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ACQUISITION AND CONSUMPTION OF ENERGY FROM RENEWABLE SOURCES IN EUROPEAN UNION COUNTRIES

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ABSTRACT: The European Union is assuming an increase in the role of renewable energy sources (RES) due to the need to diversify the energy balance and decarbonise it. These measures are also necessary because of the need to reduce dependence on uncertain and volatile fossil fuel markets. However, the priority is to minimise the energy sector's environmental impact. Member states have pledged to achieve national RES targets according to their capabilities. The purpose of the article is to assess the development of renewable energy sources and the implementation of Poland's commitments to increase the share of renewable energy in all sources of energy consumed, including the transport sector. The analysis covered EU countries in 2014 and 2020, using EUROSTAT database data. Descriptive analysis and the Hellwig method were used, which made it possible to order countries by their level of development of renewable energy sources. A distinction was made between countries with the highest, high, low and very low levels of development in question. The results of the study revealed regional variations in the level of RES development, placing Sweden, Finland and Austria as leaders. Poland ranked last in 2020, forming a group of countries with the lowest level of RES development. Binding targets at the EU level for RES development have been achieved. With regard to the share of RES in final energy consumption, all countries, with the exception of France, have achieved the target, often higher than the target for the country. Considering the share of RES in transportation, most countries have not reached the planned level.

KEYWORDS: renewable energy sources, the European Union countries, regional differences, Hellwig's method

Objectives and determinants of RES development in the EU – literature review

Energy is the lifeblood of economies, and access to it is a factor in the development of civilisation and the progress of globalisation processes. At the current level of deposit exploitation, the reserves of most fossil fuels will eventually run out. The alternative is to increase the share of renewable energy and save energy by increasing its efficiency. Ambitious targets for tightening harmful atmospheric emissions are a necessity for the world, as they result from expansive economic, technological, and environmental processes. European Union member states are part of the process aimed at assuring climate neutrality. However, each country must define its own path of transformation, taking into account not only community goals but also the internal potential for the development of renewable energy sources as a key direction to a non-carbon, efficient and secure energy industry.

At the EU level, as stipulated in treaties, energy policy is part of the internal market and responds to the many challenges facing the Community in the energy sector, notably increasing import dependence, insufficient diversification, high and volatile energy prices, growing global energy demand, the growing threat of climate change and decarbonisation. Using a variety of instruments, the EU aims to ensure the functioning of an integrated energy market, ensure the security of energy supply, and promote energy efficiency and energy savings. It is also tasked with developing new and renewable forms of energy and promoting the interconnection of energy networks, taking into account environmental protection and the fight against climate change (Treaty, 2016). Current EU policy goals are aimed at a comprehensive and integrated approach to climate and energy policy.

A number of assumptions for energy and climate policy have been adopted since 2015 by the European Commission, including, among others, in 2015 – the Energy Union Strategy to create an energy union that will ensure a secure, sustainable, competitive and affordable energy supply for EU households and businesses; and in 2016, the Clean Energy for All Europeans package, focusing on the structure of the electricity market. The overarching goal of the adopted documents is to maintain the EU's position as a world leader in renewable energy sources and to meet its emission reduction commitments under the Paris Agreement. As part of the aforementioned package, the revised Renewable Energy Directive (Directive, 2018) came into force in December 2018, setting a binding target that by 2030, final energy consumed in the Community should be sourced at least 32% from renewable sources. A complementary clause was also written in to allow an increase in this target by 2023, as well as an increase in the target for a 14% percentage of renewable energy in transport by 2030. The EU's increasingly ambitious climate policy is confirmed by the so-called "Fit for 55%" package, published in July 2021, which is a set of legislative proposals to achieve the EU's new target of reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990. Approved in December 2020, the target commits member states to intensify their efforts on the route to achieving climate neutrality by the middle of this century (European Commission, 2021).

A more secure and sustainable energy industry is a significant challenge the world is facing (Barquin et al., 2010). This is especially true for the European Union, as is evident from the overarching climate and energy policy goal of achieving climate neutrality by 2050. A key tool for achieving the ambitious intentions is the energy union – an instrument for transformation, including decarbonising the community energy system (Paszkiewicz, 2022). It adopted a governance mechanism based on integrated energy and climate plans of member states.

The EU's priorities until 2030 with regard to energy and climate are clarified by the European Green Deal, adopted in 2019, which consists of a package of measures to ensure that citizens and businesses benefit from the EU's sustainable environmental transition (Communication, 2019). The roadmap contained in the document is general in nature and addresses, among other things, investment in cutting-edge research and innovation or protection of Europe's environment. Above all, however, it sets a path for a fair transition for all EU regions. At the same time, it is a tool for implementing the UN 2030 Agenda for Sustainable Development and the Sustainable Development Goals (ONZ, 2015).

One of the EU's priorities is to increase energy efficiency and the role of renewables in the energy mix. This can be achieved by reducing overall energy consumption in the EU and managing energy in a more cost-effective manner, promoting RES, including prosumerism (Żur, 2021). These measures contribute to achieving energy savings, greater environmental protection, mitigating climate change and, crucially, reducing the EU's dependence on external oil and gas suppliers.

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The widespread use of renewable energy from the sun, wind, water, land, plant and animal matter has many potential benefits, particularly the reduction of greenhouse gas emissions (Rokicki et al., 2018). A significant advantage is the increased diversification of energy supplies and reduced dependence on fossil fuel (oil or gas) markets (Młynarski, 2019). This increases the energy security of the country/community, all the more so with the assumption that the use of RES does not reduce their resources and, in principle, does not pose a risk of depletion. Access to RES is available anywhere in the country, which means there is no need to import fossil resources from other countries.

Increased use of RES should also lead to less air pollution since dust and heavy metals are not emitted into the atmosphere during their operation. Abandoning coal-fired power plants would reduce emissions of harmful substances into the atmosphere, thereby improving the condition of the environment (Rokicki et al., 2018).

The development of renewable energy sources in the EU can also stimulate employment mainly through job creation due to the development of new technologies, referred to as green technologies. Innovation in this area fosters the development of new industries, for example, in the area of electromobility or bioeconomy (Młynarski, 2019).

In the long term, RES increases the competitiveness of the energy sector, which is due to the fact that renewable energy sources, once installed, lead to lower energy costs (Wiśniewski & Więcka, 2018). For the consumer, the use of renewable energy sources will translate into lower electricity bills and independence from energy producers and distributors.

However, the development of renewable energy sources generates significant costs, such as those associated with the construction of a hydroelectric power plant to obtain hydropower. In addition, these activities interfere with the ecosystem and landscape. Indeed, the various types of renewable energy exhibit weaknesses that are not insignificant to the environment. A disadvantage of hydropower plants, especially large ones, is the risk of bank erosion in hydroelectric power plants. The water is then not adequately oxygenated, and the tank may become silted up. Turbines that impede fish migration in rivers are also a problem. The production of photovoltaic panels from silicon, on the other hand, involves the emission of harmful substances, and the already used components of the installation must be properly recycled, otherwise, they become waste. The issue of the negative environmental impact of the huge water consumption for lithium production or water and soil contamination has also been raised (Strupczewski & Koszuk, 2019). Significant costs can be generated by the use of biomass, which requires more electricity to transport and store than coal.

However, in the long run, the cost of RES drops significantly, especially for solar and wind energy acquisition (Birol, 2019). The subsequent zero-carbon operation of photovoltaic panels provides some compensation for the adverse impact. In addition, as RES cost analyses show, there is significant potential to reduce the cost of generation source technologies that use renewable resources. The unit cost of energy generation depends on the potential of renewable energy resources and local conditions (Paska & Surma, 2018).

A key challenge related to the promotion of RES is the issue of balancing energy systems due to the difficulty of ensuring a secure supply of this type of energy. The problem here is weather conditions, such as windless weather, which results in unpredictable and uncontrollable wind farms. Similarly, when the wind is strong, energy production exceeds demand, but there are no effective solutions for storing large amounts of electricity. It is also worth noting that RES, for example, wind farms, occupy large areas (Jędral, 2020).

RES, therefore, generates a number of challenges in balancing the national electricity system. Economic, and technological solutions enabling energy storage are crucial for the future. The European Union assumes that the development of RES will provide accelerated modernisation of the EU's energy sector and economic growth while providing significant socio-environmental benefits. Support for RES investments from public funds is an instrument to help achieve these goals.

The literature presents, therefore, a number of scientific studies on energy sector transition and development, including, among other things, the issue of sustainable energy development in the European Union and individual countries (Su et al., 2020; Sobczyk & Sobczyk, 2021; Ghenai et al., 2020; Tutak et al., 2021). Many of them take into account the important issues of carbon intensity for climate neutrality (García-Álvarez et al., 2016). Considerable attention is being paid to the development of specific types of renewable energy, especially wind energy, with multi-criteria evaluation (Chudy-Laskowska et al., 2020). These studies note a certain paucity of research on the variation in

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the level of RES development in the context of the implementation of the EU priorities that member states are pursuing from each financial perspective. Due to the lack of such studies, there is a research gap in assessing the development of RES and the implementation of Poland's RES commitments in 2014 and 2020, i.e., at the beginning and end of the EU financial perspective. Hence, the purpose of the article is to assess the development of renewable energy sources and the implementation of Poland's commitments to increase the share of renewable energy in all sources of energy consumed, including the transport sector.

Research methods

In order to compare the level of development of renewable energy sources of European Union countries, descriptive analysis and Hellwig's taxonomic measure of development (Hellwing, 1968) were used to order countries by their level of development of renewable energy sources. The study looked at all EU-27 countries in 2014 and 2020, also taking a broader view of the future development of renewable energy sources in the Community. The source of the data was the EUROSTAT database. The scope of the research, taking into account inequalities in RES development and using analytical tools, makes this work both a new and original approach to the presented topic.

At the initial stage of the study, the variability of the objects was assessed so that the characteristics exhibited the appropriate variability – the classical coefficient of variation was used. And Hellwig's parametric method was used to verify the carrying capacity of the information, arbitrarily setting the threshold value of the correlation coefficient at r*=0.8.

Hellwig's method belongs to the group of pattern methods because it is based on the construction of an abstract object P0 called a development pattern (in particular, it can be a real object). The studied objects are ordered according to their distance from the development pattern. This makes it possible to identify the level of development and create comparative rankings. The construction of a taxonomic measure of development proposed by Hellwig includes the preparation of an input matrix of diagnostic variables and the standardisation of their values in order to bring about the comparability of the variables (Nowakowska, 2009).

The procedure leading to the determination of Hellwig's synthetic measure of development consists of the following stages:

- Preparation of a set of matrixes of diagnostic variables, which was divided into stimulants and destimulants. In the study in question, all selected variables are stimulants.
- In order to bring the data to comparable values, normalisation was applied using the standardisation of[1] features according to the formula:

$$z_{ik} = \frac{x_{ik} - \bar{x}_k}{S_k} \; for \; x_k \in \mathrm{I} \; (i = 1,\dots, n;\ k = 1,\dots, m), \tag{1}$$

where:

I – set of stimulants,
Z_{ik} – standardised value of feature k for region I,
x_{ik} – value of feature k in region I,
$\bar{x}_k$ – arithmetic mean of variable k,
S_k – standard deviation of the variable k,
m – number of variables,
n – number of regions.

- Determination of the development pattern (abstract object P_0), which is characterised by the highest values for stimulants and has standardised coordinates:

$$P_0 = [Z_{01}, Z_{02}, \dots, Z_{0k}], \tag{2}$$

[1] It should be pointed out that in standardizing the variables, the arithmetic mean and standard deviation calculated once for the entire study period were used. Such an operation is required to ensure comparability of data over time (Zeliaś, 2000).

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where:

$$Z_{0k} = \max\{z_{ik}\} \text{ – when } x_k \text{ is a stimulant,} \quad (3)$$

To ensure comparability of the data, a single pattern was set for both years under study.

- Calculation of the distance between each country and the adopted pattern – point P_0, according to the formula (Euclidean distance):

$$C_{i0} = \sqrt{\sum_{k=1}^{m}(Z_{ik} - Z_{0k})^2} \quad i = 1, 2, 3, ..., n, \quad (4)$$

- In order to normalise the value of d_i indicator, a relative taxonomic measure of development was constructed, which is calculated according to the following formula:

Distances from the pattern were determined separately for each year studied.

$$d_i = 1 - \frac{c_{i0}}{c_0} \quad i = 1, 2, 3, ..., n, \quad (5)$$

where:

$$c_0 = \overline{c_0} + 2S_0, \quad (6)$$

$\overline{c_0}$, S_0 – arithmetic mean and standard deviation of c_{io} (i = 1, 2, 3, ... n) sequence, respectively,
d_i – synthetic indicator,

whereas:

$$\overline{c_0} = \frac{1}{n}\sum_{i=1}^{n} c_{i0}, \quad (7)$$

and

$$S_0 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(c_{i0} - \overline{c_0})^2}. \quad (8)$$

The synthetic measure of development d_i (5) obtained as a result of the calculations assumes values in the range from 0 to 1. The closer the value of di measure is to one, the less distant the given object (country) is from the pattern and the higher level of technical infrastructure development it has.

A set of diagnostic variables that characterise the phenomenon under study was used to assess the potential of renewable energy sources. This selection meets three basic criteria: substantive, formal and statistical (Strahl, 2006). Taking into account the achievements of the researchers of the subject and the experience of the authors of the article in this area, the features for examining the potential of the RES of the European Union countries were identified. A matrix of 5 explanatory variables was prepared to conduct this analysis. The selection of variables adopted for the study was determined by the subjective assessment of the impact of individual indicators on the phenomenon under study, as well as the possibility of obtaining statistical data. The Eurostat database became the source of the information (Eurostat, 2023). As explained in the Eurostat database, the data in question are complete and comparable across countries in accordance with the Renewable Energy Directive (Directive, 2009).

All characteristics, which are the basis for the preparation of a synthetic indicator in Hellwig's method, were presented in relative values. The level of RES development is largely characterised by features such as:

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- X1 – share of renewable energy in total primary energy production (%),
- X2 – share of renewable energy consumption in the gross final energy consumption (%),
- X3 – share of energy from renewable sources in final energy consumption in transport (%),
- X4 – share of electricity from renewable sources in gross final consumption of electricity (%),
- X5 – share of renewable energy in gross final energy consumption in heating and cooling (%).

Indicator X1 measures how widespread the acquisition of energy from unconventional sources is and indicates the extent to which renewable fuels are replacing fossil and nuclear fuels[2]. The indicator of the share of energy from renewable sources in gross final energy consumption (X2) is calculated as the quotient of the value of gross final energy consumption from renewable sources and the value of gross final energy consumption from all sources[3]. Features X3, X4, and X5 supplement the analysis of the total share of renewable energy. These are indicators for the share of RES in three sectors of consumption: electricity, heating and cooling, and transport. These indicators are part of a set of indicators for the EU Sustainable Development Goals and monitor progress towards achievement of the 7th Sustainable Development Goal on affordable and clean energy and 13th Sustainable Development Goal on climate action, which are embedded in the priorities of the "European Green Deal".

Comparison of the level of development of RES in the European Union countries – results of the study

The study conducted covered all EU countries and was based on statistics obtained for 2014 and 2020. The selected diagnostic variables should be characterised by high variation and low correlation with other variables (Stec, 2011; Miłek, 2018). In order to obtain the final set of variables, their reduction was carried out on the basis of the coefficient of variation and Hellwig's parametric method (Hellwig, 1968; Hellwig, 1972) and the studies: Młodak (2006) and Szkutnik et al. (2015). In the present case, the coefficient of variation for all analysed variables has higher values than 10%, which means that the selected diagnostic characteristics have a high capacity to differentiate EU member states due to their potential to generate RES. The threshold value of Pearson's correlation coefficient was arbitrarily set as $r^*=0.8$. The determination of the correlation matrix of the variables allowed us to analyse their information capacity. Based on Hellwig's parametric method, no variable was excluded from the study. Although the variable X2 is a satellite variable, given the purpose of the study and the limited small number of variables, 5 diagnostic variables were finally adopted for the purpose of the study. On the basis of the analysis carried out in the selection of diagnostic characteristics, it can be concluded that the final set includes variables characterised by a high ability to discriminate individuals in the analysed area.

A synthetic indicator was calculated using Hellwig's development pattern method to represent the level of development of the EU countries' RES. EU countries were classified into four groups: those with the highest, high, low and very low potential in the scope of renewable sources of energy. The results obtained indicate significant disproportions in the level of development of RES of the EU Member States, which is illustrated in Table 1 and Chart 1.

2 Primary energy production is the extraction of energy products in a usable form from natural resources, i.e., wherever natural resources are used, e.g., in coal mines, in oil fields, in hydroelectric power plants or in the production of biofuels.

3 The gross final energy consumption is the energy consumed by end users (final energy consumption) plus network losses and power plant own consumption. The gross final energy consumption therefore means energy commodities supplied for energy purposes to industry, transport sector, households, tertiary sector, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy industry for electricity and heat generation and including losses of electricity and heat during distribution and transmission.

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Table 1. The level of development of RES of the EU countries on the basis of the Hellwig synthetic indicator

Item	EU country	Indicator di	Item	Country	Indicator di
2014			2020		
Group of countries with the highest level of RES development					
di ≥ 0.399			di ≥ 0.492		
1.	Sweden	0.673	1.	Sweden	0.870
2.	Finland	0.611	2.	Finland	0.546
3.	Austria	0.487	3.	Austria	0.496
4.	Latvia	0.410			
Group of countries with high level of RES development					
0.252 ≤ di < 0.399			0.352 ≤ di < 0.492		
5.	Portugal	0.360	4.	Portugal	0.482
6.	Denmark	0.337	5.	Latvia	0.472
7.	Croatia	0.303	6.	Denmark	0.461
8.	Lithuania	0.276	7.	Estonia	0.431
9.	Romania	0.268	8.	Croatia	0.395
			9.	Slovenia	0.360
Group of countries with low level of RES development					
0.104 ≤ di < 0.252			0.212 ≤ di < 0.352		
10.	Italy	0.249	10.	Italy	0.351
11.	Slovenia	0.248	11.	Spain	0.332
12.	Bulgaria	0.210	12.	Lithuania	0.330
13.	Germany	0.210	13.	Romania	0.321
14.	France	0.201	14.	Germany	0.315
15.	Estonia	0.186	15.	Bulgaria	0.308
16.	Slovakia	0.180	16.	Greece	0.306
17.	Czech Republic	0.180	17.	Cyprus	0.280
18.	Spain	0.180	18.	Ireland	0.268
19.	Hungary	0.176	19.	France	0.266
20.	Greece	0.161	20.	Luxembourg	0.262
21.	Ireland	0.148	21.	Slovakia	0.257
22.	Cyprus	0.147	22.	Malta	0.254
23.	Poland	0.141	23.	Netherlands	0.246
24.	Malta	0.126	24.	Czech Republic	0.238
25.	Belgium	0.120	25.	Hungary	0.233
26.	Luxembourg	0.119	26.	Belgium	0.229
Group of countries with very low levels of RES development					
di < 0.104			di < 0.212		
27.	Netherlands	0.084	27.	Poland	0.212

Source: authors' work based on the Eurostat (2023).

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In both years studied, the group of countries with the highest level of RES development consisted of: Sweden, Finland and Austria, with indicator values in 2020 amounting to, respectively: 0.870, 0.546 and 0.496 (in 2014, respectively: 0.673, 0.611 and 0.487) with Latvia (0.410) also included in this group in 2014. In 2020, Latvia left the group with the highest level of RES development and joined group II. However, the large gap between countries in 2014 in the group in question (0.263) increased to 0.374 in 2020. Clearly the lowest level of RES development in 2014 was achieved by the Netherlands, for which the synthetic measure took a value almost 8 times lower than that of the ranking leader, Sweden. It should be noted that the energy used in Sweden comes mainly from unconventional sources, and the most important sources of Swedish renewable energy are currently hydropower and biomass (in 2018, 66% of the electricity consumed came from renewable sources). Austria's energy sector, on the other hand, relies mainly on hydropower. Hydropower plants are responsible for producing more than three-quarters (76.5%) of the clean electricity consumed in the country – in 2018, 73% of the electricity consumed came from renewable sources (Eurostat, 2023).

In 2020, the gap between Poland and the country with the highest measure narrowed: the value of the Hellwig index for the country closing the ranking was more than 4 times lower compared to Sweden. Thus, one can speak of quite significant spatial variations in the potential for renewable energy sources, which are increasing with the passage of the analysed years – the gap between the leader and the closing country in the ranking has widened (in 2014: 0.569; in 2020: 0.658).

The group with high levels of RES development in 2012 consists of the following EU regions: Portugal (moved up one position in the ranking), Denmark (retained sixth position), Croatia (down one place), Lithuania and Romania (down four places). In 2020, the first three of the above countries remain in this group, with the aforementioned Latvia joining (down 1 position), and from Group III. Estonia (up 3 places) and Slovenia (up 3 places). Lithuania and Romania, on the other hand, were among the regions with low levels of RES development. It should be noted that Lithuania, Romania, and Latvia, despite a drop in the ranking, recorded an increase in the synthetic index, respectively: 0.054, 0.053, and 0,062.

Seventeen countries had low levels of RES potential development in 2014, as well as in 2020. Groups with a Hellwig index value of $0.212 \leq di < 0.352$ (in 2014: $0.104 \leq di < 0.252$) included Italy, Bulgaria, Germany, France, Slovakia, the Czech Republic, Spain, Hungary, Greece, Ireland, Cyprus, Malta, Belgium and Luxembourg. With that said, Slovenia and Estonia were promoted to Group II in 2014, and Lithuania was placed in Group III in 2020 (down 4 places). A particularly favourable change in the development of potential for RES concerns Estonia, which left the group with a low level of RES development and was ranked seventh (change in position by 8 places: promotion from 15th to 7th place in the ranking), in the group with high development of regions in terms of renewable energy sources (increase in the value of the Hellwig index by 0.245). Spain also saw its position increase by 7 places while maintaining its share in Group III in both years analysed. In contrast, an unfavourable change is noted for the following countries: The Czech Republic, Hungary and Slovakia, which retained their place in the low RES development group in the years under review but saw a decline by respectively 7, 6 and 5 positions, with a slight increase in the synthetic index by: 0.058, 0.057 and 0.077, respectively. Poland, on the other hand, left the group with a low level of RES development in 2014 and found itself in the last group in the second year under review (down 4 places), with an increase in the indicator under review of 0.071. In 2020, the Netherlands left Group IV, moving up 4 places in the ranking (up from 27th place to 23rd in the group of countries with low RES development, with a significant increase in the index by 0.162, i.e., almost 3 times).

Significant variations in the spatial development of RES for EU countries are also highlighted by the fact that in both years under study, a comparable number of regions fell into the group of countries with the highest and high level of RES potential, i.e., 9 countries, and 18 fell into the group of countries with the lowest and low level of RES development, with the dominance in both studied years of countries from group III (as many as 17 regions in total).

Two of the analysed features (X2 and X3) are indicators for assessing the progress of Member States' binding targets for EU climate and energy policy priorities until 2020. (Directive, 2009). The data confirm the Community's achievement of the intended targets (the share of renewable energy in gross final energy consumption at 20% – varying at the national level, and the share of renewable energy in all modes of transport – at least 10% of final energy consumption in transport). On average in the EU, the first indicator reached 22.1%, while the second reached 10.2%. However, the level

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achieved by individual countries varies, and not all countries have met their commitments. Between 2014 and 2020, there were significant favourable changes in the analysed area aimed at achieving EU climate neutrality in 2050. The share of RES in gross final energy consumption was highest in Sweden (more than 60% against a target of 49%). The majority of countries (23) met their goals by exceeding the target level. France was the only country to fall short of its commitment to the share of RES in gross final energy consumption (it achieved just over 19% against a target of 23%). In terms of the share of RES in transportation, 15 countries did not meet the adopted target. Sweden showed the highest rate of transport (nearly 32%), while Greece showed the lowest (5.3%). Lithuania, Croatia and Poland also have low levels of RES development in transport (5.5% and 6.6% each, respectively). It is noticeable that there is a significant gap between Sweden and Greece of size of 6:1. Similarly, a large distance is apparent between the leader and the subsequent countries on the list: Finland, the Netherlands and Luxembourg, which achieved rates of: 13.4% and 12.6% each, respectively.

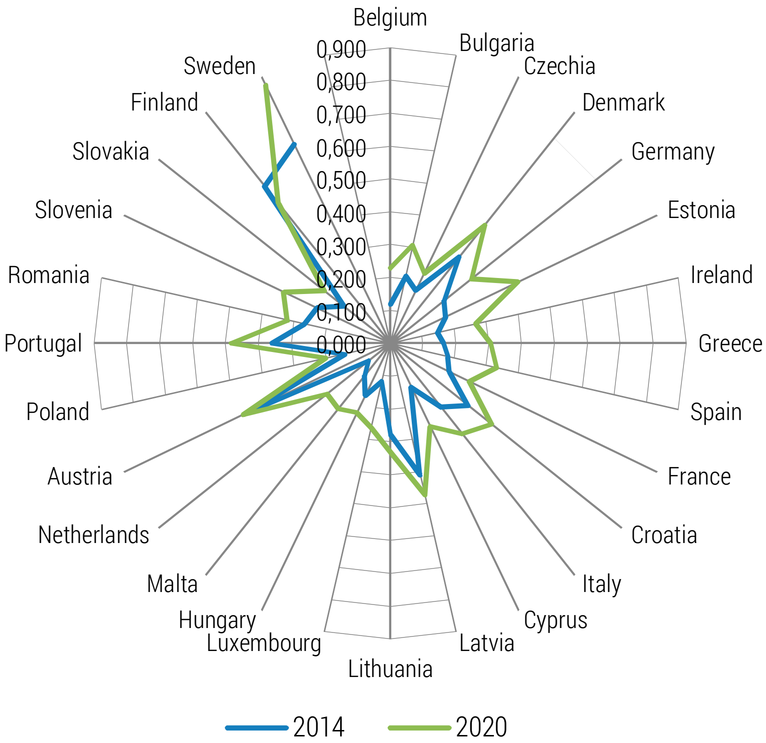

Figure 1. Distance of EU countries from the pattern of RES development based on the Hellwig method in 2014 and in 2020

Source: authors' work based on data from Table 1.

Discussion and future of RES development in the European Union

Many of the analyses being carried out prove that the EU is dynamically pursuing an energy transition, something that seemed unattainable just a dozen or so years ago (Tomaszewski & Sekściński, 2020; Hafner & Raimondi, 2020). The significant increase in the production and consumption of energy obtained from RES makes the Union a world leader. However, this does not happen without significant costs in the form of widening disparities between member states (Latosińska et al., 2022). The reason for this is probably the different approaches to decarbonisation in Western European and Central and Eastern European countries and the significantly different potential for RES development.

In light of the EU's priorities for achieving climate neutrality by 2050, a progressive and significant increase in the share of RES in the Community's energy balance is to be expected. The third decade of the 21st century should bring the benefits of increased energy efficiency in the form of greater energy security, better environmental protection and significant reductions in greenhouse gas emissions. Economic benefits, including the development of jobs in the sector, are also expected

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(Simionescu et al., 2020). Key economic benefits are also expected through increased competitiveness of the EU energy sector as a consequence of reduced fossil fuel imports (Młynarski, 2019). The future of RES development will bring a strengthening of the importance of solar, wind and water energy. The world is investing in zero-emission sources (not using combustion technology) guided by environmental and economic considerations. This is due to the fact that once they are installed, their costs decrease and subsequently, they lead to an increase in the competitiveness of economies (Ortega-Izquierdo & del Río, 2020; Wiśniewski & Więcka, 2018).

Achieving the anticipated benefits, however, requires a significant investment effort in energy infrastructure in the member states. For example, in Poland, a significant challenge is the transformation of district heating, especially system heating, where the share of RES is low (Wiśniewski & Więcka, 2018). According to many authors, the opportunity to achieve the ambitious goals is largely local measures, which can significantly accelerate the transformation of the energy sector through areas of the sector that are dispersed in terms of ownership and undertaken on a broad scale can significantly accelerate the reform of energy systems and significantly reduce carbon emissions into the atmosphere (Wiśniewski & Więcka, 2018; Mól et al., 2022).

The development of RES is based on the potential and geographic conditions of individual EU countries. Poland does not have significant opportunities for the development of large-scale RES, such as wind or solar farms, because the country has much worse geographical conditions than other European countries. In Belgium, Denmark, the Netherlands and Germany, large wind farms operate effectively in the North Sea, where wind conditions are much better than in the Baltic Sea. Photovoltaic farms, on the other hand, are being used in Spain, Portugal, and the south of France, where there is much more sunshine conducive to the development of various types of solar power plants. In turn, hydrogeological conditions in Norway, Switzerland or Austria favour the construction of large hydropower plants in these countries (Jędral, 2020).

The promotion of RES needs to give more consideration to the mass use of small, distributed renewable energy sources, as they are capable of easily and cheaply meeting the energy needs of societies regardless of weather, season or other unpredictable phenomena and events (Jędral, 2020). In addition, further dynamic development of RES, i.e., a greater share of energy from renewable sources, must ensure a rapid and accurate balancing of demand and supply in the power engineering system. Otherwise, an increase in the share of unstable RES without increasing the flexibility of the system in terms of interconnection, storage and supply may lead to the generated energy losing value (Birol, 2019). The future of RES also includes hydrogen production, including green hydrogen-like Power to Gas (P2G) and its use in renewable energy storage (Ruszel, 2022). It can partially replace coal, oil and natural gas. In addition to solving the problem of storing the renewable energy generated, it helps reduce pollution, including carbon dioxide.

Many aspects of the development of renewable energy sources require in-depth research, especially analysing the practical effects of the increasing share of RES in the energy balance. It seems that in the future, the impact of RES on the economic development of countries and the quality of life of its citizens and the further development of smart technological solutions such as smart grid will become a key issue (Drozd, 2018; Bango et al., 2022). RES is the least stable energy source, and the promotion of it will generate additional challenges related to, among other things, the need to ensure the balancing of the electricity system. Therefore, in countries such as Poland, according to PEP 2040, it is not possible to ensure security of energy supply in the balance with a dominant position of RES in the perspective of at least the next dozen or so years. This is conditioned by the underdevelopment of these technologies and the low flexibility of power engineering system operation (Ministerstwo Klimatu i Środowiska, 2021).

Conclusions

The article addresses the development of renewable energy sources in the European Union. The issue occupies a key place in the EU's economic policy as a result of the Community's ambitious goals and commitments on the international stage to combat climate change and achieve climate neutrality by 2050. The acquisition and consumption of energy is crucial to the operation and development of modern economies. At the same time, the current level of exploitation of deposits in the

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world means that fossil fuel resources will eventually run out. This poses a serious threat to the development of civilisation. Therefore, the development of renewable energy sources is seen as an opportunity to diversify the energy balance and decarbonise economies. The subjects of the study were EU member states. The analysis covered the years 2014 and 2020, using data from the EUROSTAT database. The study revealed significant progress in the development of RES by the European Union, with considerable internal variation at the level of member states.

The European Union is among the leaders in the world's energy transition. It is meeting ambitious targets for reducing carbon dioxide emissions into the atmosphere and increasing the share of renewable energy sources in the energy mix. The community assumes that the energy transition is an opportunity to increase the competitiveness of economic energy independence. To this end, it is taking on the growing challenges of modernisation and transformation toward a climate-neutral economy. The 2020 goal for RES development has been met by the European Union (22.1% against a goal of 20% share of RES). In most countries (23 EU countries), the share of RES in gross final energy consumption was higher than the target rate of the national goal for RES. One country (France) has not fulfilled its commitments. Considering the share of RES in transportation, the Union also reached the planned target (10.2% vs. 10%), but most countries (15 countries) did not reach the planned level.

The transport sector is responsible for almost a quarter of the EU's greenhouse gas emissions, therefore, a significant reduction of vehicle emissions is a major challenge. However, countries' implementation of their commitments in this regard is unsatisfactory.

The clear leader in the use of renewable energy sources in the EU is Sweden, where the synthetic indicator of RES development ranked highest in both 2014 and 2020. Sweden also met both of its binding targets (the share of renewable energy in gross final energy consumption and the share of renewable energy in final energy consumption in transport), far exceeding them and outdistancing the countries next on the list.

European Union countries have varying levels of renewable energy development. The distance between the leaders of the rankings and the closing countries (0.569 in 2014 and 0.658 in 2020) allows us to talk about quite significant spatial differences in the potential of RES. The estimated level of development using the synthetic indicator showed the distance between the leader of the ranking and the country in the last position as 8:1 and 4:1 for 2014 and 2020, respectively.

Further development of RES as part of the energy transition process in the EU is likely to be differentiated due to the different RES potentials of member states. The EU's ambitious priorities present the community with a major challenge in achieving them, as well as the problem of widening inequalities in the energy transition and competitiveness of the energy sector.

The article deepens the subject of energy transformation within the European Union. It provides an exploratory value regarding the current progress in the development of renewable energy sources, with an indication of significant differences between Member States. The results of the analyses may be important for the Member States progress evaluation and the achievement of the EU's energy goals.

The contribution of the authors

Conceptualization, D.M. and P.N.; literature review, P.N.; methodology, D.M.; formal analysis, D.M. and P.N.; writing, D.M. and P.N.; conclusions and discussion, D.M. and P.N.

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POZYSKANIE I ZUŻYCIE ENERGII ZE ŹRÓDEŁ ODNAWIALNYCH W POLSCE NA TLE UNII EUROPEJSKIEJ

STRESZCZENIE: Energia jest siłą napędową gospodarek, a dostęp do niej stanowi czynnik rozwoju cywilizacji i postępu procesów globalizacji. Jednak, przy obecnym poziomie eksploatacji złóż, zasoby większości paliw kopalnych będą się kończyły. Alternatywą jest zwiększanie udziału energii ze źródeł odnawialnych oraz oszczędzanie energii poprzez podniesienie jej efektywności. Unia Europejska zakłada wzrost roli odnawialnych źródeł energii (OZE) ze względu na potrzebę dywersyfikacji bilansu energetycznego i redukcji jego emisyjności. Działania takie są też niezbędne ze względu na konieczność zmniejszania zależności od niepewnych i niestabilnych rynków paliw kopalnych, zwłaszcza ropy i gazu. Jednak priorytetem jest minimalizacja wpływu sektora energii na środowisko dzięki zerowej lub niewielkiej emisji zanieczyszczeń z odnawialnych źródeł energii. Państwa członkowskie zobowiązały się do osiągnięcia krajowych celów w zakresie OZE, stosownie do swoich możliwości. Celem artykułu jest diagnoza bilansu odnawialnych źródeł energii i ocena realizacji zobowiązań Polski w zakresie rozwoju odnawialnych źródeł energii na tle Unii Europejskiej. Analizą objęto kraje UE w latach 2014-2020. Dla realizacji celu badawczego zastosowano analizę deskryptywną oraz metodę Hellwiga, która umożliwiła porządkowanie państw Unii Europejskiej ze względu na poziom rozwoju odnawialnych źródeł energii. Wyróżniono kraje o najwyższym, wysokim, niskim i bardzo niskim poziomie przedmiotowego rozwoju. Wyniki badań ujawniły zróżnicowania w poziomie rozwoju odnawialnych źródeł energii w krajach UE i różny stopień zaawansowania w realizacji zobowiązań unijnych w analizowanym aspekcie. Utrzymywanie się takiej sytuacji może zaważyć na osiągnięciu ambitnych priorytetów UE zawartych w Strategii Europejski Zielony Ład.

SŁOWA KLUCZOWE: odnawialne źródła energii, kraje Unii Europejskiej, zróżnicowania regionalne, metoda Hellwiga

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