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DIAGNOSIS OF THE CURRENT SITUATION AND POTENTIAL OF THE DOMESTIC SUPPLY CHAIN FOR ONSHORE WIND ENERGY IN POLAND

AND RECOMMENDATIONS FOR THE OPTIMIZATION OF ITS DEVELOPMENT

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2021

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WARSAW, NOVEMBER 2021

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50-97 thousand

New jobs

PLN 80 billion

Potential revenue stream for products and services in the supply chain

PLN 70-133 billion

Total estimated cumulative GDP growth

PLN 490-935 milion

Additional local governments inflows from real estate taxes

ONSHORE WIND FARMS DEVELOPMENT POTENTIAL UNTIL 2030

(DEPENDING ON THE SCENARIO)

LOCAL CONTENT

IN SUPPLY CHAIN FOR ONSHORE WIND FARMS BY 2030

Dictionary of abbreviations and expressions

ARE	Agencja Rynku Energii S.A.
Capex	investment expenditure on product development or system implementation - but only in the part where the capital is allocated to maintaining the company's current ability to generate income (capital expenditures)
CNC	computerized numerical control
CHP	combined heat and power plant
EENS	expected volume of energy not supplied as a result of power shortages in the period under consideration (Expected Energy Not Supplied)
PP	power station(s) / plant(s)
EGD	European Green Deal
GW	gigawatt
GWh	gigawatt-hour
IJ	Jagiellonian Institute (Pol. abbrev. IJ)
IRENA	the International Renewable Energy Agency
CDGU	centrally dispatched generating unit
EC	European Commission
NPS	National Power System
NRP	National Recovery Plan
LCA	life cycle assessment
LCOE	the average discounted cost of electricity generation for a given technology, calculated for the entire period of economic use of this technology, taking into account investment (capex) and operating costs (opex). LCOE enables a comparison between different technologies (e.g. onshore wind, offshore wind, photovoltaics, gas, nuclear) (levelized cost of electricity)
OnWF	onshore wind farms
Local content	use of domestic assets to produce the product in question at its destination
OffWF	offshore wind farms
MW	megawatt
MWh	megawatt-hour
Offshore	energy based on OffWF
Onshore	energy based on OnWF
RES	renewable energy sources
PEP2040	Poland's Energy Policy until 2040, Annex to Resolution No. 22/2021 of the Council of Ministers of February 2nd, 2021.
PRSP2030	Development plan for meeting the current and future electricity demand for 2021-2030, Polskie Sieci Elektroenergetyczne, Konstancin-Jeziorna, 2020.
PV	photovoltaics
SCADA	monitoring and supervision system (Supervisory Control And Data Acquisition)
TOTEX	total capital expenditure and operating costs necessary for planning, designing, building, commissioning and operating, servicing for 25 years and decommissioning
TWh	terawatt-hour
EU	European Union
BC	lignite (brown coal)
HC	hard coal

1. Executive summary

The key challenge of the transformation of the power sector is the so-called local content, which essentially means developing and implementing solutions that allow for the retention of the largest possible amount of investment in the national economy, the development of the supply chain and export of Polish companies, as well as the creation of new jobs.

The development of onshore wind farms in Poland has a huge impact on GDP, the labor market and the situation of production plants. The implementation of projects of this type will increase the activity of Polish companies operating in the supply chain. It is estimated that it may also contribute to the creation of 51,000 to 97,000 new jobs.

The potential of the national contribution in the supply chain for onshore wind farms is currently estimated at 55-60%, with 75% being feasible in the next 10 years. Due to the dynamic development of onshore wind energy in Poland before 2016, there are many entities on the domestic market that supply components for the onshore market. The use of the full potential, i.e. 75% share in local content, depends to a large extent on the stable development of the market and support for new investments in Poland.

An additional factor positively influencing the possibilities of increasing the share of the Polish component is the planned development and potentially available financing of offshore wind energy (synergy effect). Forecasts for offshore wind energy from the PWEA and PTMEW (Polish Offshore Wind Energy Society) report, prepared at the turn of 2020 and 2021, indicate that the current share of domestic suppliers in supply chains is 20-25%. The development of offshore wind energy in Poland may affect the transformation and reconstruction of the shipbuilding and steel industry and become one of the engines of economic development after 2021, when funds will flow to Poland from the current financial perspective of the European Union and the National Reconstruction Plan.

In the period before the commissioning of the first offshore farms, onshore wind energy may provide an impulse for many key sectors of Polish industry, including steel, construction, foundry and many others in preparation for much higher tonnages and dimensions of these structures. The green light for the development of onshore energy is a message to the domestic industry and the service and installation industry to start investments in production infrastructure, new technologies, and staff that will allow the development of supply chains for both onshore and offshore wind energy. The portfolio of orders for products and services in the supply chain of onshore wind farms will amount to as much as PLN 80 billion by 2030. This entails the possibility of generating an average annual turnover of between PLN 6 and 9 billion.

Taking into account the current potential and development of Polish companies, with the possibility of achieving national contribution levels of up to 75%, the long-term level of new capacity per year, amounting to 1 GW, will not only allow for stable growth of RES, but also sustainable development and maintenance of the supply chain's potential. Depending on the scenario under analysis, the value of accumulated cash flows related to the development of onshore capacity in Poland is PLN 27.4-52.3 billion. This interval arises from realistic turnover levels of Polish enterprises (taking into account their current and future potential) in the supply chain. It depends on the level of new installed capacity and the level of participation of Polish enterprises in the supply chain. Taking into account the multiplier effect, the impact of enterprise development, innovation, labor market - total estimated cumulative GDP growth until 2030 - depending on the adopted development scenario - ranges from PLN 70 to 133 billion.

The EU budget will contribute to the achievement of the set climate goals, and its funds have been allocated taking into account the goals of: energy transformation, circular economy, decarbonisation of production processes and transport, and innovation in many areas. In Poland, investments in the development of wind technologies not only involve facing the challenge of climate change and environmental protection, but also production innovation and the possibility of expansion into EU markets. Appropriate use of EU funds, through investments in innovative production infrastructure for renewable energy sources, will translate into economic development, quality of life and high-quality jobs in the long term.

In order to implement the above-mentioned opportunities for the Polish economy and develop the existing potential, it is necessary to make the 10H principle more flexible by allowing local communities to decide whether or not to consent to the construction of wind farms closer to residential buildings.

It is also necessary to update strategic documents regarding the planned share of onshore wind energy in the energy mix, maintenance / stable auction systems, development of the PPA contracts market, increasing system integration, ensuring an efficient process of granting the necessary permits. Such a huge scale of investments in the Polish economy confirms the need to sign a sector agreement similar to the Sector Agreement for the Development of Offshore Wind Energy in Poland signed on September 15th, 2021.

2. Introduction

2.1 Decarbonisation and the European Green Deal

One of the main goals of the EU energy and climate policy implemented since 1990 is the reduction of air emissions. The path to meeting the CO_2 reduction target is decarbonisation, i.e. a shift away from the use of coal and fossil hydrocarbons as an energy source.

The document presented by the European Commission in December 2019 entitled The European Green Deal (EGD) is the next installment of the EU's energy and climate policy and a new growth strategy. The EGD aims to transform the EU into a fair and prosperous society living in a modern, resource-efficient and competitive economy. According to the EGD vision, the EU economy will reach net zero greenhouse gas emissions in 2050, and economic growth will be decoupled from the use of non-renewable resources. The goal of the EGD is also to protect, preserve and improve the EU's natural capital and protect the health and well-being of citizens from environmental threats and adverse effects.

According to the EGD, the transformation should be fair and inclusive: people should be put first, and the development of regions, industries and workers that will face the difficulties of the decarbonisation period should be taken into account.

In December 2020, the European Council reaffirmed its commitment to a green transition in the EU. Leaders endorsed a new binding target to cut EU net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (more ambitious than the 2014 target to reduce emissions by at least 40% by 2030). EU leaders called on the Council and Parliament to include the new target in European climate law, as proposed by the Commission under the Green Deal.

An EC analysis from September 2020[1] outlines the path of reducing CO_2 emissions, aimed at achieving a 55% reduction compared to 1990 (Fig. 1). According to the analysis of the European Commission, the decarbonisation targets in the field of electricity may range from 53% to as much as 76% emissions reduction compared to 2015, in order to achieve the main target.

Poland, as a country that obtains approx. 70-75% of its electricity from coal fuels (lignite and hard coal), faces the challenge of developing sources with significantly lower CO_2 emissions compared to carbon sources (i.e. highly efficient CCGT gas sources) or zero-emission sources (i.e. onshore and offshore wind, photovoltaic, sources based on biomass from sustainable sources, as well as nuclear or so-called green hydrogen).

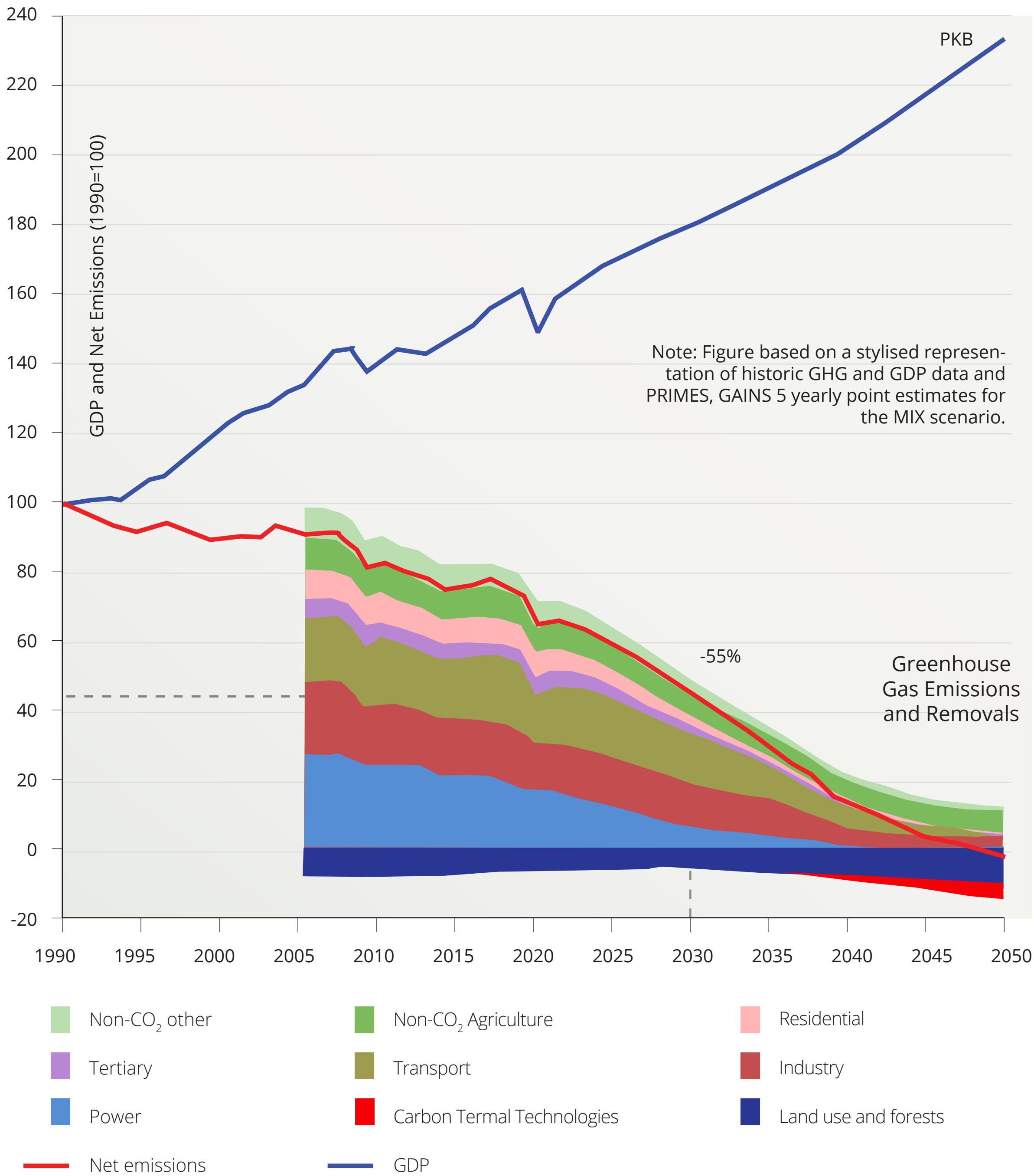
On par with the EU's decarbonisation efforts, there is a need to transform the NPS due to technical factors (especially the advanced age and low efficiency of the production infrastructure based mainly on coal), which translates into economic issues (high costs of energy production due to high CO_2 prices and low efficiency resulting in high emissions).

As a result of the above, the Polish economy is faced with the specter of rising electricity prices, which will result in deterioration of the competitiveness of the domestic economy in the international arena.

1 https://ec.europa.eu/clima/sites/clima/files/eu-climate-action/docs/impact_en.pdf.

Taking into account the indicated factors (regulatory - decarbonisation pressure, technical and economic), the transformation of the Polish energy sector towards low- and zero-emission electricity generation at lower than current costs is inevitable.

FIG. 1. TRAJECTORY OF THE REDUCTION OF GREENHOUSE GAS EMISSIONS IN THE EU TOWARDS ACHIEVING A 55% REDUCTION COMPARED TO 1990



Source: Adapted from EEA GHG data viewer (as in Fig. 35), EUROSTAT GDP data and PRIMES, GLOBION, GAINS models.

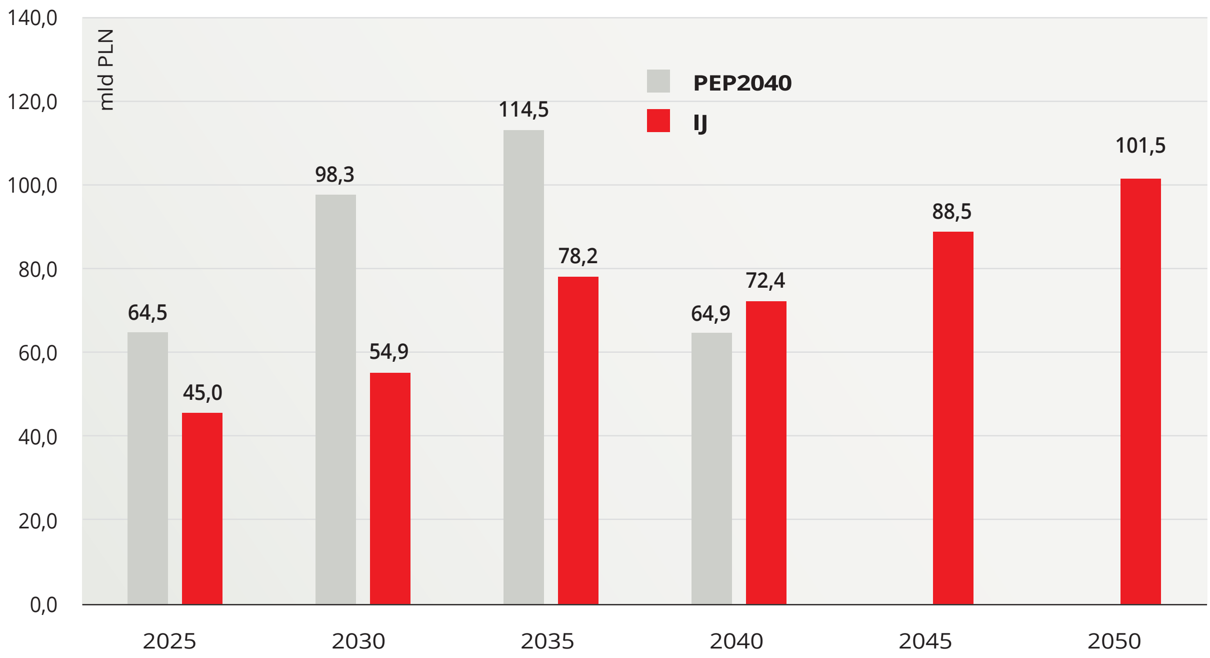
2.2 Benefits of the development of onshore wind farms in the socio-economic context

Taking into account the multifaceted impact of the electric power industry on the economy, society and the natural environment, it should be expected that the transformation of the Polish electricity generation mix will translate into:

- inflow of investments related to the construction of new manufacturing, storage and network infrastructure,
- increase in the volume of electricity from RES and reduction of emissions from the generation sector,
- downward pressure on electricity prices on the wholesale market.

According to PEP2040, the total capital expenditure in the period 2021-2040 related to the construction of new generation sources will be approximately PLN 342.3 billion by 2040 and approximately PLN 162.8 billion by 2030. According to the IJ (Jagiellonian Institute) analysis, the total capital expenditure in the period 2021-2050 related to the construction of new generation sources will be approx. PLN 440.9 billion (approx. PLN 250.5 billion by 2040 and approx. PLN 99.9 billion by 2030).[2]

FIG. 2. FORECAST AMOUNT OF OUTLAYS RELATED TO INVESTMENTS IN NEW ELECTRICITY GENERATION CAPACITY IN POLAND



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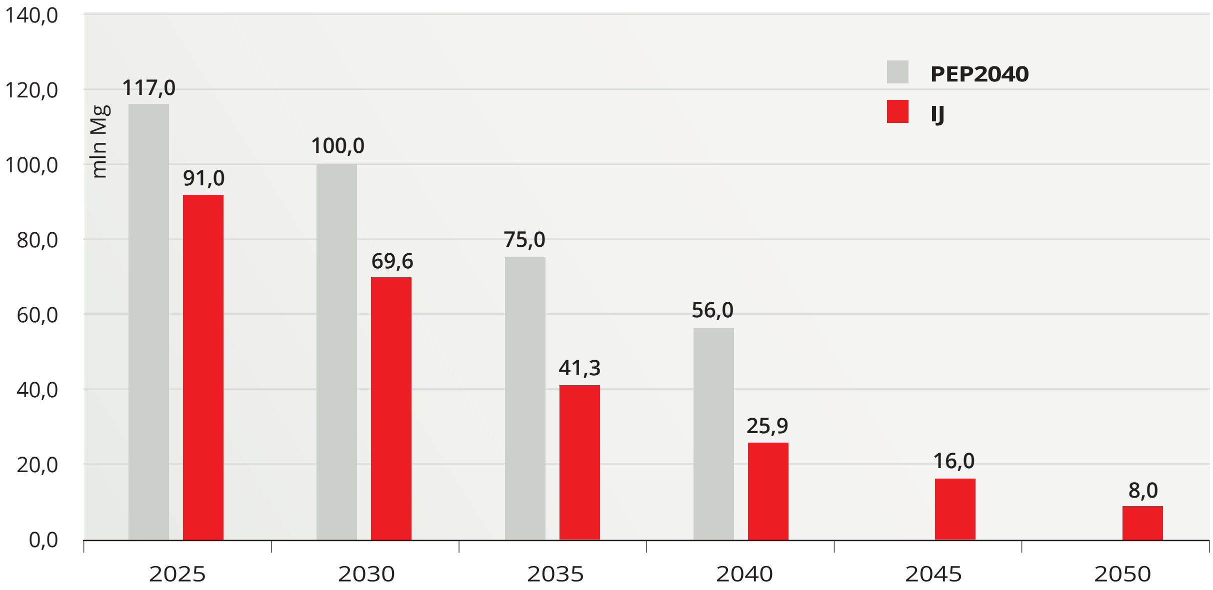
2 In the IJ analysis, the faster rate of reduction of CO2 emissions, despite lower capital expenditures, arises partly from assumptions concerning unit capital expenditures that differ from those in PEP, and above all, from a differently modelled structure of generation sources and structure of electricity production (e.g. the IJ analysis indicates higher energy production volumes from low- and zero-emission technologies, i.e. from gas sources and from onshore and offshore wind energy).

In terms of environmental effects, PEP2040 predicts a decrease in CO_2 emissions from the electricity and heat generation sector to approx. 56 million Mg in 2040 (Fig. 3). The IJ analysis shows the potential for faster reduction of CO_2 emissions, caused by the tightening of the EU's energy and climate policy (25.9 million Mg in 2040 and 8.0 million Mg in 2050).

FIG. 3. FORECAST OF CO2 EMISSIONS DECLINE FROM THE ELECTRICITY AND HEAT GENERATION SECTORS



Source: PEP2040, IJ analysis

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Onshore wind energy can significantly contribute to the achievement of the above-mentioned economic and social effects in Poland as it is one of the most mature electricity generation technologies, allowing for:

- generation of electricity in a zero-emissions manner,
- generating electricity without the use of fossil or nuclear fuels, and therefore with almost zero variable costs[3],
- producing electricity in a cost-competitive manner in terms of LCOE compared to other technologies (see section 4.2).

The direct economic effect of the development of onshore wind farms may be a decrease in the average wholesale electricity price, which in turn will positively affect the competitiveness of the economy. Considering that onshore wind energy is currently one of the cheapest sources of electricity generation in Poland (see section 4.2), the development of OnWF may contribute to a reduction in electricity prices on the wholesale market, and thus, to lowering of electricity prices for the economy.

3 Generation costs in the case of onshore and offshore wind energy include only fixed costs (approx. 50,000 EUR / MW / year and approx. 90,000 EUR / MW / year, respectively). In the case of nuclear energy, the production costs include fixed costs (approx. 85,000 EUR / MW / year), non-fuel variable costs (approx. 0.8 EUR / MWh) and fuel costs. In the case of wind energy, fuel costs do not occur.

Onshore wind energy (with zero variable cost) will exert increasing pressure on the decline of wholesale prices on the electricity market, which results directly from pricing principles on the electricity market based on the merit order mechanism. In the next few years, the increase in capacity and increase in production from onshore wind energy will therefore strongly correlate with the downward pressure on wholesale electricity prices due to the replacement of more expensive energy from fossil fuels with energy from sources with zero variable cost.

The key challenge of the power sector's transformation is the so-called local content[4], which essentially means developing and implementing solutions that allow for:

- retaining as much investment in the domestic economy as possible in order to stimulate GDP growth,
- development of the supply chain based on domestic producers and contractors,
- creating new jobs in the national economy,
- exporting the output produced by Polish economic entities.

4 Local content is defined as the use of domestic assets to produce a given product at its destination (instead of importing assets from another area).

3. Report methodology

In 2021, the Polish Wind Energy Association commissioned an analysis of the current state and of prospects for the development of the onshore wind energy supply chain in Poland. The project was completed in August 2021. The aim of the analysis was to investigate and quantify the demand for products and services resulting from planned onshore wind farm projects in Poland.

Moreover, based on the potential of individual service and supply sectors, the share of expenditure on planned and implemented onshore wind power projects in Poland, which could be incurred in the country, was estimated. These expenditures represent a locally generated value that is important from the point of view of the country (local content).

As part of the work, a projection of the development of the installed capacity of onshore wind farms until 2030 was made. Based on the forecast, the demand for components , materials and services necessary for the implementation of the planned onshore wind farm construction projects was estimated. Based on the analysis of the current possibilities of suppliers from Poland, as well as possible development options, conducted in the form of questionnaires, dialogue with key companies related to onshore energy in Poland, the level of the current and achievable (by 2030) national contribution was calculated. Based on these data, the share of project expenditure and the possibility of creating jobs that could be implemented in Poland were determined.

Questionnaires were sent to three groups of entities in order to assess the value generated in Poland during the implementation of onshore wind farm projects. Suppliers of the construction and electrical phases, developers and suppliers of wind turbines were distinguished as groups. The surveyed entities are suppliers representing each of the three phases, with many years of experience in the wind energy industry and extensive supply chains in Poland. The PWEA study is a reliable source of knowledge on the Polish supply chain for the onshore wind energy industry. The companies were asked to provide information about their current and planned activities in connection with OnWF projects in Poland. The survey included questions about the company's development plans in Poland, the supply chain and the participation of domestic suppliers, as well as an assessment of key purchasing criteria. The results of the surveys have been included in this report.

The following part of the document presents a detailed plan of initiatives and actions that should be taken in order to maintain and achieve the assumed level of local content.

The report was prepared on the basis of meetings / workshops with experts and industry representatives, key stakeholders' questionnaires and data from numerous external sources, including Polish and international reports.

4. Review of conditions and scenarios for the development of the energy sector in Poland

4.1 Development of wind energy from the perspective of the power system

According to ARE data for June 2021, the total installed capacity of electricity generation sources in Poland was approx. 52.8 GWe, of which the capacity of:

- coal plants[5] amounted to approx. 33.3 GWe (approx. 63.8%),
- wind farms amounted to approx. 6.7 GWe[6] (approx.. 12.6%),
- solar farms amounted to approx. 5.4 GWe (approx. 9.1%),
- gas-fired plants amounted to approx. 3.2 GWe (approx. 6.2%),
- plants using other energy sources amounted to approx. 4.2 GWe (approx. 8.2%).

According to the forecasts included in PEP2040, the expected volume of existing generation capacity decommissioning by 2040 is approx. 22.5 GWe (approx. 43.8% of the current NPS capacity). Volumes of decommissioned generating capacity forecast by PEP2040 are presented in Tab. 1.

TAB. 1. FORECAST OF THE VOLUMES OF DECOMMISSIONED GENERATING CAPACITY [GWE] IN POLAND ACCORDING TO PEP2040

Type	2021-25	2026-30	2031-35	2036-40	TOTAL
HC PP	-0,5	0,0	-2,9	-1,2	-4,5
HC CHP	-0,4	-0,8	-0,4	-0,4	-2,0
BC PP	-1,3	-2,9	-4,5	-0,6	-9,3
Industrial CHP	-0,5	-0,1	-0,2	-0,2	-1,0
Natural gas CHP	0,0	0,0	-0,7	-0,0	-0,7
Wind PP	0,0	-0,1	-1,0	-3,8	-4,9
TOTAL	**-2,6**	**-4,0**	**-9,7**	**-6,2**	**-22,5**

Source: PEP2040

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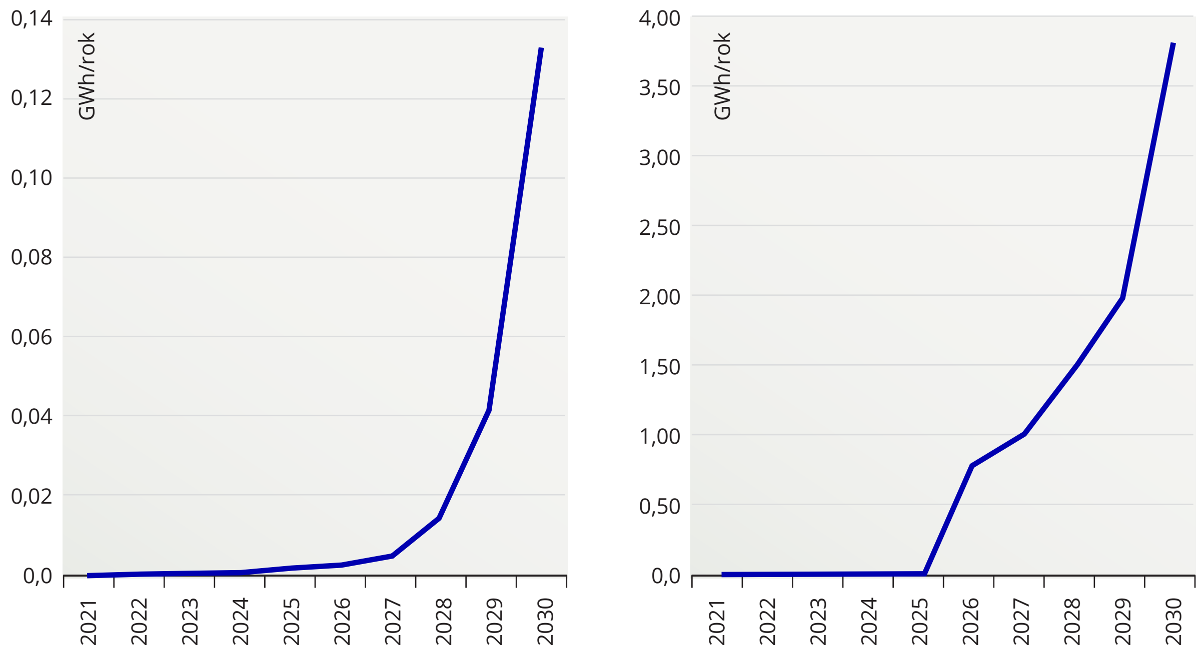
5 Of this, 24.3 GWe in hard coal-fired power plants and 9.1 GWe in lignite-fired power plants.
6 Currently, there are only onshore wind farms in Poland. PSE data for June and July 2021 indicate 7.0 GWe.

According to the forecasts contained in PRSP2030:

> In terms of CDGUs, it is estimated that if the [...] mechanisms [...] are operational after July 1, 2025 for thermal generating units [...], approximately 3 GW of installed capacity will be withdrawn by 2030. The accumulation of shutdowns of generating units will take place only in the years 2030-2040, when sources with an additional total capacity of 15 GW will cease to operate.
>
> In the absence of capacity mechanisms starting from 01/07/2025 for thermal generating units [...], it is expected that approximately 4.9 GW of net installed electrical capacity will be switched off around 2025, which will translate directly into a significant deterioration of generation sufficiency indicators in the NPS.

PRSP2030 forecasts for the expected energy not supplied (EENS) indicator as a result of power deficits in the period in question indicate that, after 2025, there may be a risk of a drastic increase in annual volumes of undelivered energy due to capacity deficits (Fig. 4).

FIG. 4. PSE FORECAST OF THE EXPECTED ANNUAL VOLUMES OF ENERGY NOT SUPPLIED AS A RESULT OF CAPACITY SHORTAGES [GWH / YEAR] (EENS INDEX)



Left graph: basic variant of PSE's analyses

Right chart: variant of delays and absence of capacity mechanisms after 01/07/2025 for CDGUs within the capacity market

Source: PRSP2030

According to information from the Ministry of State Assets:[7]

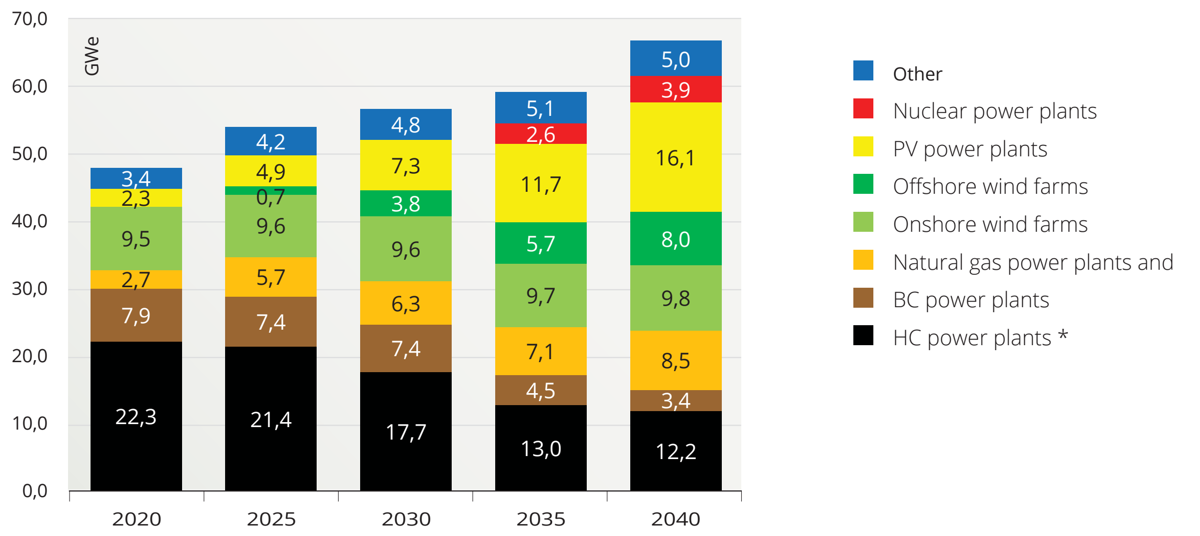
> In the coming years, Poland must fundamentally change the system, and practically build a new one. The point is to ensure the country's energy security and ability to cover the increasing demand for energy, while at the same time relying on domestic sources and protecting citizens from drastic price increases.

The above information indicates that the coming years will be a challenge for Poland in terms of building new capacity to replace the existing one, withdrawn mainly due to:

- high emissions intensity (and thus failure to meet the requirements of the stricter EU energy and climate policy),
- technical condition (especially low efficiency),
- high costs of electricity generation caused by increases in the prices of CO_2 emission allowances (drastic deterioration of production profitability).

Wind power plants are completely emissions-free and one of the most cost-competitive sources of electricity generation in Poland (see section 4.2). The development of these sources appears to be an opportunity to meet the previously mentioned challenges facing Poland in the period until 2030 and 2040.

FIG. 5. POSSIBLE STRUCTURE OF DOMESTIC GENERATION CAPACITY (GWE) ACCORDING TO PEP2040



PEP2040

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7 https://www.gov.pl/web/aktywa-panstwowe/rusza-transformacja-sektora-elektroenergetycznej [accessed on July 1st, 2021].

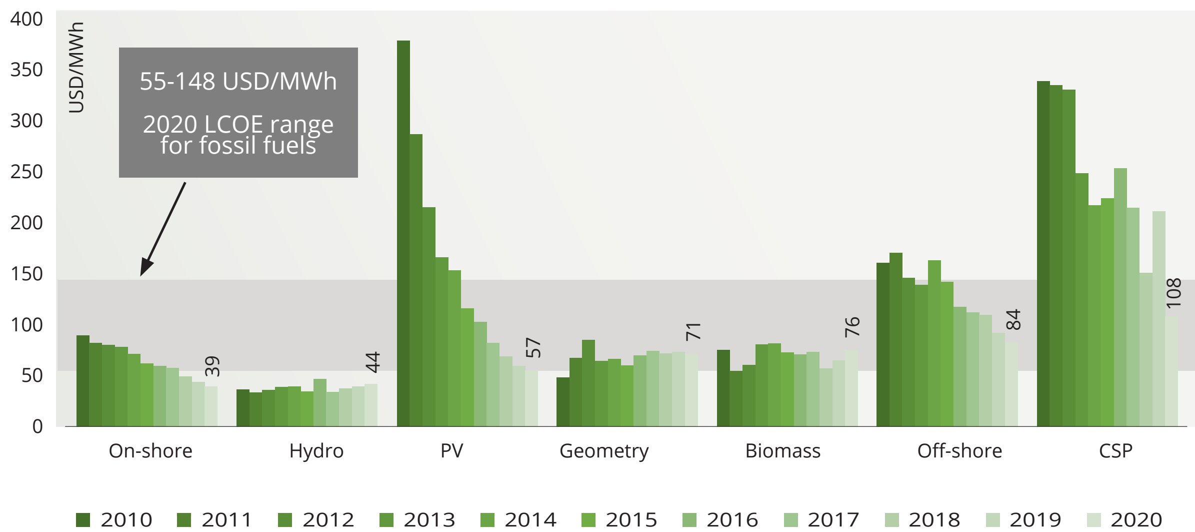
4.2 LCOE and unit investment outlays for onshore wind energy

According to IRENA data for 2020[8], onshore energy is the technology with the lowest LCOE level compared to other RES and fossil fuels.

The global average LCOE value reported by IRENA is approx. 39 USD / MWh, i.e. approx. 153 PLN / MWh. The second and third cheapest renewable energy technologies are hydropower and PV (with LCOE of approximately USD 44 / MWh and approximately USD 57 / MWh, respectively), while the LCOE range for fossil fuels reported by IRENA is USD 55-148 / MWh.

Trends in global average LCOE for individual electricity generation technologies based on IRENA data are presented in Fig. 6.

FIG. 6. LCOE COST TRENDS FOR RES AND FOSSIL FUELS (WEIGHTED AVERAGE, GLOBAL VALUES)



Source: IRENA, Renewable Power Generation Costs in 2020

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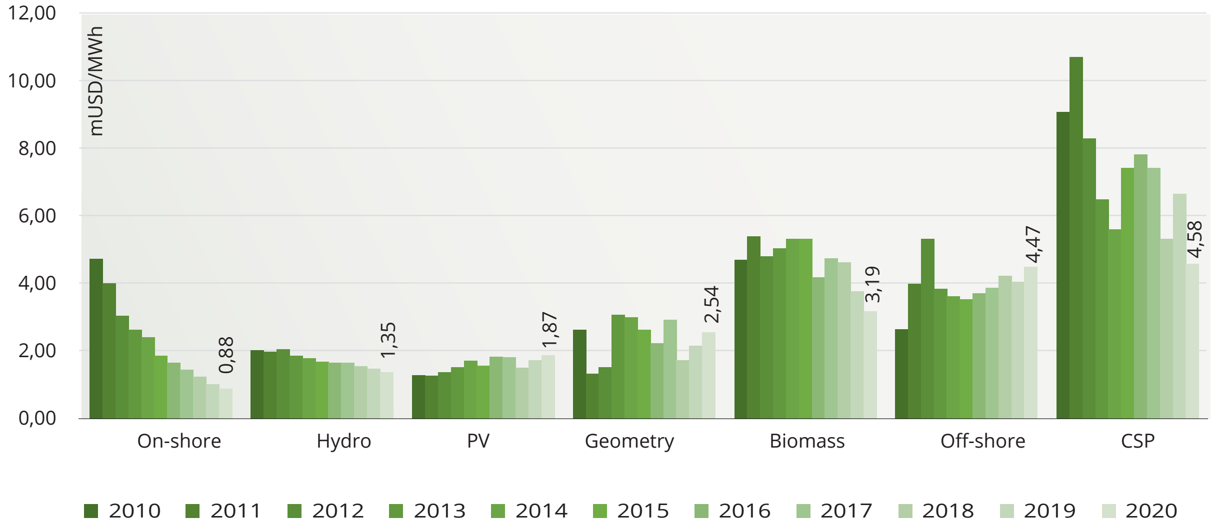
IRENA data concerning capex show that onshore wind is globally the second RES technology with the lowest level of unit investment outlays per 1 MW of installed capacity.

The global average capex value reported by IRENA is around 1.35 mUSD / MW, compared to 0.88 mUSD / MW for PV, the technology with the lowest global capex level. Trends in global average capex values for individual electricity generation technologies based on IRENA data are presented in Fig. 7.

8 https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

FIG. 7. CAPEX TRENDS FOR RES (WEIGHTED AVERAGE, GLOBAL VALUES)



Source: IRENA, Renewable Power Generation Costs in 2020

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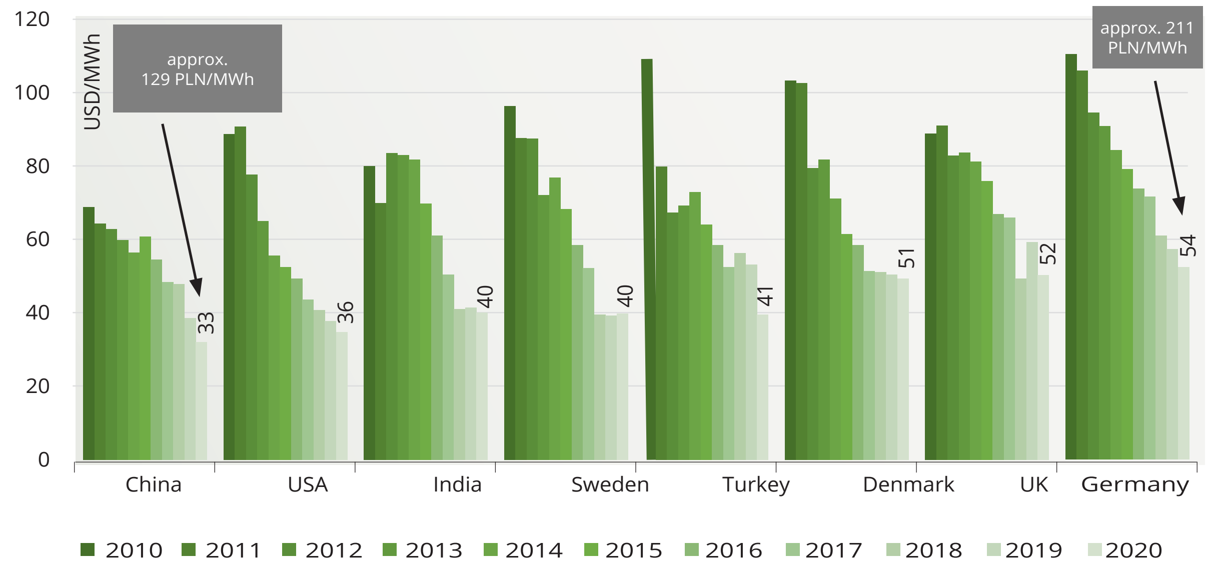
A comparison of LCOE for OnWF in terms of selected countries analysed by IRENA shows a long-term downward trend (Fig. 8).

The lowest LCOE level for 2020 was recorded in China (approx. USD 33 / MWh, i.e. approx. PLN 129 / MWh). In the case of Germany, LCOE for 2020 recorded by IRENA amounted to approx. 54 USD / MWh (approx. 211 PLN / MWh). The country with the highest reported LCOE level for 2020 was Japan (approx. 96 USD / MWh, i.e. approx. 374 PLN / MWh).

FIG. 8. LCOE COST TRENDS FOR ONSHORE ENERGY IN INDIVIDUAL COUNTRIES



Source: IRENA, Renewable Power Generation Costs in 2020

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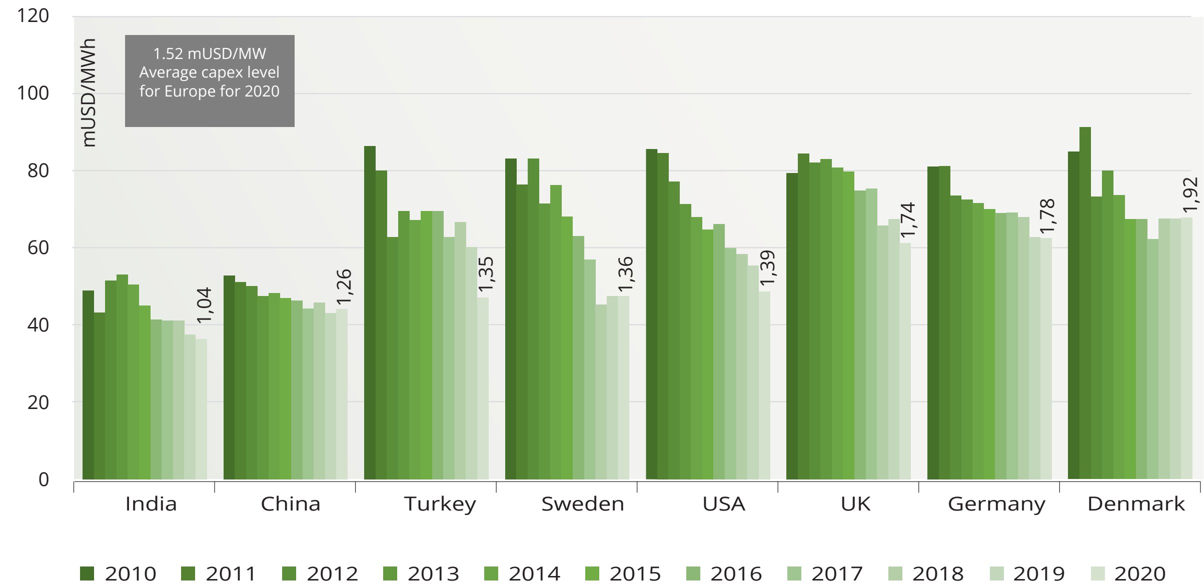
The downward trend in LCOE for OnWF reported according to IRENA is primarily the effect of decreasing capital expenditures for OnWF technology (Fig. 8). For Europe, IRENA data for 2020 indicates a weighted average capex of 1.52 mUSD / MW. On the other hand, IRENA data for the UK, Germany and Denmark for 2020 indicate 1.74 million USD / MW, 1.78 million USD / MW and 1.92 million USD / MW (Fig. 9), respectively.

FIG. 9. CAPEX TRENDS FOR ONSHORE ENERGY IN INDIVIDUAL COUNTRIES



Source: IRENA, Renewable Power Generation Costs in 2020

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In the case of Poland, the estimated LCOE for onshore energy is PLN 241 / MWh, which positions OnWF as a source of electricity with a production cost lower than the estimated variable costs for CDGU units in Poland (Tabela 2).

TA. 2. COMPARISON OF THE LCOE FOR ONSHORE ENERGY AND THE VARIABLE COST OF GENERATION FOR BC, HC AND NATURAL GAS IN POLAND

Item	BC	BC	HC	HC	Natural gas	OnWF
Net efficiency [%]	42,0%	38%	45,5%	39,0%	58,0%	[-]
Price of CO_2 emission allowances [EUR / Mg]	53,0	53,0	53,0	53,0	53,0	[-]
Net emissions intensity [Mg CO_2/ MWh]	0,918	1,015	0,741	0,864	0,344	[-]
Fuel price *	8,5	8,5	11,2	11,2	125,0	[-]
Fuel cost [PLN / MWh]	72,9	80,5	88,6	103,4	215,5	[-]
CO_2 emission cost [PLN / MWh]	219,0	242,1	176,7	206,1	82,0	[-]
Production cost ** [PLN / MWh]	292	323	265	310	298	241

* For BC and HC, the price is in PLN / GJ, for natural gas in PLN / MWh.

** For BC, HC and natural gas, the production cost is a variable cost (fuel and CO_2), for OnWF the LCOE was accepted.

*** Own LCOE calculations based on capex, opex and service life data as in section 7. Average annual capacity factor at the level of 30.5%. Discount rate at 5.0%.

Source: own study

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The LCOE level for onshore energy cited above is comparable to the reference price level[9] for sources with a total installed electrical capacity of more than 1 MW, using only onshore wind energy to generate electricity, amounting to PLN 250 / MWh. At the same time, it is worth highlighting the results of RES auctions in recent years, according to which the implied average sale price of electricity from onshore wind farms[10] was, respectively:

- 196 PLN / MWh for auctions in 2018,
- 208 PLN / MWh for auctions in 2019,
- 224 PLN / MWh for auctions in 2020.

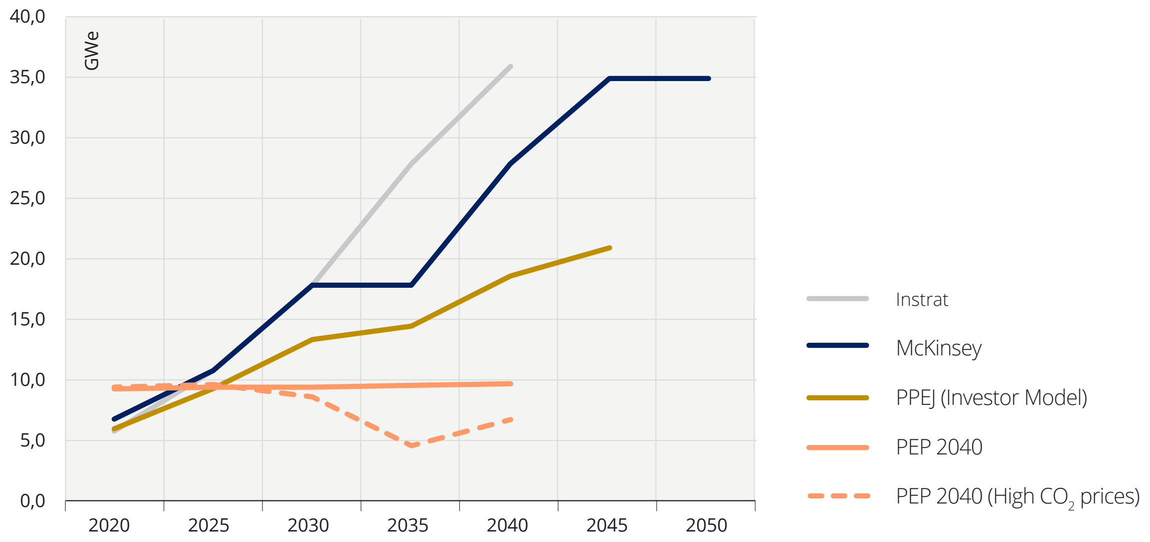
4.3. Scenarios for the development of onshore wind farms

A review of analytical studies on the development of the Polish power system allows for a compilation of the expected scenarios for the development of onshore energy.

As indicated in section 4.1, the current OnWF installed capacity is approx. 6.7 GWe according to ARE data[11] and 7.0 GWe according to PSE data[12] for July 2021. Fig. 10 presents the onshore capacity development path envisaged by PEP2040 and other identified analytical studies.

While the presented alternative scenarios for PEP2040 predict an increase in the installed capacity in OnWF, PEP2040 is the only study that forecasts a downward trend in OnWF capacity.

FIG. 10. SCENARIOS FOR THE DEVELOPMENT OF THE INSTALLED CAPACITY AT ONWF IN POLAND



Source: own study

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9 See the reference prices according to the Regulation of the Minister of Climate and Environment of April 16th, 2021 on the reference price of electricity from renewable energy sources in 2021 (https://www.ure.gov.pl/pl/oze/aukcje-oze/ceny-referencyjne/6539,Ceny-referencyjne.html).

10 Most projects are based on technology from a few years ago. In the case of the latest onshore technologies, allowing for higher capacity factors, lower prices / production costs can be expected for OnWF.

11 ARE data for June 2021.

12 PSE data for June and July 2021 indicate 7.0 GWe.

The data in the chart above are presented in Tab. 3.

TAB. 3. SCENARIOS FOR THE DEVELOPMENT OF THE INSTALLED CAPACITY AT ONWF IN POLAND

Institution	unit	2020	2025	2030	2035	2040	2045	2050
Instrat	GWe	6,0	11,0	18,0	28,0	36,0		
McKinsey	GWe	7,0	11,0	18,0	18,0	28,0	35,0	35,0
PPEJ (investor model)	GWe	6,2	9,5	13,5	14,6	18,7	21,0	
PEP 2040	GWe	9,5	9,6	9,6	9,7	9,8		
PEP 2040 (high CO^2 prices)	GWe	9,5	9,7	8,7	4,8	6,9		

Source: own study

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As indicated in section 2.3, the expected economic and social effects resulting from the development of OnWF in Poland are:

- inflow of investments related to the construction of new production, storage and network infrastructure,
- increase in the volume of electricity from RES and reduction of emissions from the generation sector,
- downward pressure on electricity prices on the wholesale market (section 2.3),
- retention of as much investment in the domestic economy as possible and development of exports in order to stimulate GDP growth,
- maintenance of the competitiveness of Polish enterprises on foreign markets thanks to the possibility of using energy with a low „carbon footprint" for the production of goods,
- development of the supply chain based on domestic producers and contractors,
- creation of new jobs in the domestic economy.

At the same time, the main factors determining the development of OnWF will be:

- administrative and regulatory restrictions, in particular the so-called 10H principle, i.e. liberalisation of regulations concerning the development of OnWF in Poland,
- the existence or absence of a specific scenario for the development of the power industry supported by objective analytics and technical and economic modelling based on a transparent methodology and assumptions,
- creation of conditions conducive to the development of the national supply chain as part of the implementation of the local content postulate;
- transmission capacity and other technical issues (including the development of storage capacity and addressing technical balancing issues) related to the functioning of the NPS and the impact of OnWFs on the system.

It is worthwhile to elaborate on the last of the determining factors of onshore wind energy development, i.e. transmission capacity and technical issues. First of all, one of the technical aspects limiting the possibility of OnWF development may be the phenomenon of network congestion, resulting from low network capacity in areas with favorable natural conditions (e.g. high wind areas correlate with areas with low capacity of the 110 kV or 220 kV network), which may result in the necessity of reducing the output of OnWF by the operator („curtailment").

Secondly, in order to remedy the phenomenon of congestion and curtailment, it is necessary to invest in the development of the capacity of the transmission and distribution networks in Poland.

The third key element is the development of generation based on weather-dependent sources (OnWF, OffWF, PV), which will require adequate storage capacity (sufficiently long storage duration) and improvement of the efficiency of utilising existing connection capacities, allowing for energy storage in periods of overproduction and discharging to the system in the period of peak demand and low generation from RES (so-called time shifting) and improvement of the network's flexibility. Currently, there are technologies that enable energy storage for long periods (pumped storage power plants, appropriately sized battery storages, compressed air-based storagees). In the next few years, promising technologies are: energy storage in the form of hydrogen, gravity storage or iron-air batteries[13]. In addition, there are solutions to improve the efficiency of using the existing connection capacities, including cable pooling, as well as solutions that do not generate a load on the NPS - direct line.

Based on the analysed scenarios of OnWF development in Poland, the following variants were adopted for further analysis: conservative, baseline, and developmental. The conservative variant provides for an average annual increase in the installed capacity of OnWF in Poland at the level of 0.6 GW, in the baseline scenario it is 1.0 GW, and the developmental variant assumes 1.2 GW.

The key factors determining the development of individual variants are presented in Tab. 4.

TAB. 4. KEY FACTORS DETERMINING THE DEVELOPMENT OF ONWF IN POLAND IN THE PROPOSED VARIANTS

Scenario	10H degree of liberalisation	Systemic inclusion of OnWF development in the directional documents of Poland (PEP)	Development of the PPA contract market for RES, availability of NRF funds	Development of network and storage infrastructure, acceleration of connection processes	Development of the node market (better availability of location signals)
Conservative	Low	No	Slow, low	Slow	No
Baseline	Moderate	Yes	Moderate, moderate	Moderate	No
Developmental	High	Yes	Rapid, high	Rapid	Yes

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13 Gravity stores allow energy to discharge for 6-14 hours, while iron-air storages can discharge energy for up to 150 hours.

Quantitative information on the subject of adopted variants is presented in Tab. 5.

TAB. 5. VARIANTS FOR THE DEVELOPMENT OF THE INSTALLED CAPACITY OF ONWF IN POLAND (GWE) ADOPTED FOR FURTHER ANALYSES

Scenario	2021	2025	2030	Increase in the period 2021-2030 (GWe)	Average annual growth (GWe)
Conservative	6,9	9,8	12,7	5,8	0,6
Baseline	6,9	10,3	15,8	8,9	1,0
Developmental	6,9	11,0	18,0	11,1	1,2

Source: own study

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4.4 Value of cash flows related to investments in onshore wind energy in Poland

Based on the scenarios for the development of installed OnWF capacity adopted for the analysis, presented in Tab. 5, Tab. 6 provides an estimation of cash flows resulting from capital expenditures and operating costs related to the development of OnWF in Poland.

TAB. 6. ESTIMATED CUMULATIVE CASH FLOWS RELATED TO THE INCREASE IN ONWF CAPACITY IN POLAND

Scenario	Average annual increase in OnWF capacity [GWe]	Total OnWF capacity increase [GWe] until 2030	Cumulative cash flows from capital expenditures until 2030 [PLN billion]	Cumulative cash flows for operating costs until 2030 [PLN billion]	TOTAL [PLN billion]]	TOTAL per year [PLN billion]
Conservative	0,6	5,8	24,5	2,9	27,4	3,0
Baseline	1,0	8,9	37,3	4,4	41,7	4,6
Developmental	1,2	11,1	46,8	5,5	52,3	5,8

Source: own study

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The forecasted calculations were made on the basis of the values adopted for the estimates in section 7, taking into account the division into the investment phase (development phase, turbine installation, construction and electrical connection) and the operational phase. The estimated local content path for each phase was also considered.

5. Characteristics of the demand for products, materials and services used in the construction and operation of onshore wind farms

5.1 Description of individual elements of the supply chain

For the purposes of this report, based on the main groups of suppliers and project phases, we distinguish the following elements of the supply chain:

1. Development phase (Project Development) consisting of:
   - choosing a location,
   - technical, environmental, legal and financial analyses,
   - planning, design and tendering.

2. The construction and balance of plant phase consists of:
   - site preparation and construction works,
   - electrical installations and connections,
   - commissioning.

3. Turbine Installation consists of:
   - production of components:
     - nacelle (power generator),
     - rotor,
     - tower,
   - logistics,
   - assembly.

4. The operation, maintenance and decommissioning (or repowering) phase, consisting of:
   - operation and maintenance,
   - decommissioning or repowering.

5.2 Structure of wind farm construction and operating costs

The estimated total cost (TOTEX) per 1MW of turbines over the 25-year operation and decommissioning period is PLN 10-11 million. The percentage share in the estimated total cost (TOTEX) of the individual phases is as follows:

- development phase - approx. 7-10%,
- construction and balance of plant phase - approx. 10-13%,
- turbine installation - approx. 45%,
- operation, maintenance and decommissioning phase - approx. 35%.

A detailed breakdown of costs together with the components of individual phases is presented in Tab. 7.

TAB. 7. DETAILED BREAKDOWN OF COSTS TOGETHER WITH THE COMPONENTS OF INDIVIDUAL PHASES

NO.	Phase / Component / Service	% share
1	**Development phase**	**7%**
1.1	Location selection	1%
1.2	Technical, environmental, legal and financial analyses	1%
1.3	Planning, designing, tenders	3%
1.4	Connection fee	2%
2	**Turbine**	**45%**
2.1	Gondola	21% in total
2.1.1	Gondola assembly	2%
2.1.2	Base plate	1%
2.1.3	Main bearing	1%
2.1.4	Main shaft	1%
2.1.5	Gear	4%
2.1.6	Generator and power take-off shaft	7%
2.1.7	Control and monitoring system	1%
2.1.8	Assembly and directional bearing	1%
2.1.9	Auxiliary system	<1%
2.1.10	Nacelle housing	2%
2.1.11	Design elements	<1%
2.2	Rotor	12 % in total
2.2.1	Rotor assembly	1%
2.2.2	Rotor blades	7%
2.2.3	Hub casting	1%
2.2.4	Blade bearings	1%
2.2.5	Rake angle mechanism	<1%
2.2.6	Hub housing and rotor auxiliary systems	1%
2.2.7	Design elements	1%
2.3	Tower	12% in total
2.3.1	Tower production	2%
2.3.2	Plate	4%
2.3.3	Collars	2%
2.3.4	Equipment and others	1%
2.3	Transport and assembly	3%
3	**Construction and balance of plant phase**	**13%**
3.1	Site preparation and construction works	5%
3.2	Electrical installations and connections	6%
3.3	Commissioning	2%
4	**Operation, maintenance and decommissioning phase**	**35%**
4.1	Operation and maintenance	30%
4.2	Decommissioning/ Liquidation	5%

Source. own study

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The most expensive element of the turbine is the nacelle, which accounts for about 21% of the value of the turbine installation. In the operation, service and decommissioning phase, gondola service makes up the largest share of total costs along with other operating costs, including land lease.

The construction and balance of plant phase consists in equal part of site preparation, foundations and electrical works, including the purchase and installation of cables, the power station and commissioning of the wind farm. The development phase consists of many elements, mainly the costs of analyses and applications, as well as the connection fee.

Due to the development of technology, including the increase in turbine power (even up to 6 MW), the total costs per 1 MW are decreasing. In the case of Poland, this decline is, unfortunately, largely hampered by the 10H rule, which has significantly limited the possibility of using turbines above 4 MW, which use new solutions and technological innovations.

5.3 Technological development

The reduction in wind energy costs is mainly due to advances in wind turbine technology. The key parameters by which wind turbine technology can be improved are: rotor diameter and hub height, allowing for more power from wind turbines, even in areas with lower wind speeds. Simultaneously with the research on effectiveness, implementation works reducing the number of elements, their size and weight - which in total is an important component of cost and operational reliability, are being carried out. Larger rotors with better efficiency increase coefficients of efficiency and open up possibilities for the use in light wind areas. Manufacturers now offer onshore turbine technologies with a capacity of 4.8 MW and 5.3 MW respectively. Models with a capacity of up to 6 MW and a rotor diameter of 170 meters have also appeared.

Intensive research and development is currently underway in the field of structures and materials used in the production of rotor blades. This research focuses on improving aerodynamic profiles and blade materials, in particular to maximize energy production and reduce O&M costs.

Electronics is another area where work on new solutions is underway. Optimizing the reliability and dimensions of inverters can lower the costs of installing and operating the turbine (power modules due to condensation and water accumulation), ensure scalability (creating new intelligent modules such as sintered modules) and reduce the number of parts thereby improving the reliability of power electronics by reducing the number of active components in modules and, thus reducing defects or failures.

Advanced preventive algorithms are tested and implemented in order to improve maintenance operations and thus reduce costs by reducing the number of failures (detecting faults in advance by monitoring the condition of the modules) and ensuring the efficiency of electronics, even in wet conditions.

The digital revolution is also affecting the wind energy industry, which is developing so-called smart wind turbines. There is a noticeable improvement in the forecasting mechanism (using big data and artificial intelligence) and the automation of turbine regulation (pitch and yaw control) to maximize total energy production. This is crucial in reducing unplanned costs due to breakdowns, which currently account for more than half of the total cost of ownership.

Another research area is related to the logistics of oversized components, particularly blades, nacelles and towers. On the one hand, the growing capacity of wind turbines optimizes the investment per MW, on the other, it causes pressure to implement transport solutions adapted to the growing weight and size of individual components. The answer to these challenges is, for example, the use of split tower sections, which significantly facilitate transport and allow for final assembly on the wind farm site.

At the same time, the effect of the above initiatives and implementations is influenced by rising labor costs and material prices. Nevertheless, the total costs of installed capacity for wind power are in a downward trend. By 2030, the total cost (Totex) per MW is expected to decline by approximately 7%.

5.4 Value of demand for products and services related to the construction of onshore wind farms

An important factor in shaping the cost of building onshore wind farms will be the technological development described in the previous sections, affecting the size and cost of producing wind turbines. Given the significant share of labor costs in the construction, installation and operation phases, one should take into account the impact of rising wages. In particular, the operation and maintenance phase - despite the reduction in labor intensity per 1 MW, due to the very high share of salary costs, will not be cheaper (hence the assumption that the unit cost will not change).

For this study, it was assumed that, by 2030, the unit cost per 1 MW of installed capacity will be most significantly reduced in terms of the cost of turbine installation, which is associated with the installation of turbines of increasing unit capacity.

TAB. 8. CUMULATIVE CHANGE IN UNIT COST PER 1 MW

Construction / operation phase	Cumulative change in unit cost per 1 MW 2022-2030
Development phase	8%
Turbine installation	-18%
Construction and balance of plant	3%
Operation, maintenance and decommissioning	0%

Source: own study

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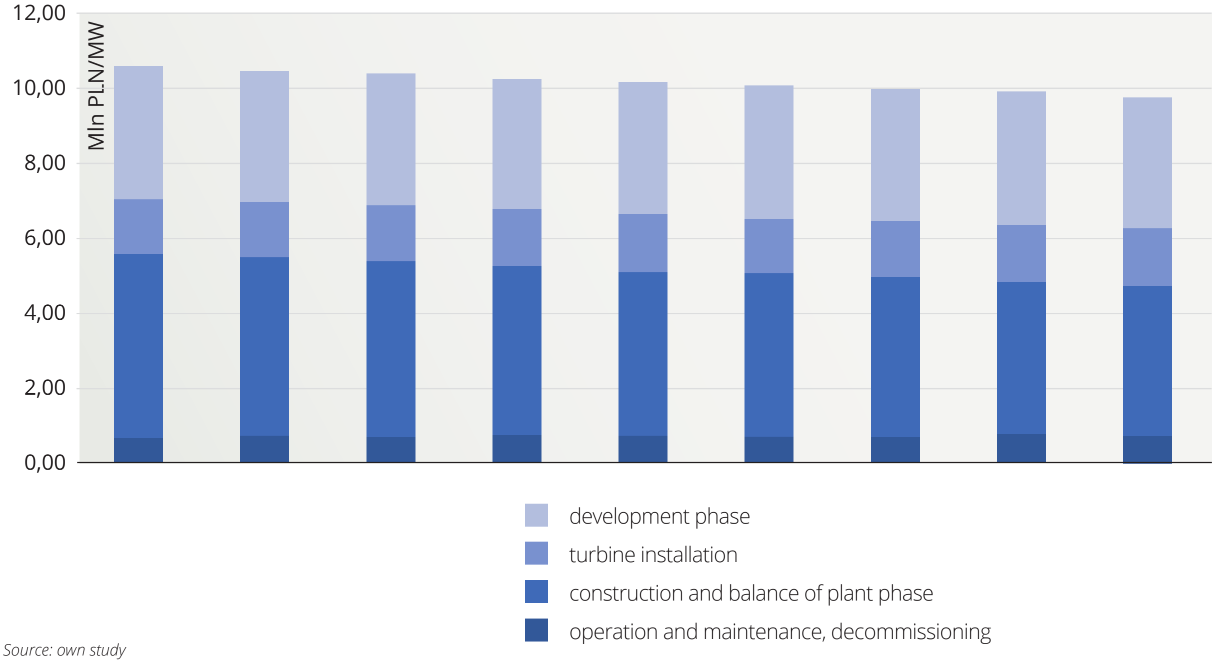
Therefore, it is assumed that, by the years 2022-2030, the total cost of construction and operation of a 1 MW onshore wind farm will fall from the range of PLN 10.7-11 million / MW to the level of approximately PLN 9.5-10 million / MW.

FIG. 11. CHANGE IN THE COST OF CONSTRUCTION AND OPERATION PER 1 MW OF AN ONSHORE WIND FARM



Source: own study

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5.5 Production materials

The basic materials for the production and installation of a wind farm are: concrete, steel, composites (fiberglass, carbon, polymers and others) as well as copper and aluminum. Most of the materials are manufactured in Poland. Tab. 9 presents the average quantities of materials necessary for the construction and commissioning of an onshore wind farm with a capacity of 50 MW.

TAB. 9. AVERAGE AMOUNTS OF MATERIALS NECESSARY FOR COMMISSIONING A 50 MW WIND FARM

Materials	Tons of materials
Concrete (used, for example, in the production of foundations, technical roads)	22 836
Steel (used, for example, in the production of wind towers, collars, nacelle housing, structural elements, castings of nacelle and rotor components)	6 687
Composites (used, for example, in the production of rotor blades, hub housing, nacelle housing, cable covers)	1 051
Aluminum and copper (electrical components, cables, accessories)	301

Source: IRENA

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The amount of materials necessary for the construction of wind farms was calculated in accordance with the variants of onshore wind farm development by 2030 presented in the report (Tab. 10).

TAB. 10. QUANTITIES OF MATERIALS (IN TONS) NECESSARY FOR THE CONSTRUCTION OF WIND FARMS IN VARIANTS

Materials (tons)	Conservative variant	Baseline variant	Developmental variant
Concrete (used, for example, in in the production of foundations, technical roads)	2 648 976	4 064 808	5 069 592
Steel (used, for example, in in the production of wind towers, collars, nacelle housing, structural elements, castings of nacelle and rotor components)	775 692	1 190 286	1 484 514
Composites (used, for example, in in the production of rotor blades, hub housing, nacelle housing, cable covers)	121 916	187 078	233 322
Aluminum and copper (electrical components, cables, accessories)	34 916	53 578	66 822

Source: IRENA, own elaboration

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We pay particular attention to the demand for steel. In the discussed period - in the developmental variant - Polish steel mills can deliver an amount of approximately 800,000 to even nearly 1.5 million tons. Polish companies can also ensure 100% supply of other materials.

6. Market quantification and demand for individual components and services. Analysis of demand on the domestic market, driving the development of local suppliers

6.1 Development phase

The development phase, including in particular works related to the selection of the location, technical, environmental, legal and financial analyses, planning, design, tender and payment of the connection fee, accounts for approximately 7% of the total cost of construction and operation of an onshore wind farm. Increasing the power of the turbines has a limited effect on reducing the cost of this phase. In addition, this work is based (apart from the grid connection fee) to a large extent on the activities of experts, the cost of which will increase. It is therefore assumed that the costs of the development phase will increase (the analysis for this report indicates a cumulative increase of around 8% by 2030).

TAB. 11. ESTIMATED EXPENDITURES FOR THE CONSTRUCTION OF ONSHORE WIND FARMS IN THE DEVELOPMENT PHASE (PLN MILLION) IN 2022-2030

Development phase	Conservative variant	Baseline variant	Developmental variant
Location selection	641	976	1 224
Technical, environmental, legal and financial analyses	641	976	1 224
Planning, design, tenders	1 924	2 928	3 672
Grid connection fee	1 283	1 952	2 448
TOTAL	**4 490**	**6 832**	**8 568**

Source: own study

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The market for services related to the development phase of the construction of onshore wind farms in Poland may amount to between PLN 4.5 and 8.5 billion in 2022-2030, including grid connection fees. **Excluding these fees, this market may reach a value between PLN 3.2 and 6 billion, which means an average annual revenue potential for companies in the supply chain at the level of PLN 300 to nearly 700 million.**

6.2 Turbine installation

The turbine installation phase is the main cost element of a wind farm, and its share is approximately 45% of the total. The outlays and costs incurred over its course include the purchase, transport and installation of the turbine. The assumed increase in the unit power of turbines clearly means that the costs per 1 MW of purchase, transport and assembly will decrease. Despite the assumed increase in prices of materials and wages, it is necessary to take into account the disproportionate increase in the capacity of the wind turbines used, which will reduce the cost per MW. It is therefore assumed that the costs of this phase will decrease cumulatively by 18% by 2030.

TAB. 12. ESTIMATED EXPENDITURES FOR THE CONSTRUCTION OF ONSHORE WIND FARMS IN THE TURBINE INSTALLATION PHASE (MILLION PLN) IN 2022-2030

Turbine installation phase	Conservative variant	Baseline variant	Developmental variant
Nacelle	12 151	18 487	23 187
Rotor	6 931	10 545	13 226
Tower	4 877	7 421	9 307
Transport and assembly	1 711	2 604	3 266
TOTAL	**25 671**	**39 057**	**48 986**

Source: own study

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The market for supplies related to the installation phase of turbines for onshore wind farms in Poland may be between PLN 26 and 48 billion in the years 2022-2030. **The largest market will be the delivery of turbines, including the transport of its main components - nacelle, rotor, tower.**

As part of the supply of components for the nacelles, the potential for generating revenues by suppliers or their sub-suppliers in the baseline variant is over PLN 2 billion, in the case of rotor components (including the production of blades and castings), it is over PLN 1 billion, and the supply of wind towers is a market worth up to PLN 900 million on average annually.

6.3 Construction and balance of plant phase

The construction and balance of plant phase accounts for approximately 13% of the total costs. The outlays and costs incurred over the course of this phase include: site preparation, construction works, supply of electrical installations and their connection, and commissioning of the farm. Increasing the power of the turbines has a limited effect on reducing the cost of this phase. Considering the increase in material prices and wages, unit costs must be expected to increase. Therefore, it is assumed that the costs of this phase will increase cumulatively by 3% by 2030.

TAB. 13. ESTIMATED EXPENDITURES ON THE CONSTRUCTION OF ONSHORE WIND FARMS IN THE CONSTRUCTION AND BALANCE OF PLANT PHASE (PLN MILLION) IN 2022-2030

Construction and balance of plant phase	Conservative variant	Baseline variant	Developmental variant
Site preparation and construction works	3 372	5 130	6 434
Electrical installations and connections	4 046	6 156	7 721
Commissioning	1 349	2 052	2 574
TOTAL	**8 766**	**13 338**	**16 728**

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The market for the supply of components and services related to the construction and balance of plant phase may amount to between PLN 9 and 17 billion in the years 2022-2030. **The largest supply market will be the supply of electrical installations along with the service of their connection. The average annual value of revenues that can be achieved by companies in the supply chain in this segment is approximately PLN 700 million. As part of construction works with site preparation, the average annual basket of revenues is approximately PLN 600 million. Enterprises providing services for the comprehensive commissioning of onshore wind farms could participate in a market with an average annual turnover of approximately PLN 200 million.**

6.4 Operation, maintenance and decommissioning (or repowering) phase

The operation, service and decommissioning phases represent the cost category that is most extended over time. Assuming operation over 25 years, one should take into account the costs associated with, in particular, ongoing maintenance and replacement of spare parts. According to the collected information, the average annual cost of operation and maintenance per MW is approximately PLN 0.15-0.2 million per year. As part of these costs, the largest item is servicing and replacement of components on the farm's site (up to 50% of this cost category).

TAB. 14. INDICATIVE ANNUAL COST OF OPERATION AND MAINTENANCE ACCORDING TO WORLD BENCHMARKS

Component costs	Annual cost (PLN / MW)	Percentage of total
Turbine maintenance	77.385 - 94.325	47,6 - 49,3%
Management and administration	31.185 - 38.115	19,2 - 19,9%
Insurances	28.875 - 37.730	18,9 - 18,4%
Property tax	15.400 - 23.100	11,7 - 9,8%
Electrical installation service and maintenance	4.235 - 5.005	2,6%
Total	**157.080 - 198.275**	**100%**

Source: IRENA

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The analyses of the construction and operating costs, and thus the demand for individual components and services, prepared for the report, cover the period until 2030. It should be remembered, however, that a significant demand for services related to maintenance and operation will occur after this period. Moreover, in order to determine the realization of revenues related to the maintenance and operation of wind farms, it is worth pointing to the currently installed wind farm capacities as a revenue potential for enterprises from the supply chain.

It is estimated that, by 2030, the commissioned wind farms (including those commissioned by the end of 2021), can generate services and supplies as part of maintenance and operation in the average annual amount of even more than PLN 1.5 billion. The predominant value (around 50%) is the supply of spare parts and related services.

TAB. 15. ESTIMATED EXPENDITURES ON THE OPERATION AND MAINTENANCE OF ONSHORE WIND FARMS (PLN MILLION) IN 2022-2030

Operation and maintenance phase	Conservative variant	Baseline variant	Developmental variant
Farms currently in operation (approx. 6.9 GW in 2021)	8 810	8 810	8 810
Farms built in 2022-2030	4 067	6 188	7 761
TOTAL	**12 877**	**14 997**	**16 571**

Source: own study

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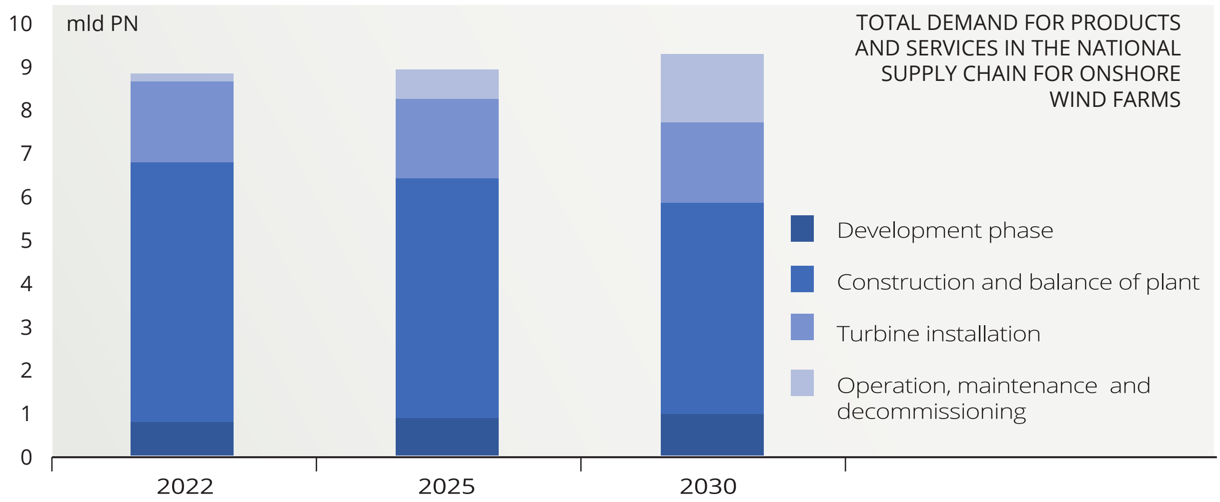
GRAPHICS: PIOTR PERZYNA

6.5 Demand Summary

The total value of revenues that can be targeted at companies in the onshore wind farm supply chain may amount to between PLN 50 and 80 billion in the years 2022-2030. This means that it is possible to generate an average annual turnover of PLN 6-9 billion. This level depends on the development of construction of new onshore wind farms, the level of costs and the pace of technological development.

FIG. 12. SUMMARY OF OUTLAYS (IN PLN BILLION) FOR THE CONSTRUCTION AND OPERATION OF ONSHORE WIND FARMS IN 2022-2030



Source: own study

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7. Analysis and estimation of the share of the national contribution to Polish onshore wind farm projects

7.1 Diagnosis of the current state of the national supply chain

Currently, the share of suppliers of components and services from Poland for onshore wind energy is estimated at 55-60%, with the aim of reaching 75% in the next 10 years. At the same time, due to the limitations introduced by the 10H rule, it is estimated that we currently use domestic production and maintenance capacities to a limited extent, meaning that the share of the national contribution is now 40%. The continuation of restrictive regulations limiting localization of wind farms in the form of the so-called 10H rule will significantly limit new onshore energy projects, and this will translate into a further decline in production capacity and service companies for the industry. Going further, one can risk the statement that failure to unlock onshore wind energy's potential will also translate into the share of domestic suppliers in supply chains for the offshore wind energy industry.

The possibility of realizing the full potential of ambitions depends, to a large extent, on the stable development of the market and support for new investments in Poland, which are discussed in the following sections of this report. An additional factor positively influencing the possibilities of increasing the share of the Polish component is the planned development and potentially available financing for offshore wind energy - which may create significant synergies, particularly in the production of nacelle components.

Due to the local nature of these services and the production of components in Poland, the companies implementing the development phase as well as the construction and balance of plant phase have the largest share in individual stages of an investment's implementation.

However, the greatest potential, both for percentage growth and for building added value (with export potential), lies in the turbine installation, operation and maintenance phase, both due to their largest share (approximately 75% in total) in the total cost per 1 MW (Totex) and the potential competitiveness of supplying production of individual components and services from Poland.

For the production of turbines (with the potential to increase the value of supplies from Poland from the current level of 30% to over 50%), three main developmental groups for the increase in the value of supplies from Poland can be distinguished:

- international technology companies that, with appropriate investment incentives, may be interested in relocating or creating new production capacities in Poland (in particular, attention should be paid to the potential of nacelle and rotor assembly plants, which may strengthen the local supply chain of individual components);
- Polish companies that already today have the necessary competences or supply wind energy components, particularly in the field of steel and composite structures, all kinds of castings and specialized thermal and mechanical treatment as well as eclectic components (including those located in coal regions);
- the Polish metallurgical industry, which, with the current technologies, is able to provide most of the steel required for the production of towers and nacelles, and, after investments, also the possible supply of flanges.

The value potential for the operation and maintenance phase (about 30% of costs) is estimated to grow from the current level of 70% to the level of 90% as a result of the natural development of competences in this area, assuming stable development of the market, and as a derivative of the development of the scope of turbine components produced in Poland. This will entail greater opportunities for local service and production of the necessary specialist spare parts in Poland. An open issue is to carry out the disposal of components, disassembly and recovery of raw materials for reprocessing. This process is not yet structured in Poland.

The present state and potential of the individual main components of the implementation phases of onshore wind farms are described below.

1. **Development phase, approx. 7% share in the entire chain**. Due to the fact that onshore wind turbines are founded on land, the share of Polish contribution in implementation of particular groups of tasks may reach the level of 90%. The main share is the choice of location and administrative decisions, which are naturally provided by Polish companies. A stable position for the future.

2. **Turbine installation** - the main element of a wind farm, its share is approximately 45% in the value chain. The weighted average share in costs (Totex), including the share of Polish components, is estimated at 30%, with a potential of over 50%. Individual distributions and impacts are presented in Tab. 16.

TAB. 16. ESTIMATED SHARE OF THE POLISH INDUSTRY IN THE PROVISION OF SERVICES AND PRODUCTION OF ONSHORE WIND FARM COMPONENTS

Item no.	Component / Service	Current local content	Developmental local content	Polish potential in components / services
1	Assembly of nacelles	10%	30%	One manufacturer is expanding their assembly center for onshore turbines with the active cooperation of a Polish industrial group. The impulse for increasing the share of the Polish contribution to 30% is cooperation with the turbine manufacturer, who may ultimately decide to establish an assembly plant in Poland, as a relocation of existing or the creation of new production capacities.
2	Bedplate	10%	70%	There are a limited number of companies that now have the right technology and manufacture the corresponding products or the like. However, the technology is known and used in Poland in similar products that only have a different end-use, e.g. for heavy motor vehicles.
3	Main bearing	10%	30%	Bearing production technology is successfully implemented for smaller dimensions or other types of bearings. Current manufacturers make up a narrow group of specialized manufacturers with a precise and proven production technology, with the possibility of increasing production capacity.
4	Main shaft	20%	70%	As in the case of the base plate, there are currently several companies in Poland using the same techniques and technologies for the production of other types of shafts. Technologies do not constitute a barrier to the development of growth. In connection with the above, it was estimated that there is a good foundation in Poland for the development of the scale of production.
5	Gearbox	5%	30%	The market is dominated by international manufacturers, mainly from the automotive industry. Poland has the competences and resources at every stage of the production of elements: wheels, gears, housings and final assembly. Polish aviation clusters have world-class equipment and technology that can be successfully used to start production. The barrier to entry is access to wind energy gear designs and technologies, but with an expected potential of 30% of supply from Poland, assuming additional investments by international concerns.

6	Generator and power take-off	10%	50%	One of the most technologically advanced elements, the entirety of which is also made as a single component - this fact is a natural logistical barrier. Currently implemented by several companies with precise CNC machining centers and appropriate production halls with indoor climate control. Polish aviation clusters have world-class equipment and technology that can successfully be used to launch additional production capacities in Poland.
7	Control and monitoring systems	30%	70%	The systems are mainly software developed by turbine manufacturers. They have SCADA data collection and monitoring centers. The production of equipment components and entire control systems mainly takes place in Lower Silesian technology clusters, by domestic companies providing parts of the software, and is considered sTab..
8	Yaw system and bearing	5%	30%	The general situation is the same as for the main bearing. The production of bearings is present in Poland for other applications, and the current manufacturers constitute a narrow group of specialized manufacturers with a precise and proven manufacturing technology with the possibility of increasing production capacity.
9	Nacelle cover	70%	90%	Implemented by an experienced foreign manufacturer in Poland (composite material) and by a Polish industrial group (steel). Most of the housings are made of plastic similar to the material used in boat hulls. It is possible to use the base of small Polish yacht shipyards in real terms. Possible development by increasing the scale of current manufacturers or new investments to the estimated level of 90% of supply from Poland.
10	Rotor assembly	10%	30%	A process that usually coexists with the assembly of the nacelle. One manufacturer is expanding their assembly center for onshore turbines with the active cooperation of a Polish industrial group. The impulse for the increase in the share of the Polish contribution is cooperation with the turbine manufacturer, who may ultimately decide to establish an assembly plant in Poland, as a relocation of existing production capacities or the creation of new capacities.
11	Rotor blades	30%	70%	Currently, a blade manufacturer with knowledge of the technology has been operating on the market for many years. Restrictions apply to the dimensions of the manufactured blades and their number – this has an impact on the size of production halls and technology (mold size). A new generation of blades requires a new plant - a production site. It may be the same manufacturer as present, or it may be necessary to build a new one, as a synergy with offshore wind energy.
12	Rot hub	20%	70%	As with other elements of steel structures, there are numerous plants - foundries that have the technology and can expand into the production of rot hub. The barrier is investments in new casting and processing lines. In connection with the above, it was estimated that there is a good foundation in Poland for the development of the scale of production.
13	Blade bearings	10%	30%	Bearing production is present in Poland for other applications. The general situation is the same as for the main bearing. Manufacturers are a narrow, specialized group with precise and proven production technology, with the possibility of increasing production capacity and increasing the level of supply from Poland.
14	Rotor spinner and auxiliary systems	50%	90%	Existing competences in Poland. The barrier to increasing the share is production capacity. Possible development by increasing the scale of current manufacturers or new investments to the estimated level of 90% of supply from Poland.
15	Tower production	70%	90%	Production carried out by two entities in Poland. Both groups have limitations in terms of production capacity - the number and dimensions of individual sections of the tower. A barrier to development are investments in new production lines, intended to increase the number of pieces and to expand the scope of production capabilities to larger and heavier sections of the towers. An additional difficulty is the possession of adequate land for a finished goods warehouse - squares and logistical infrastructure enabling the transport of newly designed sections by means of specialized vehicles. Possible development through investments of existing or new manufacturers, also as a potential synergy with offshore wind energy.
16	Primary steel	50%	70%	Steel can be delivered by steel mills in Poland. They are certified by turbine manufacturers. The limitation is the production capacity - the number and width, thickness, and thus, the weight of the steel plate. Along with the expected stabilization of the plate manufacturer in Poland, we expect solutions that give opportunities to increase the share of sheet metal within ranges that do not require changing the technologies currently applied.
17	Steel flanges	0%	40%	Currently, steel flanges are not manufactured in Poland. There are heavy industry plants with the necessary "forging" and hot joining technology for steel profiles. Currently, the manufacturers' market is dominated by Asian concerns. The barrier to starting production is investments in machines, furnaces, building a supply chain for the input material, mastering and stabilizing the technology. However, international metallurgical concerns with their plants in Poland have production potential.
18	Tower internals	70%	90%	The high percentage of the share results from the very large group of enterprises, including small and medium-sized enterprises, which manufacture specialized elements for the needs of onshore wind energy. In this group, barriers to development concern local enterprises, mainly investments in machinery and land. Some of the equipment components are not manufactures due to patents held by foreign manufacturers. Possible development through investments of existing or new manufacturers, also as a potential synergy with offshore wind energy.
19	Transport and turbine installations	100%	100%	A very well-established position of enterprises in this sector. Knowledge of local subcontractors, of the characteristics of municipal areas and roads. As the number of installations increases, there will be a demand for new equipment with generally higher technical specifications. There may be unexpected competition from other countries neighboring Poland, where turbines of a newer generation are being installed and require more modern technical equipment.

Source: own study

3. **Construction and balance of plant phase** (90% share of Polish industry). All preparatory and construction works are carried out by experienced companies - most of them using 100% Polish resources. Implementation is very often based on local construction companies. In accordance with the law, the electrical connection must be made by the energy operator.

Due to the development of onshore energy in previous years, numerous entities were established in Poland, which strengthened over time in terms of technology and organization. However, due to the „freezing" of investments in onshore wind energy in the last few years, some of these have reduced their production capacity, and some continue to export. All domestic entities that carry out the works listed below are in a privileged position (nearly 100% domestic contribution):

- the entire development phase,
- turbine transport and installation,
- construction and balance of plant phase.

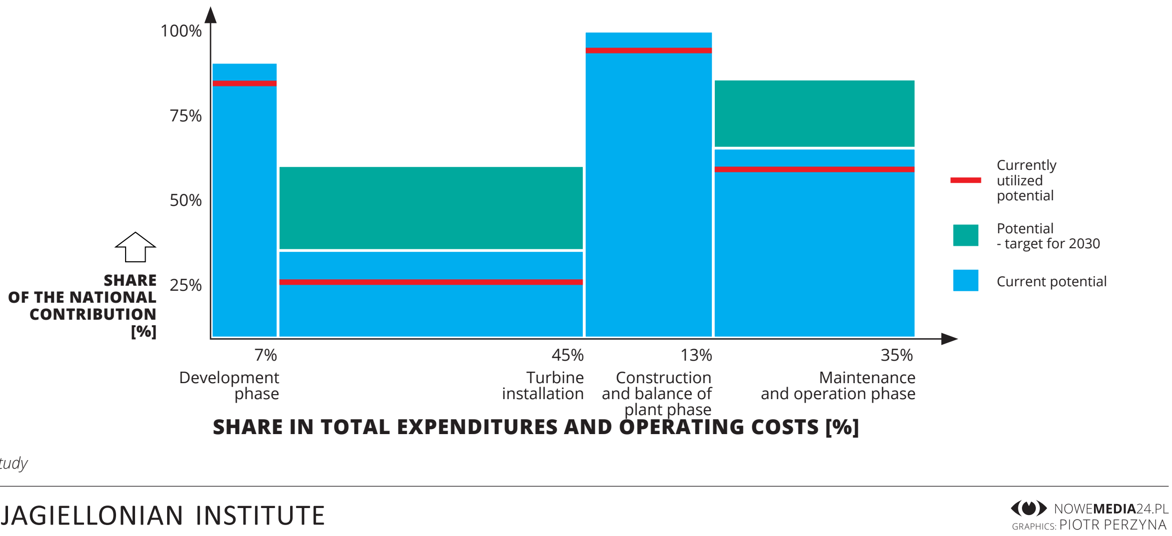
Manufacturers of the following components are a significant group with moderate and large shares in the domestic contribution:

- steel elements of equipment, these manufacturers are currently fulfilling export orders,
- large-size elements, such as wind towers, casings, blades, bedplates - with the technology at their disposal, currently manufacture for export, and the location in Poland will significantly reduce the cost of transport to wind farms,
- specialized in control systems.

The third group, which is not represented in large numbers by domestic manufacturers, is specialized turbine components and turbine assembly as well as support systems of significant importance in the value chain - where increasing the share in the local supply chain can be achieved through investments of international technology concerns:

- gearbox,
- the entire spectrum of bearings,
- generator,
- assembly of the nacelle and rotor.

FIG. 13. SHARE OF NATIONAL CONTRIBUTION IN POLISH ONSHORE WIND FARM PROJECTS



own study

7.2 Study of selected projects

7.2.1 Development of the Polish wind energy supply chain based on the experience of Sevivon

The activities of Sevivon sp. z o.o. include comprehensive development of wind farms and photovoltaic farms from greenfield to the turnkey construction stage. Since 2007, Sevivon has been successfully implementing projects in Poland. As part of these projects, wind farms with a total capacity of approx. 330 MW have been built to date. The company operates on the basis of a strong partner network built over the years, in which the main role is played by a group of experienced experts with specialist industry knowledge.

Sevivon sp. z o.o. is a Polish company owned by WKN GmbH, which began its development activity in Poland in 2000. WKN GmbH is a 100% subsidiary of PNE AG. The PNE and WKN brands have been present in the PNE Group since 2013 and are growing together as a „Clean Energy Solutions Provider". The PNE Group is an internationally operating wind energy pioneer and one of the most experienced developers of onshore and offshore wind farm projects. On land, it has built wind farms with a capacity of 3,100 MW and sold projects with a total capacity of 2,644 MW offshore.

FIG. 14. JASNA WIND FARM

Source: Sevivon sp. z o.o.

Project Jasna

The Jasna wind farm project, with an installed capacity of 132 MW, consisting of 39 Vestas V126-3.3 / 3.45 MW turbines, was built in 2019-2021 in the Pomeranian Voivodeship. The Jasna wind farm is currently the largest wind farm in Poland with one connection point.

Unique challenges faced by the contractors of the farm

A particular structural challenge was the size of the wind farm, i.e. 39 turbines with a north-south extension of approx. 17 km, and the connection route to the PSE Gdańsk-Błonia station, which is approx. 70 km long and crosses two rivers: the Vistula and Nogat. As part of the high-voltage transmission line, approx. 250 boreholes (HDD-controlled drilling) had to be made, including the longest in Poland, almost 1.5 km long, under the Vistula River. In addition, many innovative electrical power engineering solutions were applied, implemented for the first time in Poland.

Polish companies in the design and construction of the Jasna wind farm

The implementation of the Jasna wind farm project was possible thanks to the involvement of local Polish companies at every stage of design and construction. During the implementation of the investment, Sevivon cooperated with highly specialized experts, including an institute dealing with electric energy calculations, a company specializing in drilling services, design offices, environmental experts, a Polish cable manufacturer and a foundation contractor.

7.2.2 Development of the wind industry supply chain in Poland - a case study of cooperation between Vestas and ConverterTec

Vestas Wind Systems A/S has been leading the stimulation of the onshore wind industry supply chain in Poland with almost €800 million spent on Polish suppliers and subcontractors over the past decade. Vestas spent €185 million in 2020 alone, and currently employs over 500 people in Poland, with thousands more employed throughout the Polish supply chain due to Vestas' investments. Vestas sees huge opportunities in suppliers from Poland, across power electronics, towers, castings, rotor blades and other components as well as in pre-assembly and service.

FIG. 15. INSTALLATION OF ROTOR BLADES

Source: Vestas Wind Systems A/S

Control panels - critical elements

Control panels are a critical element of the turbine's electrical components. These components are used throughout Vestas' portfolio and they are similar for both onshore and offshore wind, creating potential market synergies for their manufacturer. Each one of Vestas' wind turbines includes at least five control panels, with its latest offshore wind turbine, the V236-15.0 MW, involving eight control panels at various locations and performing various control functions.

ConverterTec - Polish manufacturer of control panels

ConverterTec's major manufacturing sites are located in Niepołomice (Krakow Area), Poland with planned manufacturing expansion to Brzegi (Krakow area), with the company now employing more than 150 people in Poland.

FIG. 16. CONVERTERTEC BRZEGI, KRAKOW, EXPANSION OF PRODUCTION CAPACITY

Source: ConverterTec

Vestas – ConverterTec - a success story of Polish wind cooperation

Vestas has been partnered with ConverterTec in Poland in onshore wind since 2016. Thanks to the foresight and support from the Polish government, ConverterTec has located all its manufacturing facilities producing its highly technical control panels in Poland. In fact, 100% of Vestas' global spending with ConverterTec takes place in Poland. ConverterTec has become one of the leading control panel suppliers for Vestas globally, with a strong Polish base and delivering significant benefits for local communities in Niepołomice (Krakow Area), Poland through jobs and associated investment. The collaboration between Vestas and ConverterTec is one illustration of how local Polish companies can become regionally and globally competitive, opening avenues for expanded collaboration as the wind industry becomes one of the pillars of the global clean energy transition.

8. Determining the potential, level and employment structure (direct jobs) in the domestic sector of the supply chain for onshore wind farms

8.1 Employment in the supply chain

In 2020, despite the COVID-19 pandemic, there was a historic increase by 93 GW of new wind capacity installed worldwide. This growth is due to the development of onshore and offshore wind energy. This is a clear signal that, in the coming years, the industry and the global supply chain will be characterized by an upward trend in production and services for wind farms, and thus will create new, high-quality jobs.

Based on the IRENA report[14], working towards the supply chain for onshore wind energy means 5.24 jobs per 1 MW over the 25 years of life of a typical 50 MW onshore wind project, and this is only a national effect (excluding exports).

Jobs generated by wind farm projects cover the full value chain for this sector, including, inter alia, technical and design skills as well as soft skills. The wind energy sector provides a range of jobs distributed along a diverse value chain. For wind-powered countries, the potential to generate income and create jobs will depend on the extent to which local industries in different segments of the value chain can leverage existing production and service facilities and create new ones. Additionally, an analysis of the person days and skills required in each segment of the value chain is needed, essential to assess the job creation potential and the availability of skills needed to develop the national sector.

Researching the availability of raw materials, materials, semi-finished products and equipment needed to manufacture components can help in deciding which segments of the value chain should be located where. Depending on the availability of materials and services, domestic production of components would effectively support industries essential to wind energy. For example, in some countries there is a local steel or aviation industry, which is the basis for the development of the wind industry, as evidenced in Poland by steel mills and aviation plants which are now an important link in the production of materials for towers and blades. In 2008-2015, the Polish steel plant located in Częstochowa was a very important supplier of sheets for wind tower manufacturers for onshore wind energy. This factor made it possible to maintain production with a very slowed-down shipbuilding sector, which was an important customer of the plant before 2011.

The wind industry is involved in creating indirect jobs for people employed by suppliers and sub-suppliers. The so-called induced jobs related to expenditure generated by direct and indirect employment, e.g. personnel employed in hotels and restaurants located near the project sites and serving project employees, are also important. Tab. 17 lists jobs generated by onshore wind projects over a 25-year operational period, broken down by components, phases of construction and operation of the farm, and an indication of exemplary occupations and the necessary involvement in man-days.

14 IRENA (2017), Renewable energy benefits: Leveraging local capacity for onshore wind, International Renewable Energy Agency, Abu Dhabi.

TAB. 17. JOBS GENERATED, PER 50 MW, NECESSARY TO SUPPORT ONSHORE WIND ENERGY PROJECTS WITH A 25-YEAR SERVICE LIFE

Components / segments of the supply chain in onshore wind energy	Sample activities	Sample professions	Required man-days (% of the total)	Required full-time jobs (% of the total)
Planning and project development	• Feasibility studies • Environmental impact assessment • Community involvement • Technical projects • Project development	• Legal, property and tax experts • Financial analysts • Engineers • Environmental and geotechnical scientists	2,580 (3,8%)	10,3 (3,8%)
Production of components and systems	• Manufacture and assembly of turbines, blades and towers • Production of monitoring and control systems	• Factory workers • Quality control • Marketing and sales • Engineers • Project managers	18,967 (27,9%)	73 (27,9%)
Transport	Transport of components	• Drivers • Logistics experts • Technical staff	875 (1,3%)	3,4 (1,3%)
Installation	• Preparation of the project's site • Construction work • On-site assembly of components	• Builders • Technical staff • Engineers • Health and safety experts • Logistics and quality experts	26,800 (39,4%)	103,1 (39,4%)
Grid connection and commissioning	• Wiring and grid connection • Project launch	• Builders • Technical staff • Engineers • Health and safety experts	7,680 (11,3%)	29,5 (11,3%)
Operation and maintenance (O&M)	Ongoing operation and maintenance of the project during the operation period (usually 25 years)	• Operators • Engineers • Builders • Technical staff • Lawyers • Project managers	2,665 (3,9%)	10,3 (3,9%)
Decommissioning / liquidation	• Decommissioning or repowering • Dismantling the project on site • Component disposal and recycling • Cleaning the area	• Builders • Technical staff • Drivers • Engineers • Environmental scientists • Health and safety experts	8,420 (12,4%)	32,4 (12,4%)
		TOTAL:	**67 987 days**	**262 employees**

Source: IRENA, 2017

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GRAPHICS: PIOTR PERZYNA

The production of a 50 MW wind farm's main components (blades, turbines and steel towers) requires approximately 19,000 man-days. The turbine with its components is the part that requires the greatest commitment per man-day (almost 50% of the total). Both blade and tower production require a further 24% of the total man-days requirement.

A large part of the job requirements and skills needed to fabricate major components are low- to medium-skill. It is estimated that 66% of the work required (approximately 12,500 man-days) for the production of turbines is factory work, with medium or low qualifications related to wind energy. The production of high-tech components such as gearbox, generator and electronics also requires highly specialized skills.

TAB.18. HUMAN RESOURCES REQUIRED TO PRODUCE THE MAIN COMPONENTS OF A 50 MW WIND FARM (MAN-DAYS) AND BREAKDOWN INTO MAJOR COMPONENTS (TURBINE, BLADES, TOWER, MONITORING AND CONTROL SYSTEM)

TYPE OF HUMAN RESOURCES	Turbine	Blades	Tower	Monitoring and control system	Total by occupation
Factory workers	5 890	3 400	2 850	300	12 440
Health and safety experts	620	125	300	30	1 075
Logistics experts	620	125	300	15	1 060
Quality control experts	620	125	300	15	1 060
Marketing and sales staff	480	290	230	45	1 045
Production engineers	480	277	232	15	1 004
Administrative staff	480	113	230	45	868
Project managers	185	110	90	-	385
Telecommunications and IT engineers	-	-	-	15	15
Regulatory and standardization experts	-	-	-	15	15
Total:	**9 375 (49%)**	**4 565 (24%)**	**4 532 (24%)**	**495 (3%)**	**18 967**

Source: IRENA, 2017

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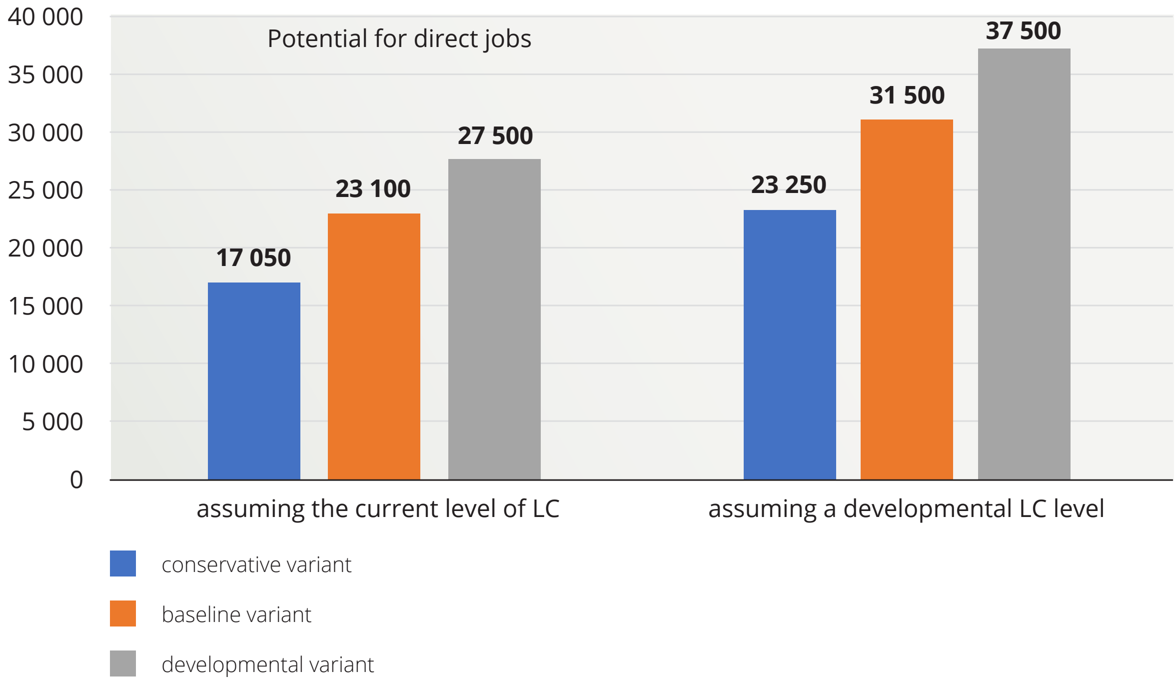
GRAPHICS: PIOTR PERZYNA

The chart below shows the potential of direct jobs according to the options presented in sections 4.2, 4.3 and 9.1. of the report and, additionally, assuming the current and potential level of local content in Poland.

FIG. 17. POTENTIAL OF ADDITIONAL DIRECT JOBS ACCORDING TO THE ONSHORE WIND DEVELOPMENT VARIANTS, ASSUMING THE CURRENT AND POTENTIAL LEVEL OF LOCAL CONTENT BY 2030



Source: own study

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GRAPHICS: PIOTR PERZYNA

Detailed data on the estimated potential of direct jobs, broken down into components and segments of the supply chain for wind farms, is presented in Tab. 19.

TAB. 19. THE POTENTIAL OF ADDITIONAL DIRECT JOBS BY COMPONENTS / SEGMENTS OF THE SUPPLY CHAIN IN ONSHORE WIND FOR THE BASELINE SCENARIO

Components / segments of the supply chain in onshore wind energy	Potential for direct jobs assuming the current LC level	Potential for direct jobs assuming the developmental level of LC
Planning and project development	908	1 243
Production of components and systems	6 490	8 810
Transport	303	410
Installation	8 993	12 322
Grid connection and commissioning	2 640	3 560
Operation and maintenance (O&M)	908	1 243
Decommissioning / liquidation	2 860	3 910
Total	**23 100 employees**	**31 500 employees**

Source: own study

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Along with the dynamic development of wind energy in Poland and in the world, companies from the supply chain for onshore and offshore energy will be looking for employees with various levels of specialization and skills. Analyses of the employment level in onshore wind energy show an upward trend, which is also confirmed by the survey of the questionnaires sent. If the developmental variant is implemented, the industry may soon face the challenge of emerging competency gaps and the lack of access to specialized staff necessary to develop and service new projects.

There are gradual changes taking place in the education and training system in the field of renewable energy. Education of future specialists in RES has not yet replaced education related to coal-based energy, however, there is an upward trend and there are many interesting proposals for people willing to develop professionally in this area. In addition to dedicated fields of study at universities, there are many training centers in Poland that allow you to obtain the necessary authorizations and competencies, often confirmed by the required certificates, including work at heights or fire safety rules. In order to prepare for the development of the labor market, other universities are opening first- and second-cycle studies as well as postgraduate studies. The Faculty of Ocean Engineering and Ship Technology at the Gdańsk University of Technology offers post-graduate studies in „Offshore Wind Energy". The Maritime University of Szczecin, on the other hand, is launching 3.5-year first-cycle studies in the field of „Industrial engineering and offshore wind farms, specializing in the operation of wind farms".

In addition to these specializations in the offshore sector, but also onshore, you can also find more managerial courses, such as green energy management at the Warsaw School of Economics and Postgraduate Studies proposed by the Institute of Renewable Energy and the Warsaw University of Technology: „Renewable energy for business: technologies, economics, implementations". Many universities also offer wider studies in the field of renewable energy sources, eco-energy and energy management. At the level of secondary schools, technical and vocational schools, specializations related to RES are created, and market demand as well as attractive, well-paid jobs will be the best motivation to educate in this field.

8.2 Supply chain decarbonization

Wind energy is currently the least impactful source of energy generation available. According to the IPCC Report, CO_2 emissions in the life cycle are[15]: 11gCO_2eq / KWh for onshore wind energy, 12 gCO_2eq / KWh for offshore wind energy. In comparison, in the case of nuclear power plants, the greenhouse gas emissions in the life cycle are at the level of 12gCO_2eq / KWh, photovoltaics at the level of 48 gCO_2eq / KWh, and the energy produced from biomass obtained from dedicated crops and RES installations is 230 gCO_2eq / KWh. On the other hand, the emission level in the life cycle of a coal-fired power plant is 820 CO_2eq / KWh.[16]

Despite the low level of LCOE emissions for onshore wind energy, the industry faces the challenge of becoming carbon neutral throughout the entire wind farm supply chain. This challenge results from the provisions of the European Green Deal, i.e. zero net emissions by 2050. Mitigating the environmental impact in the production of components forces manufacturers to start cooperation with suppliers and support them by decarbonizing their own production and building their own decarbonization plans

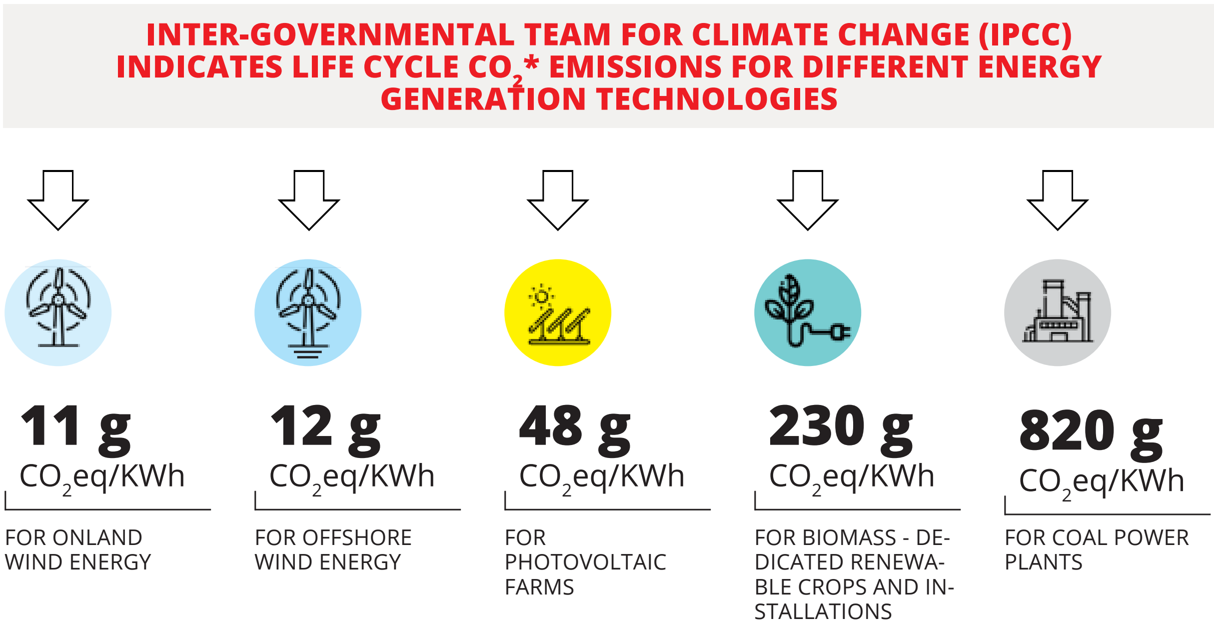
15 Greenhouse gas emissions of selected electricity generation technologies in g CO2eq1, per 1 kWh (median). Life cycle emissions additionally include methane emissions and the albedo effect.

16 https://www.ipcc.ch/sr15/.

Analyses of the environmental impact and emissivity from the point of view of onshore wind farm life cycle assessment show that the highest CO_2 emission rates occur during the extraction of raw materials, their transport and the production of components. The production phase is responsible for almost 90% of the total life cycle emissions (LCA indicated by the IPCC 11gCO_2eq / KWh) of the wind farm[17]. In contrast, transport-related activities account for 5.6% of total CO_2 emissions, and 3.5% are emissions generated during the farm service period.

FIG. 18. EMISSIVITY FOR VARIOUS ENERGY GENERATION TECHNOLOGIES

WIND ENERGY IS THE LEAST ENVIRONMENTALLY IMPACTFUL ENERGY SOURCE AVAILABLE



* Greenhouse gas emissions of selected electricity generation technologies in CO_2 eq, per 1 kWh (median). Life cycle emissions additionally include methane emissions and the albedo effect.

Source: 2018 IPCC Special Report - Global Warming of 1.5 ° C

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The production of towers for wind farms is the main source of carbon dioxide emissions and is responsible for 51% of gCO_2 emissions/ kWh[18] of all manufactured components, and therefore a great place to start implementing decarbonization projects. Steel, the key material used to build towers, is the main source of carbon dioxide emissions worldwide. In addition to the production of the tower, the following are responsible for significant CO_2 emissions: foundations 20%, nacelle 16% and the blade manufacturing 10% share in the emissions [19].

The key element in this situation are the obligations of enterprises to develop plans to achieve zero net emissions in their entire activity, but also the implementation of decarbonisation solutions with component suppliers.[20]. For the wind industry, further innovation is needed to find sustainable and cost-competitive

17 Al-Behadili SH, El-Osta WB Dernah Wind Farm Life Cycle Assessment (Libya) Renew Energy, 83 (2015), pp. 1227-1233.

18 Life cycle assessment of an onshore wind farm located on the northeastern coast of Brazil (Article) Oebels, K.B., Pacca, S.

19 https://www.sciencedirect.com/science/article/pii/S2352484720315298.

20 https://www.evwind.es/2020/12/20/decarbonizing%E2%80%AFthe%E2%80%AFsupply%E2%80%AFchain/78674.

ways to produce low carbon or "green" steel. One of the effective methods of implementing changes leading to the reduction of CO_2 emissions is to oblige entrepreneurs to disclose their own emissions, and additionally, to set targets for reducing carbon dioxide emissions. The production of wind turbines, foundations, cables, substations and other components should ultimately be manufactured using 100% renewable electricity. Only then will we be able to talk about zero emissions in 2050.

Referring to the entire life cycle of a wind farm, it can be concluded that not only improvements in logistics, transport, the use of energy mixes in production, but also more efficient production of elements and components, the use of modern materials and innovative construction techniques can reduce CO_2 emissions and energy demand in the manufacturing process. In order to implement innovative solutions related to the decarbonization of production processes and transport, it is worth paying attention to a number of financial instruments supporting the transformation prepared by European institutions (section 8.3.).

In the decommissioning stage, the key task is to design innovative solutions that will reduce energy consumption and CO_2 emissions by reusing equipment and recycling critical materials at the end of the life cycle - this will ultimately lead to a reduction in raw material extraction and the amount of total consumption of limited resources. The key is to design and build a circular economy, which will result in non-obvious changes on the market, the creation of new entities, reduction of supply shortages and independence from imports.[21]

The WindEurope report, prepared in cooperation with Cefic and EuCIA, on "Accelerating Wind Turbine Blade Circularity"[22] shows that although the industry is doing well in recycling wind turbines that are already decommissioned, further research and development is needed to commercialize innovative solutions. Currently, about 85 to 90% of the total mass of wind turbines is recycled and can be reused. Processing of wind turbine blades made of composite materials[23] is an area that still needs to be changed.

In May 2021, wind turbine manufacturer Vestas unveiled a new technology that allows the complete recycling of wind turbine blades. Within three years, the company plans to launch the production of blades on an industrial scale in accordance with the developed technology. In addition, in January, Vestas announced a new sustainability strategy with a commitment to producing waste-free wind turbines by 2040 as one of the goals.[24]

8.3 Analysis of investments in onshore wind farms in the context of the National Reconstruction Plan and other European Union programs, possibilities and sources of financing for the development of the national supply chain

8.3.1 National Reconstruction Plan (NRP)

The **Recovery and Resilience Facility (RRF)** aims to mitigate the economic and social impact of the COVID-19 pandemic and help European economies and societies become more sustainable, resilient and better prepared for the challenges and opportunities of green and digital change.

21 https://www.sciencedirect.com/science/article/pii/S2352484720315298#b22.

22 Accelerating Wind Turbine Blade Circularity, Wind Europe, Cefic and EuCIA, Maj 2020.

23 https://www.teraz-srodowisko.pl/aktualnosci/recykling-lopaty-turbin-wiatrowych-raport-8792.html.

24 https://www.vestas.com/en/media/blog/sustainability/20200511_zero-waste-turbines#!

Each country has prepared a separate National Reconstruction Plan containing detailed information on the allocation of funds for reforms, programs and investments. Under the Instrument, 37% of the allocation will be to activities related to green transformation. It consists of the Recovery and Resilience Facility and smaller funds and programs.

Under the Instrument and the approved NRP, Poland will receive approximately EUR 58 billion (approximately PLN 260 billion), of which EUR 23.1 billion are non-returnable grants, while the budget for low-interest loans is EUR 34 billion.

Implementation of the five components which constitute the areas of concentration of reforms and activities will contribute to achievement of the NRP's objectives. Component B of the NRP: green energy and reduction of energy consumption will amount to approx. PLN 28.6 billion, and funds from these sources will be used, inter alia, for the energy transformation. Due to this, Poland entered into the NRP investments in offshore wind farms and the improvement of conditions for the development of renewable energy sources.

In the grant part, the provisions of the document in the area of energy were supplemented, for example, with a reform related to the elimination of barriers to renewable energy sources and facilitating the implementation of investments in the field of onshore wind farms. The aim of the changes to regulations is to provide municipalities willing to place such infrastructure on their territory greater flexibility in determining the location of onshore wind farms.

8.3.2 The European Green Deal, or Green Deal

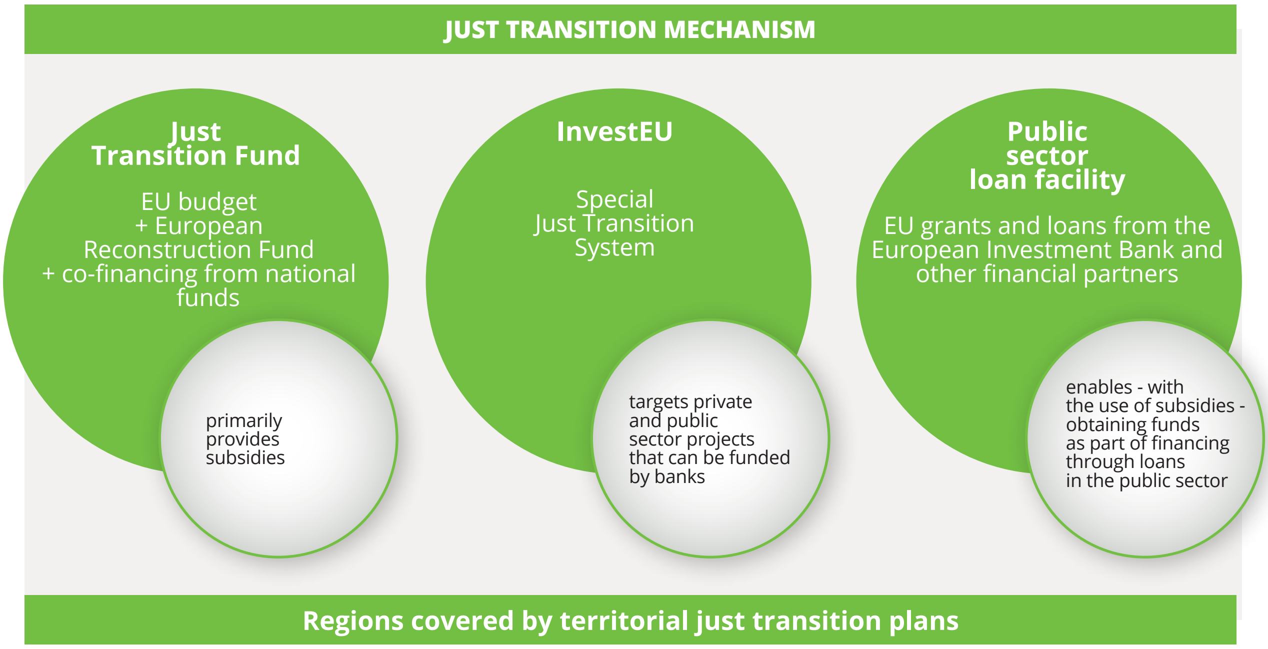
The EGD is an expression of Europe's aspirations to be the first climate-neutral continent. This program aims to help transform the EU into a modern, resource-efficient and competitive economy with net-zero greenhouse gas emissions in 2050. A part of this policy is „Sustainable Industry", which is the shift to more sustainable and environmentally friendly production cycles. The EC emphasizes that in order to achieve the EU's climate and environmental goals, a new industrial policy based on a circular economy and the implementation of measures leading to decarbonization and modernization of energy-intensive industries such as steel and cement production are necessary. In line with the Commission's proposal for the next Multiannual Financial Framework, specific actions will be included in each program to strengthen the link between the implementation of the EU budget and the goal of a more environmentally friendly, emission-free Europe. For example [25]:

- The Cohesion Fund and the European Regional Development Fund (in the 2021-2027 perspective) will invest at least EUR 108 billion in climate and environmental projects - this is over 30% of the total financial envelope;
- at least 35% of the Horizon Europe budget (or around EUR 35 billion) will be dedicated to supporting climate-related goals;
- at least 60% of the Connecting Europe Facility budget (approximately EUR 30 billion) supporting transport, energy and digital infrastructure will be dedicated to supporting climate objectives. As part of the **energy sector**, cross-border projects in the field of renewable energy will be supported, including projects on innovative solutions as well as renewable energy storage and their development.

25 Investment Plan for the European Green Deal, Brussels, 14/01/2020 COM (2020) 21.

The **Just Transition Mechanism** (part of the EGD) consists of three pillars and is intended to be a comprehensive solution to support the ability of Member States to finance activities related to the energy transition. This mechanism provides **EUR 100 billion** for Member States with the possibility of increasing this amount. The Just Transition Mechanism will allow the implementation of policies by countries and regions that will present well-thought-out action plans in 2021, of the so-called National Transition Plans and of Regional Just Transition Plans. Transformation plans must be developed in close collaboration with the regional community groups concerned.

FIG. 19. STRUCTURE OF THE JUST TRANSITION MECHANISM



European Court of Auditors Opinion No 8/2020

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The first pillar of the Just Transition Mechanism is the Just Transition Fund, which is responsible for resources worth **30-50 billion Euro**. The second pillar is InvestEu with a budget of **EUR 30-40 bln**, and the third pillar, the loan mechanism under the European Investment Bank, amounts to **EUR 25-30 bln**.

In the years 2021-2027, over EUR 4.4 billion is to be allocated to Poland from the Just Transition Fund. The fund aims to help reduce the negative social, economic and environmental effects of the energy transformation. The Polish government is currently negotiating with the European Commission to ensure that support from the EU Just Transition Fund goes to the six regions most exposed to the effects of the energy transformation: Śląskie, Dolnośląskie, Wielkopolskie, Lubelskie, Łódzkie and Małopolskie.

The Just Transition Fund will benefit areas with high employment levels in the anthracite, lignite, oil shale and peat production sectors, as well as areas with high greenhouse gas intensity industries that are disrupted or significantly reduced as a result of transformation. The level of support will reflect the scale of the challenges in these areas, in terms of both the needs for economic diversification and the transformation towards zero and low carbon activities with high growth potential, and the need to re-qualify workers to equip them with the necessary skills to undertake a new job.

The following entities will be able to apply for funds from the Just Transition Fund: SMEs, startups, business incubators, entities providing consulting services, entities conducting research and innovation activities, entities implementing technologies for clean energy and renewable energy sources.

A special system of just transformation of regions within the framework of the **InvestEU Fund**[26] will be launched to mobilize additional investment for the hardest hit regions. This will allow for the introduction of new economic activities to replace those that must be phased out due to their impact on the climate and environment. With a broader definition of investment eligibility under InvestEU, the mechanism will allow investments in a wider range of projects than the Just Transition Fund.

The InvestEU Fund is a guarantee mechanism for financial institutions. Its task is to provide a guarantee of financing for investment projects. By increasing the risk-bearing capacity, it is possible to launch long-term investments without the need to involve the budget of a given country and thus not generate public debt[27].

InvestEU will finance, inter alia, energy and transport infrastructure projects, including gas infrastructure and district heating, but also projects in the areas of decarbonization, regional economic diversification, social infrastructure and skills. It will also allow affected sectors to adapt more quickly to climate-friendly production methods. Financing from InvestEU can be used to support profitable investment in these areas and will complement and generate synergies with the Just Transition Fund.

In the context of the challenges of the European Green Deal and energy transformation, it is worth focusing on clusters that have been identified as entities implementing the Green Deal in small and medium-sized enterprises. Clusters support economic development, mainly by networking entrepreneurs and the world of science, as well as connecting large enterprises with small and medium-sized ones. Thanks to these advantages, small businesses have greater opportunities to gather the resources necessary to achieve a critical mass for the implementation of new “green” technological solutions.

26 Investment Plan for the European Green Deal, Brussels, 14/01/2020 COM (2020) 21.

27 https://www.gov.pl/web/fundusze-regiony/fundusz-investeu.

8.3.3 „New Energy Technologies” program

The National Center for Research and Development has approved a strategic research and development program called „New Energy Technologies”. The main objective of the program is to support the achievement of Poland’s climate neutrality by implementing solutions increasing the country’s energy security and increasing the competitiveness of the Polish economy. As a result, the share of energy from renewable sources in the overall energy mix of the country will increase by 20-50% (compared to the level from 2020).

The strategic national and European goals in the Program will be achieved through the implementation of research and development tasks with high innovative potential and a high degree of technology advancement (TRL 8-9) in six technological areas, including the T2 area. Onshore and offshore wind energy. The program was established for the period of 2020-2029, while the NCBR funds for the Program, amounting to PLN 800 million, come from a targeted subsidy for the implementation of strategic research and development programs. Within the area of T.2.1. Onshore wind energy has the following two sub-measures defined:

- T2.1.1 Smart wind farm,
- T2.1.2. Development of technologies for disposal or recycling of wind farm components.

8.3.4 Perspective 2021-2027, national programs

The cohesion policy for 2021-2027 is to include the following funds: The European Regional Development Fund (ERDF), the Cohesion Fund (CF), the European Social Fund (ESF) and the Just Transition Fund (FST- section 8.3.2). Detailed programs are currently under development.

European Funds for Infrastructure, Climate, Environment (FEnIKS) - successor of the Infrastructure and Environment Program (POIiŚ). The program will contribute to the development of a low-emission economy, environmental protection as well as counteracting and adapting to climate change. FEnIKS will also support transport investments and co-finance health protection and cultural heritage. The planned budget is over EUR 25 billion.

European Funds for Modern Economy (FENG) - the program is a continuation of two previous programs: Innovative Economy 2007-2013 (POIG) and Intelligent Development 2014-2020 (POIR). FENG will support the implementation of research and development, innovative and projects that increase the competitiveness of the Polish economy. The program will be available to, among others, enterprises, institutions from the science sector, consortia of enterprises and institutions in the business environment, in particular innovation centers. The planned budget is approximately EUR 7.9 billion.

8.3.5 2021-2027 perspective, programs managed by EU bodies

8.3.5.1 Horizon Europe 2021-2022

Horizon Europe is the EU's new flagship program for research and innovation, providing funding to beneficiaries in 2021-2022[28]. The program is investing € 95.5 billion in research and innovation to shape Europe's future, making it the most ambitious research and innovation program ever launched by the EU. It is estimated that 36% of the funds will support climate action. Under the program, there will be many competitions related to innovation in the field of wind energy[29].

For example, HORIZON-CL5-2022-D3-01-02 is a fund of 40 million Euro that can be spent on research to demonstrate innovative materials, supply cycles and recycling technologies to increase the overall circulation of wind energy technology and reduce the primary consumption of critical raw materials .

8.3.5.2 CINEA – Wind Energy

The Executive Agency for Innovation and Environment[30] allocates funds for the implementation of large-scale projects leading to the reduction of CO_2 emissions with a planned budget of EUR 2.5-7.5 million (60% capex subsidy). The funds are intended for private, public or international organizations, and can be applied for individually or as a consortium. CINEA can finance breakthrough technologies, processes or products for:

- energy-intensive industries, including substitute products (e.g. hydrogen). Actions supporting innovation in the field of low-emission technologies and processes in sectors listed in Annex I to the ETS Directive, including environmentally safe capture and disposal of CO_2 (CCU), which will contribute to limiting climate change;

- carbon capture and storage (CCS) / warehousing. Activities that help stimulate the construction and operation of projects aimed at the environmentally safe capture and geological storage of CO_2;

- production and use of renewable energy, including component manufacturing plants and energy storage. Activities that stimulate the emergence of innovative solutions used in the construction and operation of renewable energy sources.

The total amount of funding that onshore wind supply chain companies can apply for is currently difficult to estimate. National programs from the financial perspective for 2021-2027 are currently in the drafting phase, while European programs such as Horizon, CINEA can also be applied for by enterprises from all European countries. In terms of project phases, components and services, companies can receive funding for many activities, e.g. decarbonization of production, transport, innovation in technologies, energy storage or building a circular economy.

28 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-1-general-introduction_horizon-2021-2022_en.pdf

29 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-8-climate-energy-and-mobility_horizon-2021-2022_en.pdf.

30 CINEA - the European Climate, Infrastructure and Environment Executive Agency.

The scale of funds for the implementation of investments for entrepreneurs is enormous, and the level of their use will have an impact on the economic development of Poland and the estimated share of Polish entrepreneurs in supply chains for the land and sea industries.

8.4 Possible impact of the current scenario for the development of offshore wind farms resulting from the energy strategy for the development of the onshore wind energy supply chain

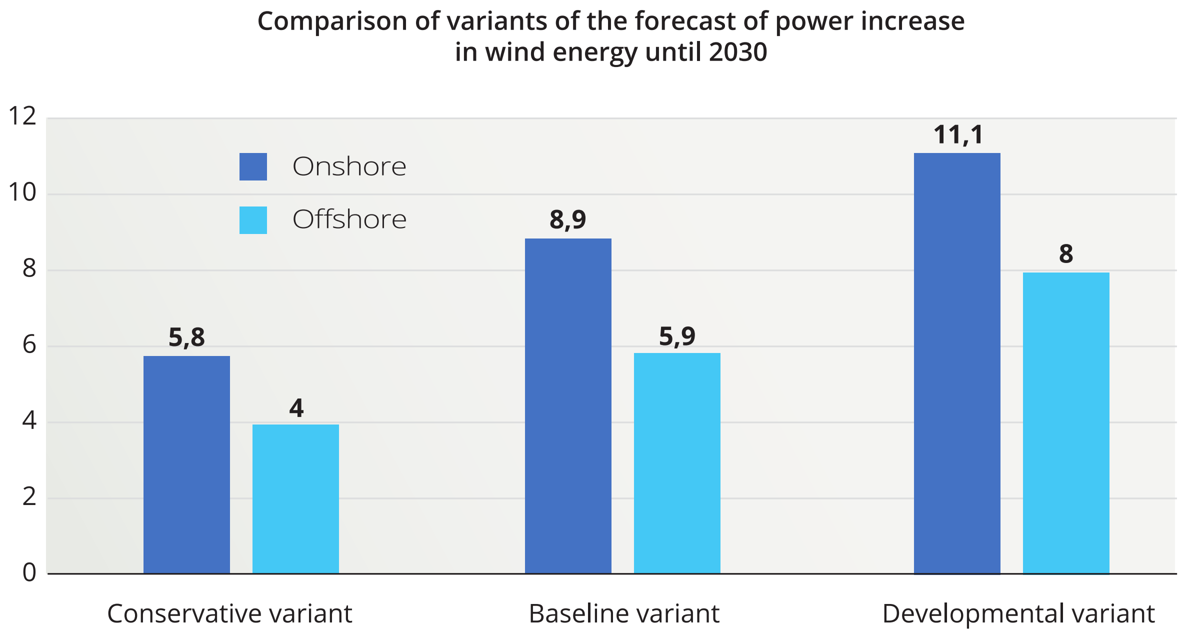
The transition from fossil fuel based energy systems to renewable energy systems is the ‚cornerstone' of the green transition to decarbonize our economic systems and mitigate climate change. Given the urgent need for effective climate change mitigation, diffusion of renewable energy must drastically accelerate. Among the many constraints on the development of renewable energy production, the important role of the supply chain is often overlooked, and synergy in onshore and offshore wind is a good example.

The offshore wind energy (OWE) industry is growing rapidly. Offshore wind resources have great potential and technological solutions are becoming more cost-competitive. Offshore wind energy translates into a reduction in greenhouse gas emission rates and at the same time increases the country's energy security, creates jobs and promotes sustainable development. The dynamics of the development of supply chains for OWE results indirectly from the existing mature and developed offshore wind energy industry. Analysis of the responses of the surveyed companies also makes it possible to determine the growth potential and synergy effect of supply chain development for the wind energy industries.

In the chart below (Fig. 20), forecasts of wind farm power growth scenarios, both at sea and on land, are compiled. The forecasts for offshore wind energy come from the PWEA and PTMEW report, which was prepared at the turn of 2020 and 2021 and presents the possible national share in the supply chain. At the initial stage, the much greater capacity of a single offshore wind turbine collides with investment needs and the lack of qualified staff for the domestic industry and the service and installation industry. The current local content in offshore wind energy estimated in the PWEA / PTMEW report is in the range of 20-25%, while the estimated national share in onshore wind energy is about 55-60%.

Polish onshore wind farm projects, the growth of which in the years 2021-2030 is estimated in the base variant at a total of nearly 8 GW (1 GW per year), may contribute to the construction of production capacity and increase the production capacity of components also required for offshore wind energy.

FIG. 20. COMPARISON OF POWER INCREASE FORECAST VARIANTS FOR WIND ENERGY



Source: own study

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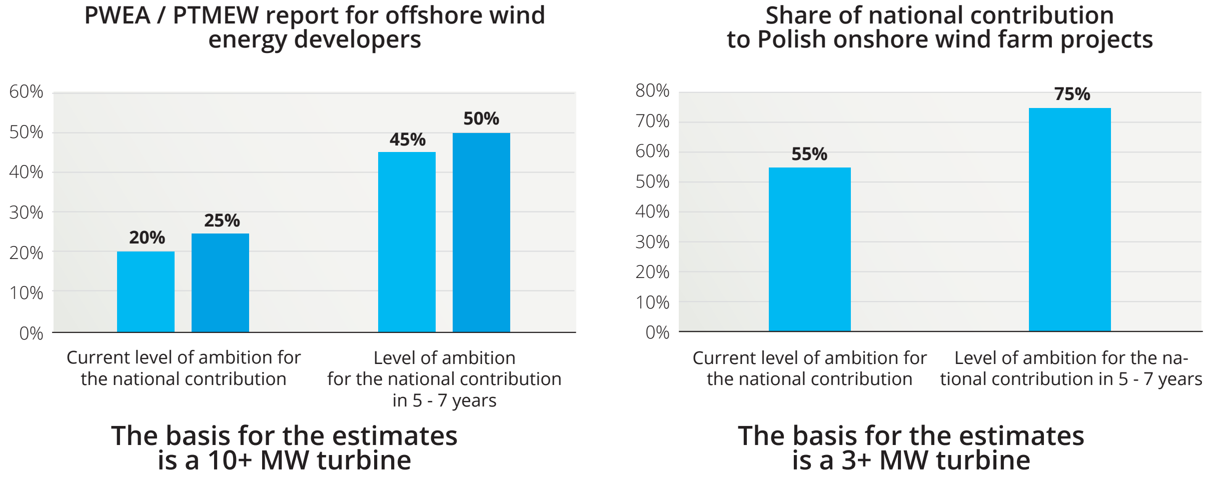
Producers of onshore and offshore wind turbines support their suppliers in increasing efficiency as well as acquiring and servicing new markets. European turbine manufacturers locally create and develop production, sales and R&D centers, through which they develop regional supply chains and employment, thus contributing significantly to the development of the European economy.

A noticeable trend in onshore wind energy is increasing the power of a single turbine to the level until recently used only in offshore farms. This not only makes it possible to increase the efficiency of onshore wind farms but also maintain and even expand existing production capacities with a significant share of local European supply chains. The European wind industry is a global success story that creates high-quality jobs and contributes to the economic growth of European countries.

The offshore wind energy sector can significantly contribute to the growth of the Polish economy, but it requires the involvement of domestic companies in the supply chain. The key to the development of competencies and experience by Polish companies is now participation in the production and provision of services for onshore wind energy. This will enable the achievement of an established position on the wind energy market and expansion into the European market, e.g. by using established production plants that provide smaller components for onshore wind energy. The number of planned offshore wind farms in Germany, Lithuania, Sweden or Great Britain creates great potential for Polish companies planning to start operating in the sector.

For the purposes of this report, a comparison was made of the estimated potential of the national contribution for offshore and onshore wind energy, comparing the data from the PWEA / PTMEW report written at the turn of 2020 and 2021 for offshore wind energy and the calculations for onshore wind farms in Poland presented in the section above.

FIG. 21. COMPARISON OF VARIANTS OF THE NATIONAL SHARE IN WIND ENERGY



Source: own study

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GRAPHICS: PIOTR PERZYNA

The industry manufacturing components and associated devices for wind farms, which has high development potential, can contribute to a faster increase in the production of these components, initially for „unblocked" onshore investments, and then form the basis for the development of supply potential for offshore wind investments. The development of the domestic wind energy market would favor the development of further production companies in this area, and would also build export potential to EU countries and beyond the borders of the EU itself. It is possible to use the significant production potential of the Polish shipbuilding, electromechanical, energy and other industries. Additionally, the development of industry education in the area of onshore wind energy competencies would make a significant contribution to the development of competencies for offshore wind energy.

The participation of Polish companies in both the onshore and offshore wind energy market will enable a reduction in costs through the learning curve and use of the scale effect. This will allow enterprises to compete with foreign suppliers when decisions are made to contract suppliers for wind farms in the Baltic Sea.

The scale of investments in both offshore and onshore wind energy will make it possible to build a supply chain in Poland through the development of domestic enterprises and the location of international companies operating in the industry. Thus, it can bring benefits not only to coastal areas, but also, due to the already developed supply chain in onshore wind energy, to companies from all over the country. Offshore wind energy in Poland may affect the development and reconstruction of the shipbuilding and steel industry and become one of the engines of economic development after 2021, when funds will flow to Poland from the current financial perspective of the European Union and the National Reconstruction Plan. Especially in the first years before the commissioning of the first offshore farms, it is onshore wind energy that can give an impulse to the steel industry, while being prepared for much higher tonnages and dimensions of wind energy structures. Moreover, the development of the sector may become an impulse for the development of the domestic potential of new innovative products, services and solutions. Realization of this potential requires resolve many challenges, but a comprehensive strategy for the development of the wind energy sector and close cooperation between key stakeholders may make Poland one of the leaders of offshore wind energy in Europe.

The EU's energy transformation process is gaining momentum, and decisions on the future shape of the EU's electricity systems need to be taken in the near future. Therefore, there should be a strong and clear financial incentive from the EU, in particular, for investments in transmission infrastructure. There is a need to continue to use existing and well-functioning financial instruments.

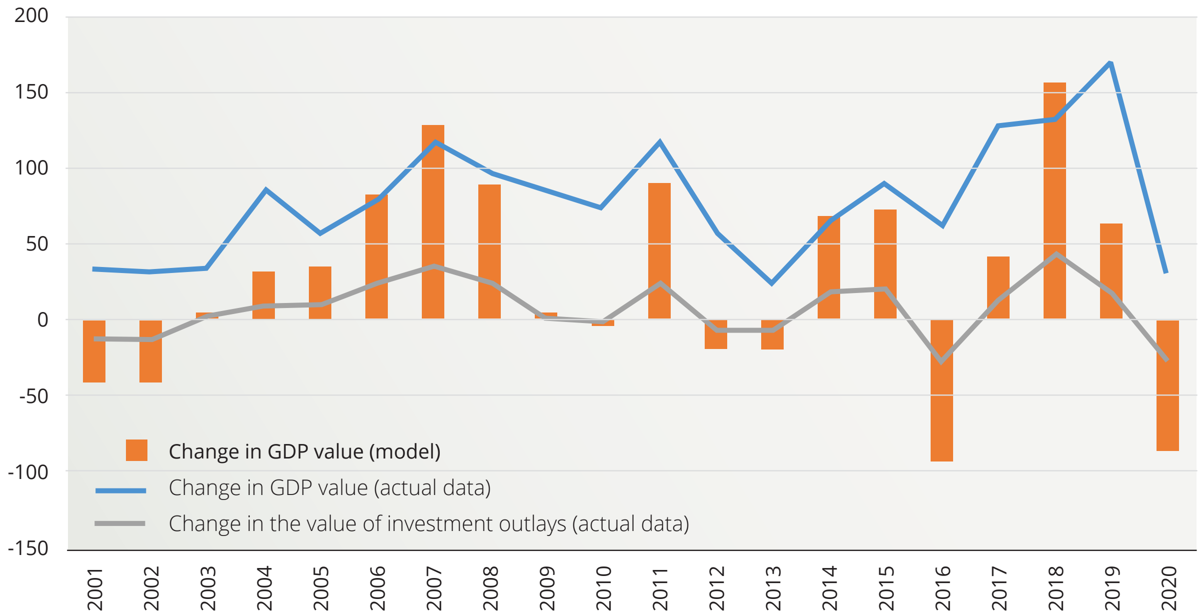
At the heart of this continuous transfer of knowledge is that the offshore wind industry in Europe can continue to grow and evolve, and its development is still possible using the knowledge and experience of onshore wind development. For both of these segments to grow, a long-term investment horizon in terms of key infrastructure, assets, equipment, personnel and skills is required.

9. Macroeconomic effects of wind energy development in Poland - estimated impact on GDP and employment based on updated existing market models

Based on the amounts of cash flows related to the development of OnWF capacity until 2030 in Poland (quantified in section 4.3), the impact of investments in OnWF on the increase in Polish GDP in the 2030 horizon was estimated.

The estimate was made on the basis of Keynes investment multiplier methodology[31] with correction *in minus* to real data. The basis for the correction were the observations of discrepancies between the modelled and actual changes in GDP (Fig. 22.).

FIG. 22. ACTUAL VALUES OF CHANGES IN INVESTMENT OUTLAYS AND GDP COMPARED WITH THE VALUES MODELED ON THE BASIS OF THE KEYNES MULTIPLIER [PLN BILLION - ANALYSIS FOR POLAND]



Source: own study

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The Keynes investment multiplier was calculated based on the historical data of the Central Statistical Office concerning the value of GDP (PLN million) and consumption (PLN million) for the years 2001-2020. The multiplier thus estimated took the value of 3.50. This means that each zloty of investment outlays translates into PLN 3.50 of additional GDP due to the investments made in the economy.

31 See e.g. Lis Ch., 2016: Keynes' investment multiplier in the assessment of the impact of investments in deepening the Świnoujście-Szczecin fairway to 12.5 m on the Polish economy, Problems of Transport and Logistics 1/2017 (37).

Based on Fig. 22., the mean absolute percentage error (MAPE) was calculated and used to correct the modelled values. The years when historical values of changes in outlays in investments were negative, resulting in a negative modeled GDP growth, were not taken into account.

The results of the estimation of the impact on GDP of cash flows related to the development of OnWF in the horizon of 2030 are presented in Tab. 20.

TAB. 20. ESTIMATION OF THE IMPACT ON POLISH GDP OF CASH FLOWS RELATED TO THE DEVELOPMENT OF ONWF IN POLAND UNTIL 2030

Scenario	Average annual increase in OnWF capacity- [GWe]	Total OnWF capacity increase [GWe] until 2030	Cumulative cash flow until 2030 [PLN billion]	Cumulative impact on GDP until 2030 [PLN billion]	
				Adjusted	Modeled
Conservative	0,6	5,8	27,4	69,7	96,0
Baseline	1,0	8,9	41,7	106,0	146,0
Developmental	1,2	11,1	52,3	133,0	183,1

Source: own study

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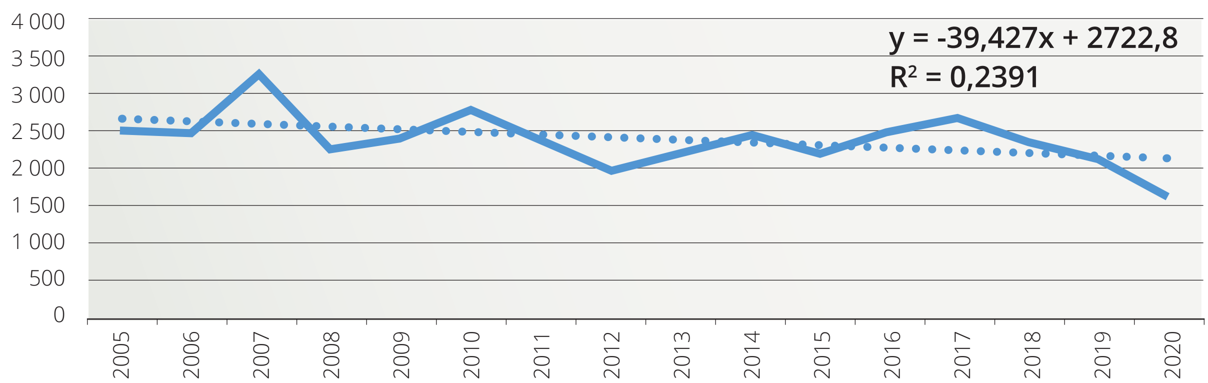
Based on the amounts of cash flows related to the development of the OnWF capacity until 2030, quantified in section 4.3, the impact of investments in OnWF on new jobs in the economy up to 2030 was also estimated. The estimate was made on the basis of a regression model based on GUS data on the evolution of the indicator of the total number of new jobs per PLN 1 billion of investment expenditure (Fig. 23).

FIG. 23. EVOLUTION OF THE INDICATOR OF THE TOTAL NUMBER OF JOBS PER PLN 1 BILLION OF INVESTMENT EXPENDITURE [PCS.]



Source: own study

JAGIELLONIAN INSTITUTE NOWEMEDIA24.PL GRAPHICS: PIOTR PERZYNA

The results of estimating the total number of newly created jobs in the Polish economy until 2030 related to the development of LFW, broken down by scenarios, are presented in Tab. 21.

TAB. 21. ESTIMATION OF THE NUMBER OF NEWLY CREATED JOBS (TOTAL EFFECT) UNTIL 2030 [THOUSAND]

Scenario	Cumulative cash flow from the development of OnWF in Poland until 2030 [PLN billion]	Estimated total new jobs until 2030 [thousand]
Conservative	27,4	50,9
Baseline	41,7	77,4
Developmental	52,3	97,1

Source: own study

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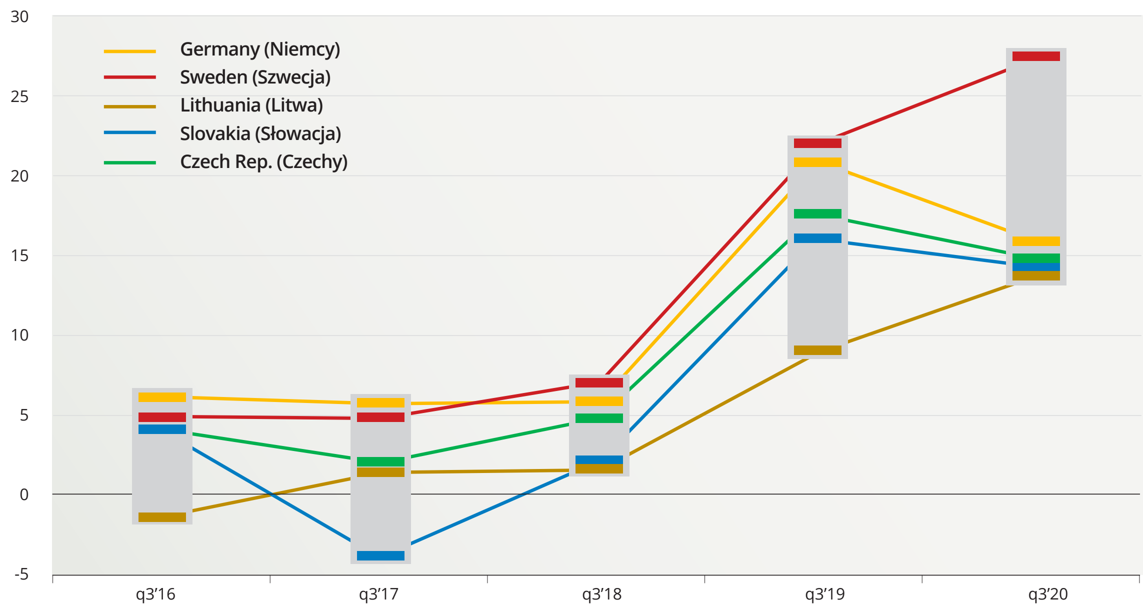
The total number of jobs estimated based on Tab. 5[32] is approximately 8.7 jobs / MWe.

In addition to the above-mentioned economic and social benefits, an expected effect of the development of OnWF in Poland is the aforementioned reduction of CO_2 emissions from the electricity generation sector, as well as downward pressure on wholesale electricity prices. This may, in turn, translate into a decline in electricity prices in the economy, thus contributing to an increase in its competitiveness. According to the analysis of the Jagiellonian Institute, Polish wholesale electricity prices have been significantly higher than in neighbouring countries for several years (Fig. 24). As indicated in section 4.2, onshore energy, which is currently one of the cheapest electricity generation technologies, has the potential to reduce wholesale electricity prices.

FIG. 24. DIFFERENCES IN THE LEVELS OF WHOLESALE ELECTRICITY PRICES: POLAND AND NEIGHBOURING COUNTRIES [EUR / MWH]



Source: own study

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32 It concerns the cumulative effect, i.e. direct, indirect and induced jobs. The previously mentioned IRENA indicator (section 8.1) relates to the direct effect.

Another identified effect of the development of OnWF in Poland will be the increase in revenues from real estate tax. Based on the value of investment outlays as in section 4.3 and assuming the rate of 2% of the value of structures, the value of the property tax related to the OnWF development until 2030 was estimated. Estimated amounts of property tax are presented in Tab. 22.

TAB. 22. ESTIMATED VALUE OF THE REAL ESTATE TAX RELATED TO THE VALUE OF BUILDINGS CREATED AS A RESULT OF ONWF DEVELOPMENT IN POLAND

Scenario	Cumulative cash flows from capital expenditures until 2030 [PLN billion]	Estimated value of the real estate tax until 2030
Conservative	24,5	490,2
Baseline	37,3	745,8
Developmental	46,8	935,4

Source: own study

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GRAPHICS: PIOTR PERZYNA

10. Challenges and Recommendations

Currently, the fight against global warming is no longer an argument for changes, and is starting to be the goal of introducing profound changes in the energy mixes of all European countries. Polish wind energy has the resources and market potential to implement advanced green energy production technologies, with development prospects in the coming decades. Large areas, both on land and sea areas in Poland, allow for great opportunities for the localization of wind farms. There is no doubt that this potential will play an important role in implementing the assumptions of the EU climate law, but it is currently not used.

In connection with the Fit for 55 package presented by the European Commission in July 2021, which is a new basis for the implementation of the updated EU target to reduce greenhouse gas emissions by 55% by 2030, new challenges arise in terms of accelerating the energy transformation. This package is also an opportunity to carry out a just transformation of the economy with the support of EU funds. It points to the need to resume discussions on the future Polish energy mix and the need to introduce urgent changes to key government documents.

Modern wind energy is a technology with a favorable (compared to other energy production technologies) impact on the environment, and at the same time, allows for economically effective implementation of the goals set for Poland under the EU climate policy. The development of wind technologies has led to the limitation of its disadvantages and the reduction of costs of obtaining energy from wind, along with the prospects of their further decline.

The state policy plays a significant role in shaping supporting mechanisms and instruments so that the economy and the whole society can fully use the enormous, untapped potential of domestic wind energy resources, highly developed and economically effective technology and experience already gained by domestic producers and contractors. It is still an extremely attractive and underused area of economic activity in Poland. The increase in investments in onshore wind farms will translate directly into the inflow of investments related to the construction of new production, storage and grid infrastructure and the creation of new jobs in the national economy. Further work is needed on a larger (compared to the current situation) and more multifaceted (larger shares also mean more problems to be actively solved) reflection of the role of wind energy in the energy sector and in the national energy policy.

Failure to meet the set energy targets may result in the need to transfer renewable energy from another country, which will translate into higher costs for the state budget. Moreover, on the basis of the model indicated in the study, it can be seen that onshore wind energy is currently the cheapest electricity generation technology in Poland. The development of this sector will bring about other positive macroeconomic effects and contribute to the reduction of harmful gas and dust emissions, while increasing the comfort of life and energy security of the country.

In the context of the key challenges for the development of the local supply chain for onshore energy, we pay attention to two aspects: macro - regarding the possibility of stable development of onshore wind energy in Poland, presented in the above section, and micro - i.e. the possibility of increasing the share of Polish companies in this development.

In the macro aspect, the main barrier indicated by all surveyed entities and other market participants is the so-called 10H principle. Without changing this, it will not be possible to use the economic potential of wind energy. Elimination of the main development barrier is the starting point for the proper use of the opportunity for the growth of Polish GDP and the creation of a large number of jobs, which was discussed in the main part of this analysis. Moreover, significant limitations are still the lack of stability and predictability of the auction system and the lack of clear rules for connecting new capacities to the power grid.

In terms of micro, there are no financial mechanisms (indicated by the majority of respondents) to support new investments in the area of implementing new and developing existing products and services for onshore wind energy. In this area, there is an opportunity resulting from the instruments of the National Reconstruction Plan and synergy from the development of offshore wind energy. It seems possible to implement new products and services for offshore wind energy financed from the instruments of the National Reconstruction Plan, some of which may be used for the implementation of onsho re projects. Moving on to the analysis of the individual phases of construction of onshore wind farms, the key element is the wind turbine and the operation and maintenance phase, which together account for about 75% of the total costs (Totex) of an onshore wind farm. Increasing the production of components in Poland will translate into an increase in the potential to provide local maintenance services and the availability of original spare parts, as well as positively affect the export potential of Poland. As part of these phases, the production of elements and assembly of the nacelle and rotor are of key importance where most of the components are currently produced outside Poland or limited production capacities are located in Poland.

It is necessary to implement initiatives at the regulatory, financial and organizational level to encourage both large international producers to create new or relocate existing production capacities in Poland (e.g. in terms of assembling the entire nacelle, rotor or new blade manufacturers), which will naturally entail pressure to create additional or new elements produced locally, due to the expected logistical benefits.

As part of the initiatives at the **regulatory level**, it is considered necessary to:

- make the 10H rule more flexible to allow local communities to influence decisions about whether or not to consent to the construction of wind farms closer to residential buildings;
- update strategic documents regarding the planned share of onshore wind energy in Poland's energy mix;
- implement stable, systematic auctions dedicated to onshore wind energy;
- supporting the development of the PPA contracts market;
- implementation of solutions enabling the connection of larger amounts of renewable sources to the grid (direct line, cable pooling, etc.);
- development of the node market (better availability of locational signals).

As part of the initiatives at the **financial level**, it is proposed to implement:

- operational instruments enabling the use of funds from the National Reconstruction Plan for the development of onshore wind energy, both in the form of subsidies and preferential loans;
- nnovative financing instruments, understood as the implementation of a technology or production that is currently not carried out in Poland.

As part of the initiatives at the **organizational level**, it is proposed to implement:

- the obligation to prepare and submit a supply chain plan for onshore wind energy as part of auction applications and its periodic reporting;
- a short sectoral agreement to increase the share of Polish companies to min. 75% in Totex, including not less than 50% in the production of turbine components and not less than 90% in the implementation of operation and maintenance until 2030;
- reporting of the participation of Polish companies in supply chain plans, in line with the above objectives.

In relation to the national policy, it is recommended to:

- develop financing programs for the development of the production of components for wind energy and service companies used in the supply chain. Appropriate regulations, including financial privileges for the entire sector, will have an impact on socio-economic development and will contribute to lowering costs for new wind farms. It is also important that research and development units are included in the development of the industry manufacturing components for wind energy. The development of new technologies for the sector in the country will increase its competitiveness in the global arena;
- conduct a nationwide public information campaign presenting all aspects related to the operation of onshore wind farms in an objective manner. Following the information campaign, extensive public consultations should be conducted in municipalities designated as being of high attractiveness for wind farms. It is necessary to conduct a reliable education and information policy. At the same time, it is necessary to listen to the concerns of residents in order to draw conclusions from them and from the available scientific research. Building permits can also be transferred to local government units so that the entire process is decided closer to the people. Tangible economic stimulus can also help;
- expand the curricula with knowledge of renewable energy sources in schools and universities, which will significantly educate and prepare the future workforce for the industry.

The implementation of the above-mentioned recommendations will contribute to the controlled, planned development of onshore wind energy. Global renewable energy development trends are undeniable and their impact on Poland is inevitable. Taking the indicated actions depends on the changes to *the act on investments in wind farms* and their inclusion in RES auctions. A consistent policy of the state is also extremely important. It is necessary to introduce appropriate corrections in the strategic document, which is "Poland's Energy Policy until 2040", containing provisions of a specific target share of renewable energy sources in the energy mix, and to systematically implement the objectives indicated in this document. Onshore wind energy should become the green flywheel to overcome the crisis after the Covid-19 pandemic.

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