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The impact of renewable energy sources on generating jobs: The case of Poland

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ABSTRACT

Objective: The aim of the article is to identify and assess the impact of Renewable Energy Sources (RES) on job creation.

Research Design & Methods: The study offers an overview of an empirical nature. A review of pertinent literature allows the author to identify, classify, and summarize the most recent scientific reports, both theoretical and empirical, with regard to that particular area of enquiry. Relying on the methodology of systematic literature review, it has been possible to distinguish a database of scientific studies (Scopus, Research Gate, and Google Scholar databases) and studies-reports by, e.g. ILO, IRENA, REN21, EurObserv'ER, Eurostat and Statistics Poland; most applicable studies were subsequently selected to be analysed and verified in terms of their usefulness for further research. The empirical part of the article includes tabulated figures showing employment changes for particular RES technologies and by means of three basic parameters, it illustrates the condition of the labour market in Poland. The strength and direction of the relationship between the analysed variables were computed using Pearson's linear correlation coefficient.

Findings: A review and study of relevant literature yielded synthetic knowledge concerning the impact of renewable energy sources on job creation. The research demonstrated a positive correlation between the number of employed in RES and the activity rate, as well as the employment rate while displaying a negative correlation with the unemployment rate.

Implications & Recommendations: Using up-to-date assessments of job opportunities resulting from the energy transition should inspire politicians and energy sector managers to develop integrated energy, environmental, and labour market policies aimed at sustainable development and job creation in the green economy.

Contribution & Value Added: A critical review of the literature on the subject and the presented results of empirical research enrich knowledge on the impact of renewable energy on employment and the reduction of greenhouse gas emissions to the atmosphere. Updated knowledge allows for a better understanding of the relationship between employment and national renewable energy policy.

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INTRODUCTION

Since the Paris Agreement of 2016, numerous countries around the world have embarked on reducing their greenhouse gas emissions. New technologies to mitigate pollution are constantly being sought. Such solutions are also being pursued in individual European Union (EU) states, and it is expected that emissions will have been significantly reduced by 2030, ultimately achieving climate neutrality by 2050. This is a major challenge for Poland, as hard coal and lignite are the dominant fuels used in electricity production (47.8% and 29.0% respectively in 2018; GUS, 2019). Another factor necessitates the departure of fossil fuels to be accelerated, as an analysis by McKinsey & Company demonstrates that about two-thirds of the capacity of coal-fired power plants in Poland relies on facilities which are more than 30 years old. With an expected life cycle of up to 60 years, this means that the installations and technologies will have reached terminal obsolescence by 2050 and should be replaced by zero-emission technologies (Engel *et al*., 2020).

Changes of this kind do not remain unnoticed by employees in the power generation industry. The increasing use of renewable sources to obtain energy has raised hopes as well as fears among the workers in the sector. It is hoped that new jobs will be created in the renewable energy sector (RES), while the loss of jobs in the fossil energy sector is a major concern. A 2018 report by the International Labour Organization (ILO) shows that if the long-term goal set out in the Paris Agreement is achieved, around 24 million new jobs will be created at the global level (ILO, 2018).

Strategic aspects of renewable energy sources are also highlighted in the European Commission's study on smart, sustainable and inclusive growth. The flagship initiatives of the Europe 2020 Strategy recommend, among other things, a transition to a low-carbon economy and increased use of renewable energy sources, as well as programmes to promote new skills and jobs (European Commission, 2010). In turn, the applicable Directive of the European Parliament and of the Council of Europe emphasizes that the objective of increased use of energy from renewable sources is to reduce greenhouse gas emissions. Furthermore, it is assumed that the implementation of the recommendations stipulated in the directive will contribute to, for example, improved energy supply security, stimulate technological development and innovation, ensure better protection of the natural environment, as well as create new jobs and boost employment which, in turn, should lead to regional development (Parlament Europejski, 2018).

Local plans and strategies have been developed in individual countries and regions of the European Union. In Poland, state-level instruments include the National Renewable Energy Action Plan, the Renewable Energy Sources Act of 20 February 2015, the National Energy and Climate Plan 2021–2030 and the Draft Energy Policy of Poland until 2050 (Ministerstwo Aktywów Państwowych, 2019; Ministerstwo Gospodarki, 2015), while in the regional dimension particular provinces have adopted their own strategies (Zarząd Województwa Warmińsko-Mazurskiego, 2020).

The National Energy and Climate Plan for 2021-2030 envisions *e.g*. a 21-23% share of RES in gross final energy consumption, whereby this target is contingent on the allocation of additional EU funds for energy transformation in Poland. Simultaneously, the share of hard coal and lignite in electricity production is to be reduced from the current 77% to 56-60% in 2030 (Ministerstwo Klimatu i Środowiska, 2019). In the context of these not-very-optimistic plans, it is important to demonstrate the impact of the RES sector's development on the situation on the labour market. The aim of the research presented in this article was to assess if employment in renewable energy sources leads to an improved situation in the labour market. The research problem was formulated as a general query, *i.e.* whether the development of renewable energy sources contributes to new jobs. In order to advance an answer, the following specific questions were explored:

– What is the global employment trend in RES?
– How have employment rates changed across RES technologies?
– How has employment evolved in the fossil fuel and RES sectors in Poland?
– How have the basic labour market parameters changed in Poland?
– What correlations have occurred between employment in RES and labour market parameters in Poland?

Given the objective and the specific questions, the following hypothesis was put forward: there is a positive relationship between employment in RES and the situation on the labour market in Poland.

The article is divided into sections. It begins with an introduction to the topic of the impact of renewable energy sources on generating jobs. Then, the latest literature was reviewed. The next part of the article explains the research methodology. The main part of the article are the results of empirical research. The article ends with the final conclusions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Carbon dioxide emissions have been exceeding acceptable standards for years. Hence, one of the many contemporary challenges is the transformation of the energy sector towards increased efficiency and the use of renewable energy sources. According to the International Energy Agency (IEA), in 2019, the energy sector accounted for 41% of global energy-related CO_2 emissions (International Energy Agency, 2020). In Europe, energy consumption in EU countries accounts for 75% of CO_2 emissions (European Commission, 2021a), while around 413 million tonnes of greenhouse gases were emitted that year in Poland (GUS, 2021). In the study of Firoiu *et al*. (2021), Poland was included, together with 9 other EU countries, in the subset with the highest average value of primary energy consumption and the lowest average value of energy efficiency. The unfavourable effects of the implementation of the climate and energy policy in the context of the country's energy security also emerged in the research by Pach-Gurgul and Ulbrych (2019). The authors showed the deterioration of Poland's position among the countries of the Visegrad Group. As a response to the magnitude of those emissions, the recommendations of the Renewable Energy Directive set the share of RES in the energy mix at 40 % by 2030 (European Commission, 2021b). However, the analysis of RES in the context of sustainable development goals (SDG) indicates difficulties in achieving the adopted assumptions in the 2030 perspective. They result mainly from socio-economic policies implemented in individual countries, reduced flow of funds for the development of RES to developing countries, low energy efficiency, crisis situations, such as the Covid-19 pandemic, climate change and armed conflicts (He *et al*. 2020; United Nations 2022).

The impact of renewable energy on the labour market is extensively presented in the literature. However, a consensus among the researchers is lacking. The diversity of opinions and conclusions should mainly be attributed to:

- distinct research methodologies and availability of data (Moummy *et al*., 2021; O'Sullivan & Edler, 2020);
- types of renewable energy, financing modalities (co-financing), and subsidies earmarked for the renewable sources sector (Mu *et al*., 2018);
- the timeframe in which particular relationships are evaluated (short- and long-term analyses) (Khobai *et al*., 2020; Musa & Maijama'a, 2020);
- the costs of implementing renewable energy and energy efficiency technologies (Apergis & Salim, 2015);
- investment volumes and support policies for renewable energy (*e.g*. tax incentives, tax exemptions, reducing energy dependence on foreign sources) (Yilanci *et al*., 2020).

Example results of studies on the impact of RES on job creation are summarised in Table 1.

It follows from the literature review that a positive relationship occurs between RES and employment. The first studies listed in the table examined changes in employment in EU countries between 1995 and 2009. The results demonstrate that positive changes occurred in 21 out of 27 EU member states. The job pool increased by a net total of 530 000 positions, whereby two-thirds of those new jobs were created directly in those Member States that saw changes in the electricity and gas supply sector, while the remainder were generated in other Member States (indirect employment) (Markandya *et al*., 2016). In turn, Garrett-Peltier (2017) showed that USD 1 000 000 spent on fossil fuels generates 2.65 full-time jobs, and as many as 7.49 and 7.72 full-time jobs in the renewable energy sector, meaning that each USD 1 000 000 reallocated from so-called brown to green energy will result in a net increase of five jobs. In their respective studies, Khobai *et al*. (2020) and Musa and Maijama (2020) also demonstrated a positive relationship between renewable sources installations and employment growth, even though such effects were observed over a longer period of time.

Other studies show no relationship between the analysed variables (Bohlmann *et al*., 2019; Moummy *et al*., 2021; Mu et *al*., 2018). The cited studies showed an increase in employment in RES at the expense of jobs in fossil energy. For example, Mu *et al*. (2018) report that producing 1TWh of renewable energy (solar and wind) generates up to 45.1 thousand and 15.8 thousand direct and indirect jobs (respectively), but at the same time, they determined an equivalent employment reduction in the traditional energy industry and other indirect jobs. It is claimed in the conclusions from the study that the results do not warrant any decided claim that the development of renewable energy involves a net increase in jobs.

Table 1. Impact of renewable energies on employment

Author	Research method	Research territory (country)	Result
Markandya *et al*. (2016)	Input-output (I-O) model	EU countries	Positive impact
Mu et al. (2018)	Computable general equilibrium (CGE) model	China	Lack of unequivocal findings
Garrett-Peltier (2017)	Input-output (I-O) model	United States of America	Positive impact
Moummy *et al*. (2021)	VAR model, introduced by Christopher Sims.	Morocco	Moderate impact (minor)
Bohlmann *et al*. (2019)	Computable general equilibrium (CGE) model	South Africa	Marginal impact
Khobai *et al*. (2020)	Autoregressive distributed Lag (ARDL) model	South Africa	Positive impact in the long term; in the shorter term – relationship insignificant
Khodeir (2016)	Autoregressive distributed Lag (ARDL) model	Egypt	Positive impact in the long term; moderate impact in the short term
Musa and Maijama (2020)	Toda and Yamamoto causality test	Nigeria	Positive impact in the long term
Rafiq *et al*. (2018)	Econometric techniques and time series estimation techniques	41 countries	Averaged result - negative impact
Apergis and Salim (2015)	Granger causality tests	80 countries	Averaged result - positive impact
Yilanci *et al*. (2020)	Fourier ADL Cointegration Test	12 OECD countries	Averaged result – positive impact
O'Sullivan and Edler (2020)	Input-output (I-O) model	Germany	Positive impact
Van der Zwaan *et al*. (2013)	Integrated evaluation model TIAM-ECN	Middle East countries	Positive impact
Wei *et al*. (2010)	Analytical model	United States of America	Positive impact
Grafakos *et al*. (2020)	Value chain analysis; Input-output (I-O) model	Mexico; Indonesia; Rwanda	Positive impact
Bukowski and Śniegocki (2015)	Input-output (I-O) model	Poland	Positive impact
Ulrich *et al*. (2012)	Input-output (I-O) model	Germany	Positive impact
Ram *et al*. (2021)	Analytical model	92 countries	Positive impact

Source: own elaboration of Apergis and Salim, 2015; Bohlmann *et al*. 2019; Bukowski and Śniegocki 2015; Garrett-Peltier, 2017; Grafakos *et al*., 2020; Khobai *et al*., 2020; Khodeir, 2016; Moummy *et al*., 2021; Mu *et al*., 2018; Musa and Maijama, 2020; Markandya *et al*., 2016; O'Sullivan and Edler, 2020; Rafiq *et al*. 2018; Ram *et al*., 2021; Ulrich *et al*., 2012; Van der Zwaan *et al*., 2013; Wei *et al*., 2010; Yilanci *et al*., 2020..

Other studies show that a positive correlation between RES and job creation occurs only in the long term but proves marginal in the short term (Khobai *et al*., 2020; Khodeir, 2016; Musa & Maijama, 2020). On the other hand, Rafiq *et al*. (2018) demonstrated that an increase in renewable energy consumption coincides with higher unemployment, which decreases significantly with non-renewable energy consumption (fossil fuel consumption). The authors of the study conjecture that this unfavourable outcome for the labour market may be due to the capital-intensive nature of energy production from renewable sources.

In a study conducted in 12 OECD countries, Yilanci *et al*. (2020) arrived at discrepant results. The averaged result indicated a positive relationship, although negative, positive and zero impact were noted in individual countries.

Van der Zwaan *et al*. (2013) estimated potential job figures in the renewable energy sector in Middle Eastern countries. The calculations relied on the premise that RES in that region (mainly wind and solar farms) will generate 210 GW of power by 2050, accounting for 60% of the total demand for electricity. According to their calculations, about 155 000 direct and 115 000 indirect jobs will have been created by mid-century.

Wei *et al*. (2010) analysed the impact of RES on job creation by 2030. In their analytical model, the computations were made with respect to renewable energy, energy efficiency, carbon capture and storage, as well as nuclear energy, with job losses in the coal and gas industry taken into account. In their conclusions, the authors state that all non-fossil fuel technologies create more jobs per unit of energy than coal and natural gas and that reducing greenhouse gas emissions into the atmosphere to 30% in 2030 should result in more than 4 million full-time jobs. In the same timeframe, another 500 000 jobs may be created by increasing nuclear power share to 25% and CCS (CO_2 Capture and Storage) to 10% of the total output.

Research conducted by Global Green Growth Institute experts in Mexico, Indonesia, and Rwanda shows that investments in RES yield new jobs at different stages of the value chain, not only in the RES sectors, but also throughout the economy by virtue of the domino effect. If the adopted targets for reducing CO_2 emissions into the atmosphere are indeed met by 2030, approximately 370 000 new direct jobs, 170 000 indirect jobs, and 110 000 induced jobs will be created in Mexico. In Indonesia, this will amount to between ca. 2.1 and 3.7 million direct jobs and the same quantity of indirect jobs. In Rwanda, on the other hand, the estimate for direct new jobs ranged from 14 000 to 31 000. The substantial discrepancies in estimations have resulted from analysing various RES investment scenarios that would translate into minimised GHG emissions and climate neutrality (Grafakos *et al*., 2020).

These remarks concern the findings from studies that examined new jobs solely in the electrical power sector obtained using a number of technologies and sources. However, publications on renewable energy also include research which relies on a cross-sectoral, comprehensive approach to the entire energy system, operating under the premise that 100% of energy is obtained from renewable sources. Nonetheless, the dominant role of electricity in all energy sectors should be emphasized. For example, a holistic study was carried out by Ram *et al*. (2021) to assess job creation in the 2050 horizon in industries such as electricity, heating and transport. The researchers determined prospective direct employment in energy generation, storage, transmission, and distribution. Based on the results, the authors concluded that renewable energy technologies have the potential to create a significant number of jobs in global energy. They also underlined that a quantitative increase in employment would be accompanied by a qualitative effect, as positions in new energy technologies require employees with higher skills.

According to the latest studies published via One Earth, 50 countries around the world will witness an almost 80% decrease in employment in fossil fuel extraction (coal, oil, and gas extraction) by 2050. It is anticipated then these job losses will be offset by new jobs in the RES sector, resulting in a likely employment increase in the sector to around 22-25 million people (Pai *et al*., 2021).

A literature review demonstrates that employment is most often estimated based on input-output (I-O) modelling. At the same time, it must be noted that when modelling RES impact on employment in the long term, individual researchers take into account many variables, *e.g.* energy prices, public spending on RES development, regional climatic conditions, exports and imports of RES technologies, job retention time, labour productivity, learning rate in new technologies, economies of scale, sources and amounts of financing, including subsidies for renewable technologies, fiscal thresholds, and development of renewable technologies, whereby labour intensity is reduced and productivity increases (Meyer & Sommer, 2014).

RESEARCH METHODOLOGY

The research presented in this article was carried out in two stages, the first of which involved a study of literature spanning scientific publications concerned with the impact of employment changes in the renewable energy sector on labour markets. The aim of the review was to identify, classify, and summarize the most recent scientific reports, both theoretical and empirical, on the issue in question. Using the methodology of a systematic literature review, a database of scientific studies was extracted and applicable studies were selected and analysed to verify their usefulness for further research.

In the course of investigations, Scopus database studies dating from 2000-2021 were searched. Publications were then selected using keywords: renewable energy sources, employment, and labour market. The first, second, and third queries in titles and abstracts identified 82 207, 1 435, and 123 studies, respectively. Following content analysis of all selected abstracts, 79 articles were qualified for detailed analyses, while the remainder were rejected as they diverged significantly from the research problem or failed to clearly specify the analysed employment modality and the type of RES technology.

The following stage consisted of secondary research. With the research object in mind, statistical data were compiled to analyse changes in the volume and structure of employment in total and with respect to individual RES technologies, as well as assess the consequences for the labour market. The data were collated based on statistical figures provided primarily in IRENA, REN21, ILO, EurObserv'ER reports, as well as in Eurostat and Statistics Poland studies. Further analysis was conducted using methods of descriptive statistics. The strength and direction of the relationship between the analysed variables were determined by Pearson's linear correlation coefficient. Changes in total employment, particularly in RES technologies, were compared in the global dimension, while correlations between the number of RES employees and labour market parameters were examined by reference to the labour market in Poland. The analysis targeted the timeframe between 2009 and 2018.

By way of additional observation of the research premises stated above, it should be emphasized that the methodology to estimate employment in the RES sector presents researchers with at least three essential problems. The first is a conceptual one and concerns the identification of activities that create new employment. The choice of methods for operationalizing employment is another issue, and the third relates to the accuracy of measuring the variables analysed (Allan *et al*., 2017). The location and the types of work performed decide whether direct, indirect, or induced employment is determined and whether it is calculated as gross or net output. These distinctions are very important because, first, gross estimates do not take into account job losses in alternative sectors, such as fossil fuel extraction, and second, they eliminate double-counting (Pai *et al*., 2021; Van der Zwaan *et al*., 2013; Wei *et al*., 2010). Another important element is the duration of employment, which differs for the production and installation of equipment (temporary employment relating only to the volume of power output) and the operation and maintenance activities, which generate and sustain employment over the entire lifetime of a RES source and tends to be associated with the total installed capacity (IRENA and ILO, 2013; Lambert & Silva, 2012). In these respects, significant differences in employee figures are observed. For example, a study by Bukowski and Śniegocki (2015) showed that the construction of a 10 MW onshore wind farm requires 114 people. These are, of course, new jobs, but they are created and last only for the duration of the construction undertaking. On the other hand, the number of permanent jobs, *i.e.* existing throughout the operation of that renewable energy source, was estimated at five people. The calculations of the aforementioned authors also demonstrate that the largest number of jobs in wind energy is created in turbine manufacturing and wind farm construction and that each direct job generates approximately 1.5 indirect jobs.

RESULTS AND DISCUSSION

The European Union's climate and energy policy is aimed at minimizing CO_2 emissions. The effectiveness of this policy will depend on the degree of extraction and combustion of solid fossil fuels in all member states. The objectives adopted, *e.g.* in the legislative package Fit for 55, which defines the ways and means to achieve climate neutrality (European Commission, 2021a), in the directive concerning the share of renewable energy in the EU energy mix (up to 40% by 2030) (European Commission, 2021b) and in the communication entitled *The European Green Deal* with its detailed vision of Europe as a climate-neutral continent by 2050 (European Commission, 2019), are a major challenge for Poland, where electricity generation relies primarily on hard coal and lignite. Changes in extraction, import, and consumption of either type of coal are shown in Figures 1a-d.

The data in Figure 1a show a consistent decline in hard coal production. In relation to 2017, hard coal production in 2018 decreased by 3.3%, reaching 18.3% in the analysed period (2009-2018). At the same time, it is noted that in the period in question, Poland imported hard coal, mainly from Russia; of the 12.8m tonnes purchased in 2020, 9.1m tonnes came from that country (Kaszyński *et al*., 2021). It should also be added that Poland is an exporter of hard coal, though its volume has decreased over the years. In 2020, 4.6 million tonnes were exported, compared with 8.4 million tonnes in 2009 (a decrease of 45.2%). Therefore, in total, there was a greater volume of hard coal available each year, which fully met domestic demand, including some marginal reserves. With 74.8 million tonnes available in 2018, 75.8% was used for conversion to other energy carriers, while direct consumption accounted for 24.0%. A comparison of domestic hard coal consumption in 2018 and 2009 demonstrates a slight increase.

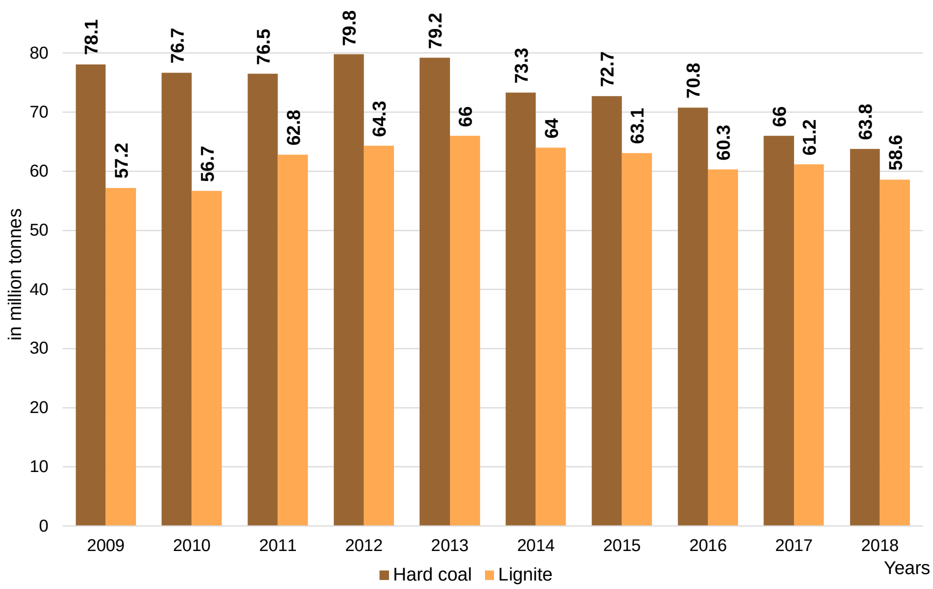

Figure 1a. Coal balance in Poland: Comparison between portfolio and CAC 40 Index
Source: own elaboration based on Statistics Poland, 2010-2021.

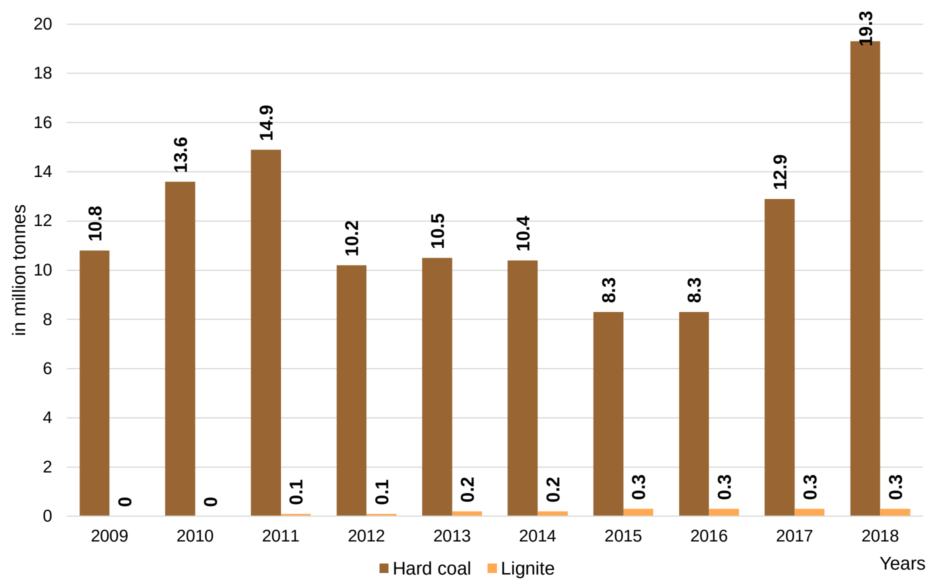

Figure 1b. Coal balance in Poland: Coal mining from imports
Source: own elaboration based on Statistics Poland, 2010-2021.

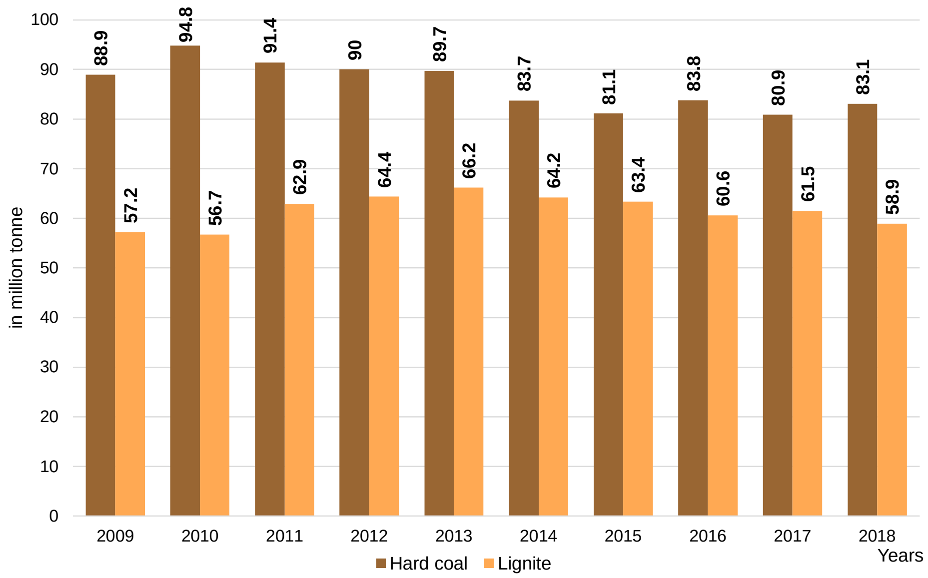

Figure 1c. Coal balance in Poland: Total coal
Source: own elaboration based on Statistics Poland, 2010-2021.

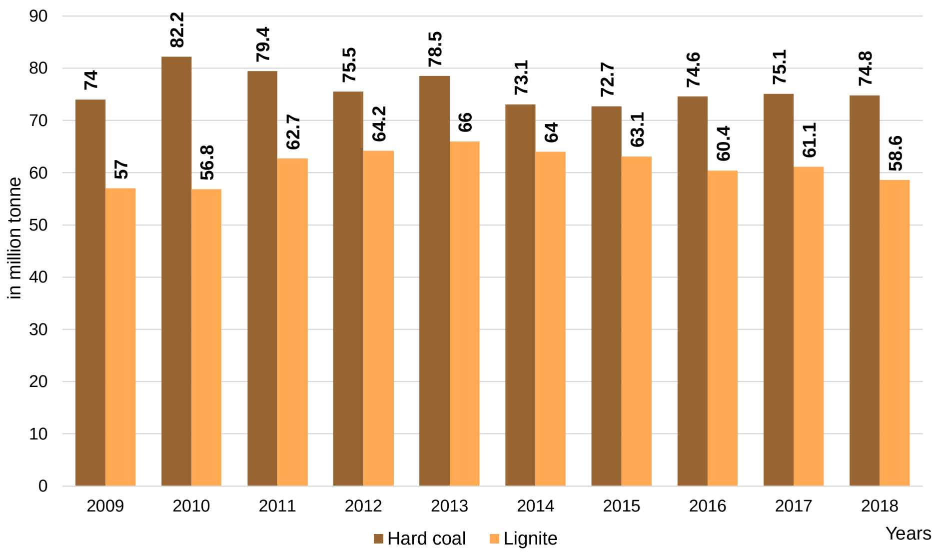

Figure 1d. Coal balance in Poland: Coal domestic consumption
Source: own elaboration based on Statistics Poland, 2010-2021.

Similar downward trends were observed in the extraction and consumption of lignite. Incidental import and export transactions in the analysed period had no impact on the resources of this raw material. Compared to 2009, domestic output and consumption in 2018 slightly increased by 2.4% and 2.8%, respectively. It should be emphasized, however, that extraction of lignite tended to increase until 2013, and significant decreases occurred only from 2016 onwards. The dynamics of changes in domestic consumption of both raw materials are presented in Figure 2.

Even though mining and consumption of hard coal and lignite have decreased, Poland is still a significant producer of both solid fuels (Table 2). In the global listing of hard coal producers, Poland has invariably ranked in tenth place since 2013 and was second among European countries. Lignite mining put Poland in similarly high positions, as the country has ranked fourth in the world as of 2018 and third in Europe as of 2015.

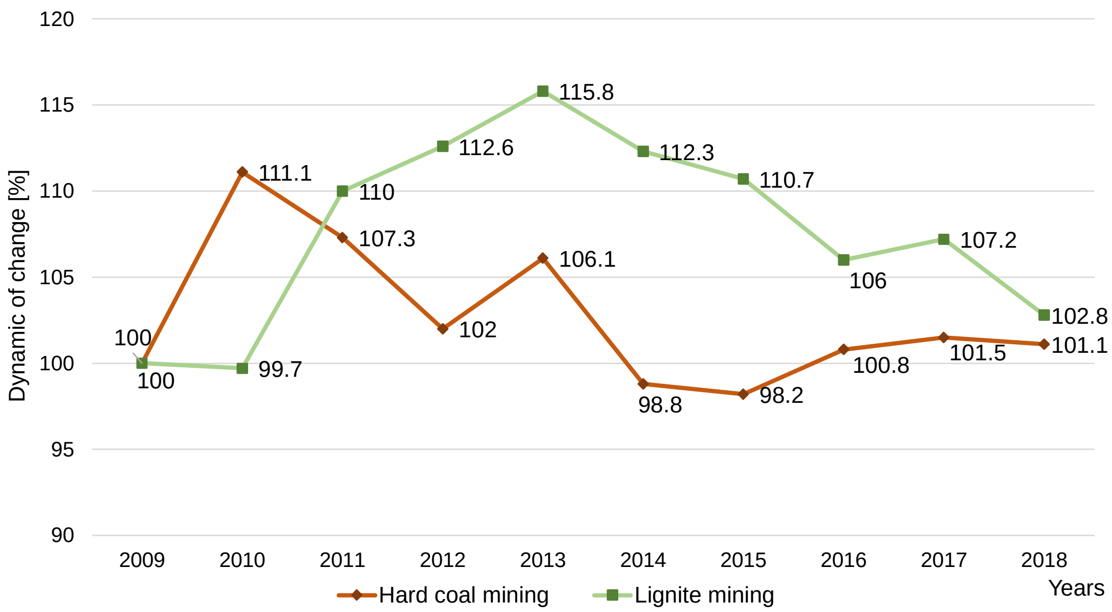

Figure 2. Dynamics of changes in the amount of coal consumed in Poland (in %)

Source: own elaboration based on Statistics Poland, 2010-2021.

Table 2. Poland in the world and Europe by coal output

Specification		units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Hard coal mining	in % of the world	%	1.5	1.2	1.2	1.1	1.2	1.1	1.1	1.1	1.0	0.9
	place in the world	-	9	9	9	n.a.	10	10	10	10	10	10
Lignite mining	in % of the world	%	6.2	6.7	5.7	n.a.	7.2	7.9	7.7	7.8	7.4	7.3
	place in the world	-	7	7	8	n.a.	n.a.	4	5	5	5	4
Hard coal mining	in % of Europe	%	n.a.	18.4	19.6	n.a.	18.5	16.3	17.6	17.9	15.6	14.5
	place in Europe	-	n.a.	2	2	n.a.	2	2	2	2	2	2
Lignite mining	in % of Europe	%	n.a.	10.5	n.a.	n.a.	n.a.	n.a.	11.7	n.a.	11.6	11.4
	place in Europe	-	n.a.	4	n.a.	n.a.	n.a.	n.a.	3	n.a.	3	3

Source: own elaboration based on Statistics Poland, 2010-2019.

Regrettably, the figures presented in Table 2 are not optimistic given the objective of decarbonizing the economy by systematically reducing greenhouse gas emissions, including carbon dioxide (CO_2). It appears that Poland is unlikely to achieve the CO_2 emission limits recommended in the EU Directives by 2030 and 2050 with the current national schedules of eliminating fossil fuels used to generate electrical power. The emission of gaseous air pollutants relative to the extraction of hard coal and lignite is presented in Figure 3. The figures indicate a positive trend, as in the analysed time interval, the total emission decreased by 4.5% and CO_2 emission by 26.5%. The reduction in total greenhouse gas emissions is due to less coal being mined, as well as to the retention of gases in pollution reduction facilities. For example, in 2019, the entire mining and quarrying sector retained 190.4 thousand tonnes of gases produced (excluding carbon dioxide abatement).

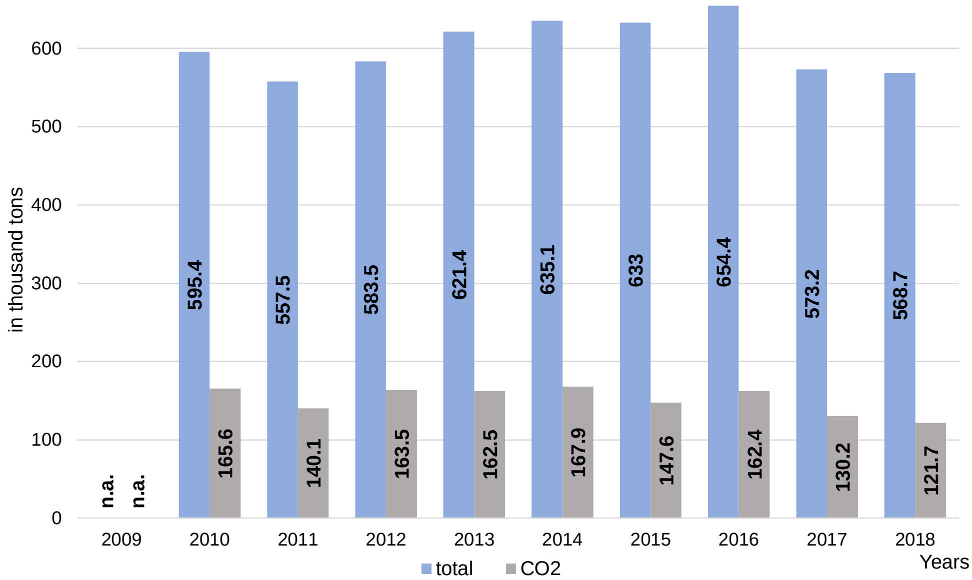

Figure 3. Greenhouse gas emissions in hard coal and lignite mining in Poland
Source: own elaboration based on Statistics Poland, 2010-2021.

European Union studies, followed by those conducted by individual member states with respect to climate and energy policy, indicate that one of the measures to achieve climate neutrality is the development of renewable energy sources (RES). Obtaining energy from such sources may be examined from various standpoints. For instance, an economics-oriented approach will focus on, for example, the costs of energy generation, the degree of elimination of environmental pollution (which will be important in the ecological perspective), the technical dimension (which will prioritize the use of technologies without greenhouse gas emissions), while the impact of electricity generation from renewable sources on the creation of new jobs will serve to elucidate the social aspect. Given the aims of this study, analyses were concerned with changes in employment in the renewable energy sector. Table 3 presents them globally by energy generation technology.

Table 3. Global employment in renewable energy by technology

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Solar photovoltaics	0.30	0.35	0.82	1.36	2.27	2.49	2.77	3.09	3.37	3.68
Bioenergy[a]	1.50	1.50	2.50	2.40	2.50	2.99	2.88	2.74	3.05	3.18
Hydropower[b]	n.a.	n.a.	0.04	1.66	2.21	2.04	2.16	2.06	1.99	2.05
Wind energy	0.50	0.63	0.67	0.75	0.83	1.03	1.08	1.16	1.15	1.16
Solar heating /cooling	0.30	0.32	0.90	0.89	0.50	0.76	0.94	0.83	0.81	0.80
Others[c]	n.a.	n.a.	0.13	0.22	0.23	0.19	0.20	0.24	0.16	0.18
Total	3.00	3.50	5.00	7.30	8.50	9.50	10.0	10.1	10.5	11.1

Note: a – includes liquid biofuels, solid biomass, and biogas; b – direct jobs only (years 2012-2018), 2011 – only small hydropower; c – 'other' include geothermal energy, concentrated solar power, heat pumps (ground-based), municipal and industrial waste, and ocean energy. Column totals do not match due to rounding.
Source: own elaboration based on IRENA and ILO, 2021; REN21, 2010; REN21, 2011; REN21, 2012.

The volumes shown above are indicative of positive developments in the number of direct and indirect jobs in the renewable energy sector. Between 2009 and 2018, there was almost a fourfold increase in total employment. In 2018, the largest number of people worked in energy generation by means of PV (an increase of 3.4 million persons). This activity saw a consistent employment increase over each year of analysis. Comparable positive changes occurred in the number of people employed in bio-production (from liquid biofuels, solid biomass and biogas) and involved in obtaining energy from aquatic sources (increases by 1.7 and 2.0 million persons, respectively). As for the remaining sources, changes in employment were not that significant, but they were nevertheless positive.

Furthermore, employment in Poland was analysed in the light of changes in global employment in renewable energy production (Table 4), showing that changes in total employment are proportionally similar. Comparing the final and initial years of analysis, employment in energy production from all renewable sources multiplied by a factor of 4.5. In 2018, the largest number of employees were involved in energy production from biofuels and biomass (increases by 36.0 and 22.6 thousand people, respectively). Employment in power generation from other renewable sources rose with some distortions, but the number of employees was not significant in the overall employment balance.

Table 4. Total employment in RES and by technology in Poland (in thousands)

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total	19.1	28.5	34.6	33.8	34.9	33.1	84.7	81.8	73.9	85.8
Biomass	7.0	7.5	21.8	20.5	19.5	18.5	33.5	26.1	25.9	29.6
Wind	3.0	7.0	1.6	2.8	3.0	2.5	12.1	11.4	8.0	3.0
Biofuels	5.2	9.6	6.5	5.5	7.5	5.9	29.5	34.8	31.4	41.2
Heat pumps	n.a.	1.5	n.a.	0.6	0.7	0.7	2.0	2.2	3.0	2.6
PV	0.1	<0.05	0.1	0.4	<0.05	0.3	1.2	1.5	1.1	3.1
Hydro	0.3	0.3	1.0	1.0	1.0	2.0	1.3	3.1	1.1	1.0
Biogas	1.0	1.0	0.5	0.3	0.5	0.4	2.5	1.3	2.3	2.7
Waste	n.a.	<0.05	<0.05	0.05	<0.05	<0.05	<0.1	<0.1	0.7	0.2
Solar thermal	2.0	1.3	2.2	2.5	2.5	2.6	2.3	1.1	0.3	2.2
Geothermal	0.6	0.2	1.0	0.2	0.2	0.2	0.3	0.2	0.1	0.2

Source: own elaboration based on The State of Renewable Energies in Europe – Edition 2011-2019.

In the ranking of the EU member states per number of employees in particular renewable energy technologies, Poland leads in biofuel energy employment, occupies leading positions in energy production from biomass and, in recent years, from solar thermal as well. As for employment involving other renewable energy sources, Poland placed lower throughout the analysed period (Table 5). Among all EU member states, Germany is the leader in the total number of people employed in the renewable energy sector. In 2018, they ranked the highest in total employment, as well as in energy production from biomass, wind, PV, biogas, and waste (Table 6).

Table 5. Poland among the EU Member States by employment in RES

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total	13	10	10	10	9	9	6	6	6	6
Biomass	8-9	8	5	5	7	8	2	3	4	3
Wind	7-10	7	17	12	12	12-13	4	6	6	12
Biofuels	5	5	6	5	3	5	1	1	2	1
Heat pumps	n.a.	6-7	n.a.	16	13-14	13-15	10-11	10	9	11
PV	18-20	20-27	19	17	23-28	20-21	13-14	11	13-14	6
Hydro	11-14	13-14	9	9	9	7	14-15	5	16	18
Biogas	8	7	8-9	9	7-9	9	5	14-15	6	6
Waste	n.a.	15-27	19-27	14-27	17-28	15-28	16-28	16-28	10-11	15-17
Solar thermal	7	10	7	7	6	7	4	8-9	9	3
Geothermal	9	7-10	10-11	6-7	6-8	6-7	7-8	7-9	11-15	11-12

Source: own elaboration based on The State of Renewable Energies in Europe – Edition 2011-2019.

Figure 4 illustrates the employment shift in fossil fuel extraction and energy production from renewable sources. The data show a definite decreasing trend in the number of employees working in the coal mining sector with a simultaneous increase in those employed in the renewable energy sector. In the analysed period, both variables demonstrated a very strong correlation, with Pearson's linear correlation coefficient amounting to -0.942227993. The results presented here should be assessed in positive terms, although it is reasonable to expect a greater intensity of employment reduction in the fossil fuel sector.

Table 6. EU employment leaders by RES technology

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE
Biomass	DE	DE	DE	DE	DE	DE	DE	DE	DE	DE
Wind	DE	DE	IT-ES	DE	DE	DE	DE	DE	DE	DE
Biofuels	DE	ES	FR	FR	FR	FR	EN	EN	RO	EN
Heat pumps	n.a.	DE	n.a.	FR	FR	FR	IT	IT	ES	ES
PV	DE	DE	DE	DE	DE	DE	GB	GB	DE	DE
Hydro	IT	IT	DE	DE	DE	DE	IT	DE	ES	IT-AT
Biogas	DE	DE	DE	DE	DE	DE	DE	IT	DE	DE
Waste	DE	DE	DE	DE	GB*	NL*	DE	DE	GB	DE
Solar thermal	DE	DE	DE	DE	DE	DE	ES	ES	ES	ES
Geothermal	FR	IT	DE	IT	IT	IT	FR	IT	IT	IT

Note: AT – Austria; GB – Great Britain; DE – Germany; FR – France; ES – Spain; NL – Netherlands; PL – Poland; IT – Italy; RO – Romania. * no data available for DE.
Source: own elaboration based on The State of Renewable Energies in Europe – Edition 2011-2019.

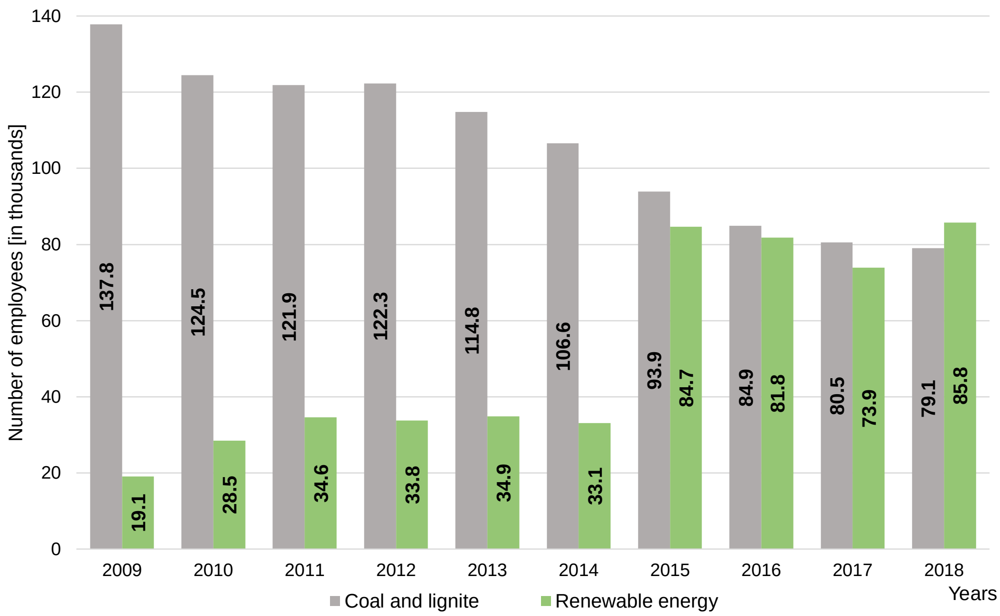

Figure 4. People employed in coal and lignite mining and renewable energy in Poland
Source: own elaboration based on Statistics Poland, 2010-2019;
The State of Renewable Energies in Europe – Edition 2011-2019.

To show the impact of employment in the RES sector on the labour market, three basic parameters describing the population's activity on the labour market were compared, *i.e.* activity rate, employment rate and unemployment rate (Figure 5). Table 7 presents values of Pearson's linear correlation coefficient between those labour market parameters and the number of employed in RES categorized by technology.

The figures shown in the table indicate a positive relationship between the number of total employees, the labour force activity rate, and the employment rate, as well as a negative relationship with the unemployment rate. The correlations are strong: labour force activity rate and employment for Biomass and Waste are correlated strongly or very strongly. Moreover, a strong or very strong linear relationship is observed between the employment rate (positive correlation) and the unemployment rate (negative correlation) in conjunction with employment in Biofuels, Heat pumps, PV, and Biogas technologies. Based on these figures, one may conclude that there is a positive relationship between employment in renewable energy sources and the economic activity of Poles.

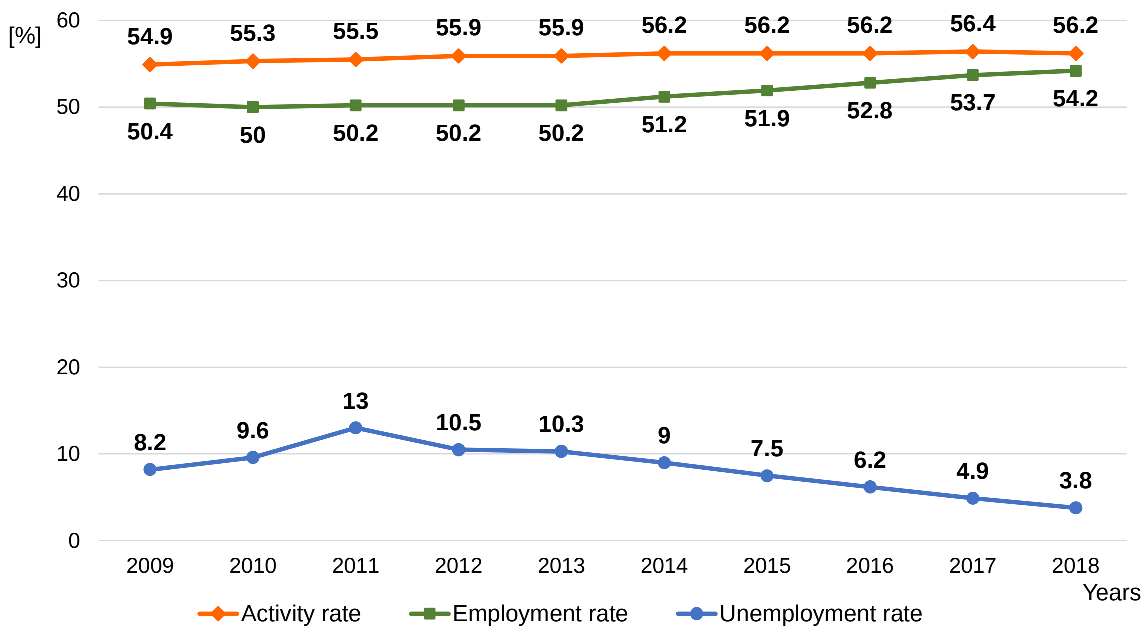

Figure 5. Labour market indicators in Poland

Source: own elaboration based on Statistics Poland, 2010-2019.

Table 7. Relationship between the number of employed persons and labour market measures in Poland

Specification	Labour market indicators		
	Activity rate	Employment rate	Unemployment rate
Total	0.748763940	0.879324959	-0.759564228
Biomass	0.832609651	0.680428519	-0.436239647
Wind	0.380727978	0.400282895	-0.450152582
Biofuels	0.641999685	0.93195998	-0.861648364
Heat pumps	0.457772049	0.879220167	-0.923425074
PV	0.548232097	0.869902338	-0.801572653
Hydro	0.628997711	0.396196811	-0.249338076
Biogas	0.445764392	0.82779799	-0.830522975
Waste	0.914563063	0.589813183	-0.558113795
Solar thermal	0.14565853	0.461138001	-0.479693572
Geothermal	0.75102618	0.364353114	-0.157976214

Source: own elaboration.

CONCLUSIONS

The assumed research aim was achieved in its entirety, and the formulated hypothesis was positively verified. The conducted literature review and empirical research permit both detailed and general conclusions. With regard to the former, the following should be stated:

- the development of renewable energy sources does generate new jobs globally, in Europe, and Poland;
- all renewable energy technologies create more jobs per unit of energy than fossil fuels;
- successive development of RES facilities results not only in an increase in employment, but also contributes to a reduction of greenhouse gas emissions, including CO_2;
- production and exploitation of renewable sources is conducive to new jobs at various stages of the value chain, *i.e.* not only in the RES sectors, but also in other sectors of the economy as it creates indirect and induced jobs;

- there is a very strong negative linear correlation between the number of employees working in the coal mining sector (hard coal and lignite) and the number of people working in the renewable energy sector;
- although extraction and consumption of both types of coal have consistently dropped, Poland is still a significant producer of these fuels on a global scale and on the European market;
- due to the reduced use of fossil fuels and the efficient retention of gases by pollution abatement facilities, there is a positive trend in the reduction of greenhouse gas emissions into the atmosphere;
- globally, the majority of employees are involved in energy production through PV, whereas in Poland they are concentrated in the biofuels industry. Germany is the leading European state with the highest employment in energy production for five out of 10 RES technologies analysed in the last year of the period under investigation;
- throughout the said period, the Polish labour market demonstrates a positive relationship between the total number of employed persons, activity rate and the employment rate, as well as a negative relation with the unemployment rate.

Furthermore, a number of general conclusions – which incorporate certain methodological and conceptual issues – may be drawn:

- there is a lack of systematic public statistics regarding the RES sector in Poland as well as in other countries around the world, which renders multifaceted comparisons and comparisons between individual countries problematic and sometimes impossible;
- the assessment of RES impact on job creation and, consequently, on the labour market, is somewhat hampered, as many studies do not provide estimation methods or the type of employment analysed;
- multifaceted RES analyses can be carried out using available methodologies which offer specific procedures and methods/models, although they cannot be uncritically integrated into authorial research, as each model represents a certain simplification and does not take into account all the variables involved in the broadly defined technological, economic, cultural, geographical, and competence-related circumstances of potential employees;
- renewable energy sources constitute state-of-the-art technologies, which require operating personnel to possess novel and very often digital skills. Therefore, plans for RES deployment in a specific region should take into account the balance of occupations, required skills, and plans for retraining and professional development of potential employees along the entire value chain;
- in view of the fact that the transition from fossil fuel-based energy production towards renewable sources will inevitably impact employment (resulting in a positive or negative net effect), it is necessary to draft strategic national and regional plans aimed at sustainable development and improved quality of life, in which worthwhile jobs in the green economy will play a part.

In conclusion, it may be stated that the transition to a low-carbon economy is economically and socially justifiable because – as this study demonstrated – the increased share of renewable energy in the energy mix produces a positive net effect in the form of new jobs. The reported shortcomings in estimating job availability, the complexity of the issue itself, and the dynamic changes in RES technologies and in the labour market, undoubtedly translate into certain limitations of this study, hence its findings should be approached with due caution. Nevertheless, the author is convinced of the necessity for repeated research, in which the new knowledge that relies primarily on empirical insights may be useful, primarily for political decision-makers and heads of businesses, facilitating more accurate decisions and, secondly, may contribute to the improvement of methodologies and encourage further investigations.

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Conflict of Interest

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