must not be built in the vicinity of national parks and landscape parks.
Wales	Recommendations: <ul style="list-style-type: none"> 500 m from houses – the distance may vary, depending on background noise measurements and other neighbouring noise-generating investments.
Ireland	Recommendations: <ul style="list-style-type: none"> 500 m
Northern Ireland	Lack of statutory regulations concerning the distance. Recommendations: <ul style="list-style-type: none"> Distance corresponding to the turbine height from base to the tip of the blade + 10 %
Italy	No generally applicable regulations concerning the distance.
Spain	Distance corresponding to 500 m from residential properties, 120 m from roads and power grids.
Portugal	Recommendations: <ul style="list-style-type: none"> 200 m from residential properties
Sweden	Recommendations: <ul style="list-style-type: none"> 400-1000 m
The Netherlands	Recommendations: <ul style="list-style-type: none"> four times the height of the wind turbine [measured to the hub (tower)] from the neighbouring buildings
France	500 m from residential properties

The survey was prepared and presented to respondents 9 months after the effective date of the ‘distance act’.

Respondents were of the opinion that the biggest negative impact on the development of wind power in Poland is exerted by legal factors (fig. 2). More than 1/2

of all respondents (62%), irrespective of seniority and work placement, indicated this factor as the most important [42]. Nearly 1/5 of respondents were of the opinion that the environmental factor plays major role in the development of wind power sector, with further 11% saying that sociocultural barriers may be significant for the development of wind energy. Only 3% of respondents considered manufacturing and technological barriers to hinder the growth of wind energy share in the country’s power mix.

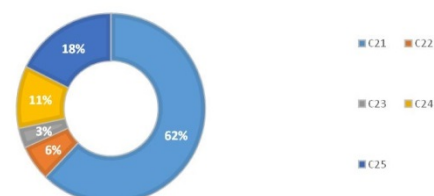


Fig. 2. Significance of 1st order barriers for the development of wind power in Poland.

Respondents indicated that among all legislative barriers, it was the introduction of the distance act that had the biggest impact on the hindered development of all wind projects. Significance of this factor was assessed as 58%. The runner-up to this factor, responsible (in the respondents ‘opinion) for the poor condition of the market was (tab. 3) the lack of motivation to support wind power among legislators and complicated administrative procedures, including long waiting time for permits required in order to build wind turbines (18%), with successive places taken by: restrictions pertaining to poor coverage of the territory of Poland by local zoning plans (11%), stability of state and local government (7%) and risks connected with the implementation of bidding system (6%).

Table 3. Share of individual barriers in the development of Polish wind power.

Parameter symbol	Share, %	Coefficient of variability
C21		
C211	58	1.09
C212	11	
C213	7	
C214	18	
C215	6	
C22		
C221	31	1.55
C222	36	
C223	12	
C224	10	
C225	11	
C23		
C231	44	0.59
C232	29	
C233	14	
C234	13	
C24		
C241	36	0.75
C242	45	
C243	5	

Table 3: continuation.

C244	14	0.47
C25		
C251	10	
C252	24	
C253	15	
C254	35	
C255	18	

The second most important hazard to onshore wind power indicated by respondents was the environmental factor. The average percentage rate allocated to environmental barriers by respondents equalled 18. Among the environmental factors, the one related to the limited area available to carry out the investment, due to the presence of various nature conservation forms within a substantial portion of the country's area, was considered the most significant (35%). This restriction is closely connected with one of the legal factors, i.e. the requirement that the distance between wind power stations and residential buildings (or nature conservation areas) must not be smaller than 10 times the turbine length. 24% of respondents also listed the negative impact on birds and bats among the negative environmental effects of wind power stations. Another 18% were of the opinion that negative perception of the impact of wind power stations on landscape was an important barrier, while further 15% indicated the hazard to anthropological environment (noise emission, flicker effect, shadow cast by turbines, magnetic field emission, impact on value of the nearby properties). Only 10% was attributed by respondents to adverse wind conditions in areas available for the execution of wind energy projects. Sociocultural factors, among which are conflicts with local communities and ecological circles, received 11%, with further 6% being allocated to economic factors. Among the most significant hazards in 'economic' group, respondents enumerated high initial capital expenditures and relatively high costs of production of wind energy when compared to traditional energy.

In the opinion of respondents, the least important factors with the potentially inhibiting impact on wind energy in Poland were manufacturing and technological factors, which received 3% of votes. In this field, respondents pointed mainly to the inadequately developed power grid for power reception from wind devices.

Introduction of the act of 20 May 2016 on investments in wind power stations had a substantial limiting effect on the development of wind energy in Poland.

Out of the three scenarios proposed, the majority of respondents chose scenario 1, which stipulated significant cuts in investments in wind power. The likelihood that this option will be selected was assessed as 82% (tab. 4). 14% was attributed to scenario 3, assuming growth in the number of household systems and 5% to scenario 2, according to which wind power will keep thriving in Poland despite the distance act, although less dynamically than before. The coefficients analysed show that the consensus of expert opinions is not accidental.

Table 4. Scenarios of wind power development in Poland.

Scenario		Likelihood, %	Coefficient of variability
1	Between 2017 and 2020, there will be a significant cut down in investments in wind power, leading to a material decrease in the number of wind turbines, especially those with high towers.	80	0.55
2	In the years 2017-2020, despite the restrictions imposed by the act, the wind power sector will develop, which is going to translate into a bigger number of turbines, even if the development will not be as dynamic as it used to be.	3.33	3.55
3	In the years 2017-2020, despite restrictions imposed by the distance act, the number of wind turbines will grow, but their structure will change, i.e. turbines with low towers will outdistance turbines with tall towers and the number of offshore installations will grow.	16.67	2.00
Concordance coefficient		0.168	
Criterion χ^2		10.067	

4 Conclusions

Analysis of the wind power market in Poland enabled assessment of the as-is state, the environmental and technical potential and the most plausible development scenario for the sector. Upon a review of factors significant for the past, presence and future of wind energy in Poland, their relevance for the shaping of the wind energy market was established. The following conclusions have been drawn from the study:

1) The review of legislative factors and an own study pointed to legislative barriers, including introduction of the distance act, as the most significant factor responsible for the current stagnation of the onshore wind energy sector. Available readings concerning recommendations and permitted distances between wind farms and residential buildings/nature conservation forms for different countries, show Poland as the only country with such harsh restrictions.

2) In the opinion of respondents, the second most important barriers hindering and preventing increase in the installed capacity of onshore wind power sector are environmental barriers, among which is a factor correlating with the distance act, i.e. limited space available for the installation of wind power stations due to the existence of nature conservation areas.

3) The analysis of sociocultural factors revealed benefits from the development of wind energy, mainly in terms of employment and additional funds for

communes/municipalities and the economy. In this phase, we found out that offshore wind energy is perceived positively by the local community and that there are no conflicts with fishing environments.

4) The share of individual manufacturing and technological factors demonstrated that barriers such as obsolete grid infrastructure and inadequately developed power grid can be eliminated by projects by PSE (Polish Power Grids) concerning expansion of the national transmission system in terms of power evacuation, connection of new energy generating sources and reconstruction of the central point.

5) Analysis of economic factors confirmed information about the dropping investment and operating costs due to expansion of the power market and technological progress.

6) With reference to the biggest barrier faced by the onshore wind energy sector, the most plausible prospect for the years 2017-2020 is a significant drop in the number of wind turbines.

Analysis of the resources available and benefits of wind power showed that Poland has good environmental conditions and technical capacities and has the potential to become a European leader in wind power production. The only barrier here is the regulatory environment and political instability on the national level. Without improvements to this end, there is no chance for new wind projects to be implemented, as it is these very factors that make foundations for the development of wind energy.

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