OLSZTYN ECONOMIC JOURNAL
2024, 19(1), 31–44
ISSN 1897-2721 e-ISSN 2083-4675 DOI: 10.31648/oej.10093

ORIGINAL PAPER

RENEWABLE ENERGY SOURCES IN POLAND IN 2014-2023 AND THE PERSPECTIVE OF THEIR DEVELOPMENT UNTIL 2030. A CONTRIBUTION TO THE DISCUSSION

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JEL Classification: Q01, Q2, Q420.

K e y w o r d s: renewable energy sources, energy independence, energy goals.

A b s t r a c t

This article discusses the state of renewable energy sources (RES) in Poland, comparing it with the one in the EU-27. It has been emphasised that the Polish government is obliged carry out the EU policy, also in terms of energy targets. Thus, Poland is committed to achieving a 31.5% share of RES in all energy generation sources by year 2030. The aim of this study has been to determining the state of RES in Poland and determining the prospects for their further development based on it. The state of RES development in Poland has been determined on the basis of generally available statistical data (Poland Statistics GUS). Eurostat was the source of data pertaining to the European Union. According to preliminary data, in 2023, the share of RES in Poland was 27%, compared to 44% in the EU-27. Having determined the state of RES development in Poland, we were able to identify prospects for their future development. The prognosis made in this study substantiated the conclusion that the set target of 31.5% share of RES in all energy sources will not be achieved in Poland. The Polish economy is progressing in the right direction, and the RES share is increasing year to year, but the pace of this progress is too slow. Some ways of increasing the RES contribution to overall energy generation as well as certain obstacles to the growth of RES are implicated in this article. Attention has been drawn to the impact of the COVID-19 pandemic and war in Ukraine on the energy sector.

How to cite: Świdyńska, N. (2024). Renewable Energy Sources in Poland in 2014-2023 and the Perspective of their Development until 2030. A Contribution to the Discussion. *Olsztyn Economic Journal*, *19*(1), 31-44. https://doi.org/10.31648/oej.10093

ODNAWIALNE ŹRÓDŁA ENERGII W POLSCE W LATACH 2014-2023 I PERSPEKTYWA ICH ROZWOJU DO 2030 ROKU. PRZYCZYNEK DO DYSKUSJI

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S ł o w a k l u c z o w e: odnawialne źródła energii, niezależność energetyczna, cele energetyczne.

A b s t r a k t

W artykule przedstawiono stan odnawialnych źródeł energii (OZE) w Polsce, porównując go ze stanem w UE-27. Podkreślono, że polski rząd musi realizować politykę Wspólnoty, również w zakresie celów energetycznych. W związku z tym Polska jest zobowiązana do uzyskania do 2030 r. 31,5-procentowego udziału OZE w źródłach wytwarzania energii. Celem badań było określenie stanu OZE w Polsce i ustalenie na jego podstawie perspektyw ich dalszego rozwoju. Stan rozwoju OZE w Polsce określono na postawie ogólnodostępnych danych statystycznych (GUS). Źródłem danych o europejskim zasięgu był Eurostat. Według wstępnych danych udział OZE w 2023 r. wyniósł 27% w Polsce i 44% w UE-27. Po określeniu stanu rozwoju OZE w Polsce możliwe było określenie perspektywy ich rozwoju. Wyniki przeprowadzonej prognozy pozwoliły na stwierdzenie, że w Polsce do 2030 r. nie zostanie osiągnięty cel 31,5-procentowego udziału OZE w źródłach wytwarzania energii. Polska gospodarka zmierza w dobrym kierunku. Z roku na rok wzrasta udział OZE, tempo zmian jest jednak zbyt wolne. W artykule wskazano na sposoby zwiększenia udziału OZE w źródłach wytwarzania energii, podkreślając jednocześnie liczne bariery ich rozwoju. Zwrócono uwagę na wpływ pandemii COVID-19 i wojny w Ukrainie na sektor energetyczny.

Introduction

Renewable energy sources (RES) are a concept that most of us are well familiar with. What is more, the vast majority of people are in favour of the development of RES (cf.: Witkowska-Dąbrowska *et al*., 2021, p. 9-11; Wierzbicka, 2022, p. 4, 5; Sikora & Zimniewicz, 2023, p. 456-475). Public support is a favorable factor for RES development. Its absence could cause spatial conflicts and consequently block further development.

Being a member state of the European Union, Poland is obliged to implement the European Community's policies, including the energy policy. The first goal of the EU-planned development of RES, which was to achieve a 12% share of RES in all energy sources by year 2010, was planned back in 1997 (the Kyoto Protocol) (Communication from the Commission. Energy for The Future, 1997). This aim was not binding for the EU countries, but it served as a tool to monitor progress of the ongoing transformation. In the subsequent years, there were other agreements and directives that modified the above goal. Mention should be made here of the following RED directives (Renewable Energy Directive). The first, RED I (Directive 2009/28/EC of the European Parliament and of the

Council of 23 April 2009…, 2009), imposed an obligation on all European Union countries to increase the share of energy generated from RES in total energy consumption by 2020. (15% for Poland). The second, RED II (Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018…, 2018), maintained this goal. The third version of the RES Directive (RED III) set the share of RES at a level of 42.5% for the European Community's economy to be attained by year 2030 (Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023…, 2023). It did not introduce mandatory targets for individual countries. However, the transformational goals it set allowed for an estimated share of 31.5% in Poland. Setting energy goals is essential for stimulating the transformation, adjust the network infrastructure, and to ensure the availability of adequate production capacities (Adamczewski & Wójcik, 2023, p. 5).

No discussion that raises the question of deviating from fossil fuels can neglect the European Green Deal, a strategy for the growth that aims to create a resource-efficient, up-to-date and competitive economy, and whose ultimate objective is to achieve zero emission of greenhouse gases by 2050 (Wrzaszcz & Prandecki, 2020, p. 156-179). The cost of building zero-emission economy in Poland is estimated at 700-900 billion Polish zloty. Such high estimates are a consequence of the Polish economy possessing an energy-intensive structure, with a high share of coal in the energy mix (Sobolewski, 2020, p. 1-4). More on RES in the context of the European Green Deal is written by:

– Mielczarski (2021, p. 84-87), who already in the introduction emphasized that although the European Green Deal is controversial, it can contribute to the long-term modernization of the Polish economy;

– Olczak (2020, p. 115-128) pointed out that the development of RES is primarily the diversification of energy sources and, consequently, the improvement of the country's energy security;

– Ciechanowicz-McLean (2021, p. 9-20), summarizing her consideration of the European Green Deal, pointed out that it is "an effort to face the challenge of disturbed relations: human-environment";

– Szczubełek (2022, p. 175-190) pointed out that due to the scale of reforms planned, the European Green Deal is the most extensive legislative initiative in the entire history of the EU.

Importing fossil fuels, which are the fundamental source of energy generation in the EU member states, from outside the European Union lead to several negative consequences (Adamczewski & Wójcik, 2023, p. 6; Adamowicz, 2021, p. 13-33; Pangsy-Kania & Wierzbicka, 2022, p. 86-102):

– financial ones: these imports cost the EU economy € 720 billion in 2022 (*Import produktów energetycznych od UE*…, 2023);

– economic ones: this money is transferred to other economies, the EU competitors, driving their development;

– environmental problems: high carbon dioxide emission (*Emisje gazów cieplarnianych*…, 2023).

An antidote to these problems, able to alleviate their adverse impact, is to increase the use of RES. Unquestionably, renewable energy sources are friendly to the environment (they are an alternative to fossil fuels and help to reduce GHG emission) and, in the long term, they create a chance to ensure energy independence (Gomółka & Kasprzak, 2023, p. 483-507), the significance of which became so acutely felt after the invasion of Ukraine by the Russian Federation and the outbreak of fuel war between Russia and the EU. Krzykowski (2022, p. 93-113) and Tokarski (2022, p. 10-16) report in greater detail on the economic consequences of war in Ukraine and on its impact on the energy market. Krzykowski stresses that in an interdependent, globalized world, war cannot be narrowed down, to a single region. The Russian invasion has caused numerous consequences, including instability in energy security. Tokarski points to rising gas prices and supply shortages as a result of the war. Domestic sources of energy generation should be rebuilt (offshore wind farms, nuclear power, photovoltaics should replace coal-fired power plants).

A possible way to achieve the goal set by the EU could involve firstly changes within the road transport sector, including the development of electromobility (Brdulak & Pawlak 2021, p. 31-42; Dereń & Owczarek, 2021, 19-30), and secondly the use of green hydrogen (Stocki & Hübner, 2021, p. 117-128). It is also crucial to develop onshore and offshore wind energy and photovoltaics. However, these sources, due to their dependence on the weather conditions, can be problematic. Moreover, restrictive legal regulations also constrain the growth of such energy generating facilities (Tora *et al*., 2022, p. 111-118; Bojar-Fijałkowski, 2021, p. 63-75; Act of 20 May 2016 on investments in wind farms, 2016). Thermal insulation of buildings and use of heat pumps are also important (Adamczewski & Wójcik, 2023, p. 20).

The aim of this study has been to determining the state of RES in Poland and determining the prospects for their further development based on it. The following research questions were put forth: are we in Poland moving away from conventional sources of energy? Is there an increase in the use of RES? Is Poland able to reach the energy goals set by the European Union? Is it able to secure energy independence? Which type of RES is developing most rapidly?

The above research questions led to the following hypotheses:

H1: Although there is progress in the development of renewable energy sources in Poland, the Polish economy is significantly different in this regard from other EU economies.

H2: With the current rate of growth, the Polish economy is able to reach the goal set by the European Union.

Recent years have seen increased development of RES and an increase in their share of energy generation sources (more than ¼ in 2023). Maintaining the growth trend at this high level could result in Poland achieving its energy goals faster than the European Union imposes. The present work is a probe to fill this research gap.

The share of RES use in the Polish economy should reach 31.5% by year 2030. It is one of the lowest targets in the EU-27. It is only the Czech Republic that has a lower goal, while the highest one was set for Sweden (around 75%). Poland met the energy goal for year 2020, which was 15%. This was made possible due to the outbreak of the COVID-19 pandemic, which limited the consumption of fossil fuels in the countries where lockdowns were imposed (cf. Bulut, 2020, p. 284-295; Prol & Sungmin, 2020, p. 1-29), especially in transport (more on this topic in: Adamczewski & Wójcik, 2023, p. 13; Łukasiewicz, 2022, p. 85-108). It should be underlined, however, that the COVID-19 pandemic brought about many negative consequences in the energy sector. Just & Echaust (2023, p. 41-66) pointed out that the period from the outbreak of the pandemic to early 2023 is associated with an increase in energy market price volatility. Górska (2023, p. 109-128) saw in the pandemic the reason for the increase in energy poverty levels in Europe. It is worth emphasising that according to the strategies already prepared by the Polish administration, that is the Polish Hydrogen Strategy until year 2030 with an outlook until 2040 (2021), the National Plan for energy and climate for years 2021-2030 (2019), Strategy for the heating sector until 2030 with an outlook until 2040 (2022), the Energy Policy for Poland until 2040 (2021), the 31.5% goal will be achieved until 2030. Thus, the measures taken for the sake of energy transformation have already been planned. However, with the current pace of development, is it realistic to achieve this goal?

Research Methodology

The state of the RES development in Poland has been determined on the basis of publicly available statistical data. The website of Statistics Poland (GUS) provides many reports and studies, which are updated on an ongoing basis. Another valuable source of European data is Eurostat.

Having determined the current state of the RES development in Poland, it was possible to identify the prospects for their further growth. Forecasting consists of predicting the course of probable future events. The literature describes many methods for prognosis of economic processes and phenomena. Mathematical models based on the assumption of continuity and predictability of processes and the use of historical data are employed for forecasting – and one of the main requirements for growth models is their consistency with the development observed in the past (Strużak, 2009, p. 39). Continuation of the current state is the most probable within the predictability horizon (Peitgen *et al.*, 2002). This study employed a logistic function to model various growth processes. According to this function, as development proceeds, the initial rapid growth rate decreases to reach an impassable limit at the final stage. The logistic function is characterized by a good fit to historical data. This argument spoke for its use in the study.

In the simplest form, this function can be written as follows (Strużak, 2009, p. 45):

$$y = \frac{1}{1 + \exp(-t)},$$

where:

y – function of growth (equal 1 at the most),

t – time.

For its practical application, this function was modified by introducing three time-constant numerical parameters determining the course of the function – a, b and c (Grzegorek & Wierzbicki, 2009, p. 119):

$$y = \frac{a}{1 + b\exp(-c \cdot t)},$$

where:

$a, b, c \geq 0$,

a – saturation of the analysed phenomenon determined heuristically,

b, c – parameters of the function selected through statistical estimation.

For the logistic function to serve the forecasting of economic phenomena and processes, values of parameters a, b and c must be adjusted to historical data, with the shortest time series having at least three elements so as to obtain reliable results; however, the longer the time series, the better the estimation – owing to the lower impact of random errors (Grzegorek, 2012, p. 32).

In the research conducted, parameter a, which defines the natural saturation level, was taken at 31.5%, as this is the target the Polish economy is expected to reach by 2030. Parameters b and c were selected through statistical estimation performed in Statistica 13.

Surówka (2023, p. 135) in her research confirmed the hypothesis: "Dynamic changes in the production of electricity from renewable energy sources mean that making forecasts of the formation of this phenomenon should be considered experimental", but it should be remembered that forecasting is only an attempt to predict the future. Setting energy goals is essential for stimulating the transformation, adjust the network infrastructure, and to ensure the availability of adequate production capacities.

The State of RES in Poland

Coal, both hard (43%) and brown (26%), was still the most important fuel in Poland used for the generation of electricity in 2022. In comparison to year 2014, however, there was a notable decrease in their contribution to energy generation in 2021 (from 48% and 34%, respectively), mostly to the advantage

of RES (increase from 12% to 21%) (Fig. 1). According to some preliminary data, the share of RES in 2023 reached 27% (Derski, 2024).

There are countries in the European Union with an energy dependency ratio, which determines the share of imported energy sources in total energy consumption, of more than 90% (Cyprus, Luxembourg, Malta). The least dependent European country is Estonia (5%) (Pangsy-Kania & Wierzbicka, 2022, p. 93-94). In Poland in 2021, the rate was about 40% (Cierpiał-Wolan (supervisor) *et al.* 2023b). A clear answer to the question of whether Poland can achieve energy independence is difficult. An opportunity to achieve this goal is more dynamic development of RES. It is therefore not a goal that Poland will achieve in the coming years.

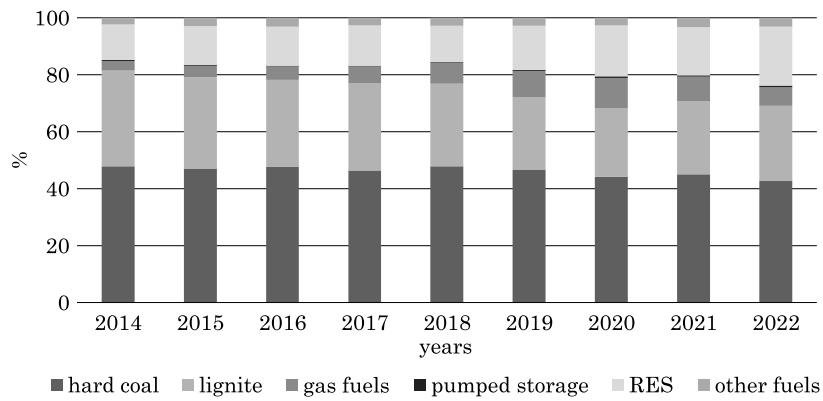


Fig. 1. Production of electricity according to carriers [%]
Source: based on Cierpiał-Wolan (supervisor) *et al.* (2023b).

As reported in the *European Electricity Review 2024* (2024), production of energy from RES in the EU-27 was record high (44%). This high increase was mostly contributed to by photovoltaic installations and wind farms (27%). Meanwhile, the lowest share of fossil fuels was recorded, and the contribution of RES to electric power production exceeded that of fossil fuels for the first time in history. This confirms the general trend of abandoning fossil fuels in favour of renewable energy sources.

The structure of RES-based energy production primarily depends on the country-specific geographical conditions, which explains why it is different in Poland than in the entire EU-27. For example, the highest contribution to energy generation from renewable energy sources in 2021 was made by: hydropower facilities in Slovenia (35% vs 1.6% in Poland, solar energy in Malta (61% vs 3.3% in Poland, heat pumps in Malta (36% vs 2.9% in Poland, wind energy in Ireland (56% vs 10.9% in Poland) (Cierpiał-Wolan (supervisor) *et al.*, 2023a).

Although solid biofuels dominated among RES in both Poland and the EU-27, they made up 69.4% in Poland and only 41.2% in the EU. An analysis of the structure in 2014 and 2021 demonstrated that the share of solid biofuels in Poland decreased (down by 6.7%) in favour of other RES carriers, especially solar power (up by 2.9%) and wind energy (up by 2.8%). As for the EU-27, an increase between these two years was observed in the contribution of heat pumps, wind power and solar power (up by 4.1%, 2.8%, and 1.5%, respectively). A comparison of the shares of particular energy carriers in Poland and in the EU-27 in the mentioned time period shows that Poland had a distinctly higher contribution of solid biofuels to energy generation (by 28.2% in 2021), but a much lower share of water energy (by 10.7% in 2021) (Fig. 2).

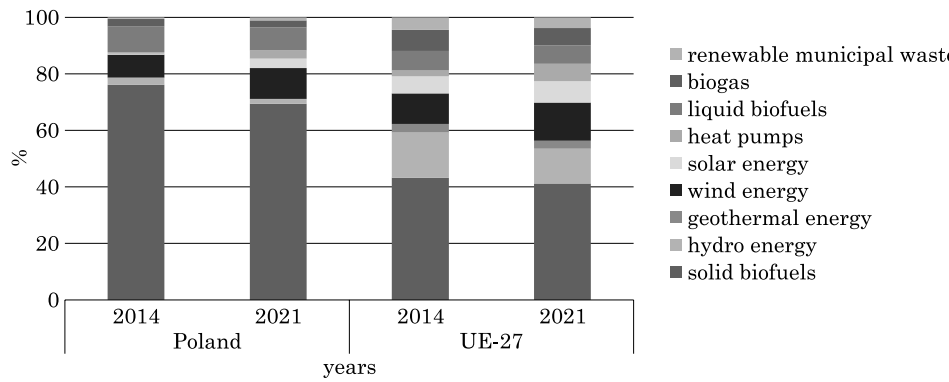


Fig. 2. Structure of energy production from RES (according to carriers) in Poland and in the EU-27 [%] in 2014 and 2021

Source: based on: Cierpiał-Wolan (supervisor) *et al*. (2023a); Walkowska (supervisor) *et al*. (2019).

A priority issue from the point of view of achieving Poland's energy goals is the share of renewable energy sources in the production of electricity from renewable sources. In Poland, there was an evident increase between years 2014-2021 in the share of wind energy (up by 14.2%) and solar power (up by 12.6%), while that of solid fuels decreased (down by 25%). With respect to geothermal energy and liquid fuels, their contribution was close to 0%. In the European Union, an increase in the share of RES in energy generation was only observed for solar power (up by 4.4%) and wind power (up by 8%). When comparing shares of individual energy carriers in total production of electricity from renewable sources in Poland and in the EU-27, it became evident that the share of wind power and solid biofuels was much higher in 2021 (up by 16.7% and 12%, respectively), while that of hydropower was distinctly lower (down by 24.1%) (Fig. 3).

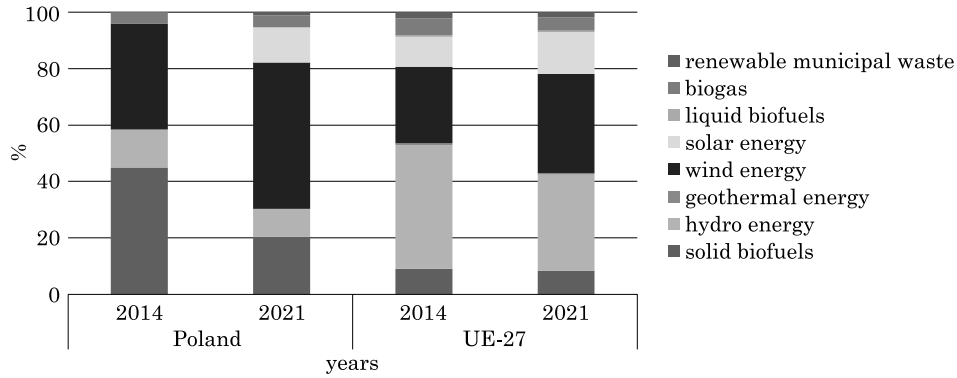


Fig. 3. Structure of electricity production from renewable energy carriers in Poland and in the EU-27 [%]
Source: based on: Cierpiał-Wolan (supervisor) *et al.* (2023a); Walkowska (supervisor) *et al.* (2019).

A decline in the consumption of solid biofuels is a desirable trend because they are not an innovative or sustainable source of energy; they cause high emission of smog and can lead to deforestation (Lorek & Lorek, 2023, p. 114-131). The growth of wind and solar farms progresses under the strain of numerous barriers, such as legal, economic, technological and organisational obstacles, which are difficult to overcome (Sikora & Zimniewicz, 2023, p. 456-475). Many authors point to several disadvantages of renewable energy sources, of which the one highlighted by Bielewicz is worth attention (2022, p. 20, 21): „the sun does not shine all the time or everywhere, and winds do not always blow", which implicates the need to store energy. Moreover, some fuels (e.g. gas, atom), which used to be considered as harmful to climate, have now been accepted to be environment--friendly ones, mainly in the face of the war in Ukraine (Héjj & Sommer, 2023).

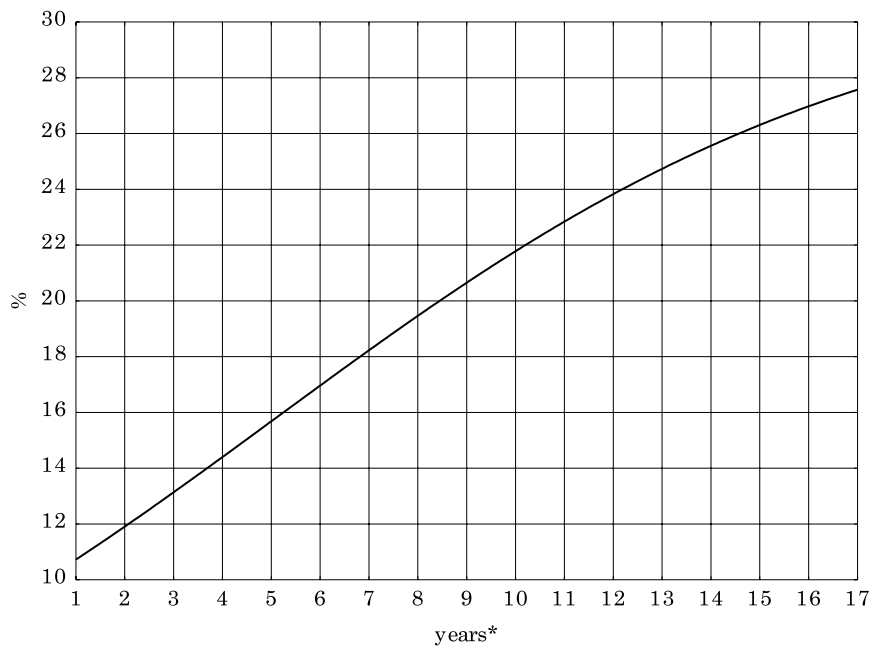
Unfortunately, the use of renewable energy in Poland differs greatly from the levels achieved in other EU-27 countries. This is confirmed by other scholars, e.g. Grzebyk & Stec, 2023, p. 244-264; Witkowska-Dąbrowska, 2018, p. 397-409. In conclusion, the first research hypothesis, H1: Although there is progress in the development of renewable energy sources in Poland, the Polish economy is significantly different in this regard from other EU economies, has been confirmed.

Use of RES in Poland in 2030

For the purpose of this study, parameter a, which refers to the natural saturation level, was assumed to equal 31.5% because this is the goal set for Poland by the European Union. Based on data from years 2014-2023 regarding the share of RES in the sources of energy generation in Poland, and then, using

Statistica 13, a software statistical and analytical package, parameters *b* and *c* of the logistic function were calculated (*b* = 0,909; *c* = -0,005). The application of the logistic function enables us to identify development trends until 2030 according to the time series.

At the current pace of RES development in Poland (data for years 2014-2022 and preliminary data for year 2023 – from 1 to 10 on the cut-off axis), a steady increase in RES in all energy generation sources in Poland can be predicted. Until 2030, (17 on the cut-off axis), for which year Poland's goal is to achieve a 31.5% share of RES, the said percentage will reach barely 28% (Fig. 4).



* 1–10: 2014–2023 – secondary data; 11–17: 2024–2030 – prognosis

Fig. 4. Perspective on changes in the share of RES energy in power generation sources
Source: the authors, based on Cierpiał-Wolan (supervisor) *et al.* (2023b); Derski (2024).

Therefore, the second research hypothesis, H2: With the current rate of growth, the Polish economy is able to reach the goal set by the European Union, had to be refuted.

Conclusions

The aim of the study, which was to determining the state of RES in Poland and determining the prospects for their further development based on it has been achieved. The research questions have been answered:

– in Poland, there is a trend away from conventional energy sources;

– the use of RES is increasing;

– at the current pace of development, Poland is unable to reach the 31.5% contribution of RES to energy generation until year 2030;

– Poland will be unable to secure energy independence in the near future;

– in Poland, solar and wind power generation is developing the fastest.

Two research hypotheses were verified. H1: Although there is progress in the development of renewable energy sources in Poland, the Polish economy is significantly different in this regard from other EU economies, was verified positively, while H2: With the current rate of growth, the Polish economy is able to reach the goal set by the European Union, had to be rejected.

The very high share of fossil fuels in Poland's energy mix has many negative consequences, among which the need to import them from outside the country's borders should be highlighted. By far the dominant supplier of raw materials to Poland is Russia. Poland is therefore not, firstly, energy secure, and secondly, energy independent. The importance of these aspects was highlighted by Russia's attack on Ukraine and the outbreak of the Russia-EU fuel war. The war in Ukraine has significantly affected the energy market.

The Polish economy is progressing in the right direction. The share of RES is increasing year to year, but the pace of changes is too slow. Legal restrictions do not aid the growth. However, it is worth bearing in mind that the structure of energy generation from RES and therefore the volume of energy harvested from each energy carrier depend first and foremost on the country-specific geographical conditions. Furthermore, Poland does not have a nuclear power plant, and plans to build one, which are put forth from time to time, are met with public protests.

The road to independence and energy security is a multi-track one. The second path, after RES, is nuclear power. As a consequence of numerous turbulences, among them the Chernobyl Nuclear Power Plant disaster, the implementation of the investment in Poland has not materialized so far. The difficult geopolitical situation, the real danger of an energy crisis and the increase in electricity prices have revived the discussion of nuclear energy development. It is worth recalling that the establishment of the European Atomic Energy Community (1957) laid the foundation for the construction of the European Union. Currently, 13 countries in the Community have nuclear power plants in operation. In 2022, nuclear power plants generated ¼ of the total electricity produced in the EU (Sobolewski, 2020, p. 1-4).

Translated by Jolanta Idźkowska

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