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Levels of Renewable Energy Use in Selected European Union Countries – Statistical Assessment of Changes and Prospects for Development

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Abstract

The search for and use of green energy sources is an important course of action for the European Union (EU). The paper compares the 13 EU countries that acceded to the EU in 2004 and afterwards in terms of the level of renewable energy use. The primary indicator used to assess the use of renewable energy sources (RES) was the share of renewable energy in gross final energy consumption from 2007 to 2021. Statistical data were sourced from the Eurostat database. The results of the study confirm that between 2007 and 2021, there were positive changes in the use of renewable energy in most of the countries. The prospects for renewable energy development in these countries were assessed by constructing forecasts of the indicator concerning the share of renewable energy in gross final energy consumption

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for 2022–2024. For most of the countries, the forecasts were highly and sufficiently precise, meaning the countries have a chance of meeting the RES targets set out in EU directives.

Keywords: renewable energy, European Union, forecasting methods, development perspectives

JEL: O39, O40

Introduction

The progress of world civilisation is significantly affecting the environment, as well as the living environment of humans and animals, increasing the demand for electricity. In the nineteenth century, energy consumption was mainly based on coal and lignite; in the twentieth century, the fuel was oil (Johansson 2013). When fossil fuels are burnt, gaseous pollutants are emitted into the atmosphere, and significant amounts of solid waste are released into the environment, causing its degradation. In view of this, the combustion of these fuels contributes significantly to exacerbating the greenhouse effect (Latkowska, Fitko, and Stelmach 2011; Kruk 2012; Daroń and Wilk 2021). Coal combustion causes a significant deterioration of air quality through the emission of toxic substances, harmful dust and heavy metals (Ociepa-Kubicka 2015). Such structure of primary fuel consumption causes the development of increasingly stringent environmental protection standards (Frątczak 2015, p. 202).

Today, in the 21st century, given the economic and environmental aspects, humanity is forced to search for new, non-conventional energy sources (Latkowska, Fitko, and Stelmach 2011). The continued growth in global energy demand and the prospect of depleting fossil fuel stocks are significantly increasing interest in renewable energy sources and how they can be used. This course of action is part of the global trend of searching for and diversifying green energy sources.

Electricity generation is one of the most important elements of the global economy. It is also important for individual regions and is a factor that significantly influences their economic development. In modern times, energy determines the growth of industrial production, innovation, the creation of workplaces, the development of society, inflation, and poverty status, including housing affordability, a topic that resonates in many European countries today (Łuczak and Kalinowski 2022). The use of raw materials of natural origin for energy production is closely correlated with legal regulations at the European Union (EU) level. This has important implications for the supply of raw materials for energy production from renewable energy sources (RES) (Molo 2016).

The natural limitations to RES development in individual EU countries are mainly climatic and natural conditions, including too little sunshine, light winds, and a lack of geothermal water deposits. Restrictions are also placed on established forms of nature conservation (including landscape parks, national parks, nature reserves, Natura 2000 network areas, and bird migration routes), where, for example, wind energy cannot be developed (Kruk 2012).

Some authors, such as Stec and Grzebyk (2022), have drawn attention to several important energy-related issues that have been under consideration in the EU in recent years, such as oil price volatility, disruptions in energy supply from non-EU countries, and difficulties in accessing the market for gas and electricity suppliers. These issues have made the topic of energy one of the main political agendas in Europe, especially after 24th February 2022 (i.e., the beginning of the war in Ukraine). Thus, the use of renewable energy sources is seen as a key element of energy policy, including energy security. Energy security issues were also highlighted by Żuk and Żuk (2022) and Mišík (2022), who showed how the last three years have clearly changed the outlook for shaping and evaluating energy mixes. The sense of threat associated with the COVID–19 pandemic and war in Ukraine has intensified the need for security, and the issue of ensuring energy supply for individual countries is now a prerequisite for the smooth functioning of European economies. Individual EU countries are expected to increasingly base their development on their own renewable energy resources and gradually move away from dependence on major fossil fuel exporters such as Russia and Saudi Arabia (Van de Graaf 2018). It is, therefore, recognised that energy independence and security of the energy supply are major key factors in economic growth and development (Kryszk et al. 2023). The development of renewable energy is important for implementing the fundamental climate and energy policy objectives of the EU as a whole, as well as of its constituent countries. Increasing the use of renewable energy sources offers opportunities for increased energy efficiency and economic independence (Gaigalis and Katinas 2020).

This article assesses the changes in renewable energy use in selected EU countries between 2007 and 2021 and identifies the prospects for its development between 2022 and 2024. The research subjects are the following countries, which acceded to the EU in 2004 and later: Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia (hereinafter: the EU–13). A measure that assesses renewable energy use in selected countries is the share of renewable energy in gross final energy consumption. The article provides an extensive statistical analysis of this ratio, and the prospects for renewable energy use in the EU–13 between 2022 and 2024 are assessed using selected forecasting methods, including linear and non-linear trend functions.

The article seeks to answer the following questions:

- How did the share of renewable energy in gross final energy consumption evolve in the EU–13 between 2007 and 2021?

- Which of the EU–13 are leaders in the use of renewable energy, and which are low achievers?
- Are the EU–13 likely to meet their individual RES energy production targets in accordance with existing EU directives?

Guidelines for the development of renewable energy in EU documents

Renewable energy refers to energy derived from recurring natural processes from renewable, non-fossil energy sources (i.e., water, wind, solar, geothermal, wave power, current and tidal flows) and energy generated from solid biofuels, biogas and liquid biofuels, as well as ambient (environmental) energy from heat pumps (Daroń and Wilk 2021). In the 1990s, interest in RES significantly increased. As Devine-Wright (2019) and Papież, Śmiech, and Frodyma (2018) noted, renewable energy sources have undergone an evolution from a technological novelty to a viable tool used to produce energy to meet the growing needs of the world's population.

Renewable energy sources are an alternative to traditional, primary, non-renewable energy carriers (fossil fuels). Their resources are replenished through natural processes, making it possible to treat them as practically inexhaustible. Furthermore, obtaining energy from these sources is, when compared to traditional (fossil) sources, more environmentally friendly. The use of RES significantly reduces the harmful impact of energy on the environment, mainly by reducing emissions of harmful substances, especially greenhouse gases (Rajchel and Walawender 2018).

The EU's energy policy is based on respect for natural resources and independence from fuel imports from non-EU economic areas, including a move away from fossil fuels towards the production of energy from renewable sources (Directive 2009/28/EC; Wawrzyniak 2016). This is particularly relevant now with the ongoing war in Ukraine. The extent of renewable energy use in the EU member states is regulated by the relevant EU normative documents and acts that set general and specific targets concerning the obligation to achieve set indicators for the share of renewable energy in gross final energy consumption (Rajchel and Walawender 2018).

Higher-level EU legislation promoting the use of energy from renewable sources has existed since 2001, when the first directive on the promotion of electricity produced from renewable energy sources in the internal market was adopted (Directive 2001), followed by the directive of 2003 (Directive 2003/30/EC) on the use of biofuels and other renewable energy sources in transport (Papież, Śmiech, and Frodyma 2018). The enlargement in 2004 forced an update of the RES energy share targets to

21% and it included targets for candidate countries. However, these demands were non-binding and did not result in consequences for member states if they were not met (Olczak 2016). The subsequent 2009 directive aimed to establish a common framework for the promotion of energy from renewable sources by setting mandatory targets for Member States. The directive stipulated that by 2020, 20% of the EU's total energy consumption had to come from renewable sources, with this target being broken down into binding sub-targets for the Member States.

In the transport sector, Member States had to achieve a 10% share of fuels from renewable sources by 2020. The directive sets out the mechanisms that the Member States could use to achieve their targets (support schemes, guarantees of origin, joint projects, co-operation between Member States and third countries), as well as sustainability criteria for biofuels (Directive 2009/28/EC; Molo 2016). The target, defined as the share of RES energy in total energy consumption, is defined as the quotient of the gross final energy consumption from RES and the gross final energy consumption from all sources, expressed as a percentage (Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii). Gross final energy consumption means energy commodities supplied for energy purposes to industry, the transport sector, households, the tertiary sector (including public services), agriculture, forestry and fisheries. It also includes the consumption of electricity and heat by the energy industry for electricity and heat generation, as well as losses of electricity and heat during distribution and transmission (Directive 2009/28/EC).

Further changes came in December 2018, when a more stringent framework was introduced for the share of energy from renewable sources as part of the 'Clean Energy for all Europeans' package (Directive 2018/2001/EU; Hoicka et al. 2021). The purpose of the package was to maintain the Union's position as a global leader in renewables and, more broadly, to help the EU meet its emissions reduction commitments made under the Paris Agreement. The directive set a binding target of at least 32% of the final energy consumed in the EU to be derived from renewable sources by 2030. It also includes a clause to bring this target forward to 2023 and to increase the target to a 14% share of renewable energy in transport by 2030. Additionally, an increase in the share of RES in heating and cooling will also be required (by 1.3% and 1.1%, respectively, each year) relative to the annual average calculated for the periods 2021–2025 and 2026–2030.

The Member States were required to incorporate the changes into their national law by June 2021, with effect from 1st July 2021. If the changes had not taken place, the national renewable energy targets for 2020 should be each Member State's minimum contribution for the year 2030. Each state was obliged to propose a national energy target and establish ten-year national energy and climate plans under the program 'Horizon 2030'. As Hoicka et al. (2021) noted, if the changes are effectively implemented and transposed into national laws, it could accelerate a more equitable and sustainable energy transition by facilitating the widespread implementation of 'Renewable Energy Communities' (RECs).

Under the 2018 directive, Member States have to report on their progress in this scope every two years. The commission will assess the plans and may take measures at the EU level to ensure that the plans are consistent with overall EU objectives.

Discussions on the post–2030 energy policy framework are currently underway (Wiśniewska, Pusz, and Rogalski 2020). The European Green Deal is a new growth strategy that aims to transform the EU into a sustainable, fair and prosperous society, resource-efficient and with no net greenhouse gas emissions by 2050, i.e. working towards the goal of achieving EU energy neutrality. The strategy outlines ways to accelerate the development and deployment of low-carbon technologies considering the targets set for 2030 and 2050 (Communication… 2019).

The EU aims to develop its strategy and infrastructure for the further decarbonisation of the energy system by 2050, including an 80–95% reduction in greenhouse gas emissions compared to 1990 levels. It also aims to further increase the share of RES in gross final energy consumption (up to 55% in 2050) and other measures to increase energy efficiency while taking into account the objectives of supply security and competitiveness (Bekirsky et al. 2022).

Materials and methods

An indicator for the share of renewable energy in gross final energy consumption was used to assess renewable energy use in the EU–13 using statistical data from 2007–2021 taken from the Eurostat database. The research methods used were measures to describe the structure of collectivity (arithmetic mean, coefficient of variation, asymmetry coefficient), measures of dynamics, and selected forecasting methods. A description of the statistical measures and forecasting methods used in this paper can be found in Aczel (2000), Cieślak (2001), Zeliaś, Pawełek, and Wanat (2003), and Frątczak (2015).

The simplest measure of dynamism is absolute growth, which is the difference between the magnitude of a phenomenon in the period under study and the baseline (base) period:

$$\Delta y_t = y_t - y_0, \quad (1)$$

where: y_t – the magnitude of the phenomenon during the period considered, y_0 – the magnitude of the phenomenon in the base period.

Absolute increments indicate by how much the phenomenon increased (decreased) during the study period compared to its level during the base period. The average rate of change is defined by the following equation:

$$\overline{y}_g = \sqrt[n-1]{\frac{y_n}{y_1}}, \tag{2}$$

where: y_n, y_1 – absolute levels of the phenomenon from the last and the first period.

The average rate of change, expressed as a percentage, indicates the average periodic percentage increase in the phenomenon over the time interval under consideration.

Forecasting economic processes is one way of anticipating the future. It involves rational, scientific predictions of future events (Cieślak 2004) and facilitates decision-making, with the quality largely depending on the accuracy of the forecast.

The academic literature contains many time series forecasting methods, and the choice of the right one depends on the course of the phenomenon under study in time. By visually assessing the time series values, the appropriate analytical form of the model can be selected. Furthermore, assessing the model's quality involves assessing measures of how well the model fits the empirical data and conducting relevant statistical tests. The acceptability of the designated forecasts is typically judged based on forecast error values.

When the time series shows a developmental trend and random fluctuations, analytical models (linear or non-linear trend function) can be used for forecasting.

The linear development trend model takes the following general form:

$$y_t = \alpha_0 + \alpha_1 t + \varepsilon, \tag{3}$$

where: t – time variable, ε – random component.

The parameters of the linear trend functions a_0 and a_1 are determined using the Least Squares Method from the following equations:

$$a_1 = \frac{\sum_{t=1}^{n}(y_t - \overline{y})(t - \overline{t})}{\sum_{t=1}^{n}(t - \overline{t})^2}, \tag{4}$$

$$a_0 = \overline{y} - a_1\overline{t}. \tag{5}$$

The estimated linear trend model takes the following form:

$$\hat{y}_t = a_0 + a_1 t. \tag{6}$$

Of the many forms of non-linear trend functions, this paper uses second and third-degree polynomial functions.

The general form of a polynomial of the second degree is as follows:

$$y_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \varepsilon. \tag{7}$$

This function is transformed into a linear model by introducing replacement variables: $Z_1 = t$ and $Z_2 = t^2$. When substituted into the general form (equation 7), the following linear model is obtained:

$$y_t = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \varepsilon. \tag{8}$$

Structural parameter estimates are determined by the Least Squares Method using the following vector:

$$a = (Z^T Z)^{-1} Z^T y. \tag{9}$$

The general form of the trend function as a polynomial of the third degree is defined by the following equation:

$$y_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \varepsilon. \tag{10}$$

The function is transformed into a linear model using replacement variables: $Z_1 = t$, $Z_2 = t^2$ and $Z_3 = t^3$.

Structural parameter estimates are determined using the following vector:

$$a = (Z^T Z)^{-1} Z^T y. \tag{11}$$

Once the structural parameters of the trend models have been estimated, it is important to validate the resulting models.

The fitness of models to the empirical data can be assessed using the coefficient of determination and coefficient of random variation.

The coefficient of determination, R^2, has the following form:

$$R^2 = 1 - \frac{\sum_{t=1}^{n} (y_t - \hat{y}_t)^2}{\sum_{t=1}^{n} (y_t - \bar{y})^2}. \tag{12}$$

The closer the value of the coefficient of determination is to one, the better the model fits the empirical data.

On the other hand, the coefficient of random variation, W_e, is determined based on the following equation:

$$W_e = \frac{S_e}{\overline{y}} \cdot 100, \tag{13}$$

where: S_e – standard deviation of the residual component, $\overline{y}$ – average value of the explained variable.

The coefficient indicates what percentage of the arithmetic mean of the explained variable of the model constitutes the standard deviation of the residuals. The smaller the W_e coefficient, the better the fitness of the model to the data.

The standard deviation of the residual component is calculated using the following equation:

$$Se = \sqrt{\frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{n-2}}. \tag{14}$$

It indicates by how much, on average, the empirical values deviate from the theoretical values of the model.

In the process of verifying linear development trend models, it is also worth checking the significance of structural parameter estimates. The relevant statistical hypotheses are of the following form:

$$\mathrm{H}_0 : \alpha_i = 0 \, H_1 : \alpha_i \neq 0 \, .$$

Hypothesis H_0 assumes that parameter α_i is not statistically different from 0, while the alternative hypothesis H_1 assumes otherwise.

The test statistic is defined by the following equation:

$$t_i = \frac{|a_i|}{S(a_i)}. \tag{15}$$

If $t_i \leq t_\alpha$, there are no grounds to reject the H_0 hypothesis. Conversely, when $t_i > t_\alpha$, the H_0 hypothesis should be rejected in favour of the alternative hypothesis H_1.

The critical value t_α is determined from the t-test distribution tables for the chosen significance level α (usually 0.05) and $n - 2$ degrees of freedom.

In practical applications based on computer programmes, the p-value (test probability level) is often used to assess the significance of structural parameters. If the p-value is lower than the accepted significance level α (usually 0.05), the H_0 hypothesis should be rejected, indicating that the parameter under study differs from zero in a statistically significant manner.

A correctly verified model can be used as the basis for building forecasts of a phenomenon for subsequent years.

Determining the forecast of a phenomenon based on a linear trend model can be done by extrapolating it:

$$y_T^* = a_0 + a_1 T, \tag{16}$$

where: y_T^* – point forecast for Y variable, T – forecasting period.

The average forecast error (S_{pT}) for the linear trend function is determined using the following equation:

$$S_{pT} = Se\sqrt{\left[\frac{(T-\bar{t})^2}{\sum_{t=1}^{n}(t-\bar{t})^2} + \frac{1}{n} + 1\right]}. \tag{17}$$

In order to express the average forecast error in percentage terms, the average relative ex-ante forecast error is calculated using the following equation:

$$V_T = \frac{S_{pT}}{y_T^*} \cdot 100. \tag{18}$$

The following criteria are adopted to assess the quality of a forecast (Cieślak 2001):

$V_T \leq 5\%$, high-precision forecast,

$5\% < V_T \leq 10\%$, sufficiently precise forecast,

$V_T > 10\%$, insufficiently precise forecast.

In the case of a trend of the phenomenon under study with a polynomial of the second and third degree, the average forecast error (S_{pT}) is determined using the following equation:

$$S_{pT} = S_e\sqrt{X_T\left(Z^T Z\right)^{-1} X_T^T + 1}, \tag{19}$$

where: X_T – vector of time variable value.

The vector of time variable value contains the following components:

$X_T = \left[1\,T\,T^2\right]$ for a trend function in the form of a polynomial of the second degree,

$X_T = \left[1\,T\,T^2\,T^3\right]$ for a trend function in the form of a polynomial of the third degree.

Results and discussion

The study of the level of use of renewable energy covered the EU–13 countries, which acceded to the EU in 2004 and later. Table 1 contains a general characterisation of the study group with key statistical indicators about the countries for 2021.

Table 1. Basic statistical indicators of selected EU countries, 2021

Country	Area in km^2	Population in millions	GDP per capita in €	Investment rate (% GDP)	GERD*	Unemployment rate (%)	Gini coefficient	Persons at risk of poverty or social exclusion (%)
Bulgaria	110,910	6.88	10,330	16.3	0.85	5.3	39.7	32.1
Croatia	56,594	3.96	14,720	20.7	1.24	7.6	29.2	23.2
Cyprus	9,251	0.90	26,680	19.5	0.84	7.5	29.4	21.3
Czechia	78,870	10.51	22,270	26.0	1.99	2.8	24.8	11.9
Estonia	45,228	1.33	23,640	28.9	1.75	6.2	30.6	23.2
Hungary	93,025	9.71	15,840	27.2	1.59	4.1	27.6	17.8
Latvia	64,573	1.88	17,890	22.3	0.69	7.6	35.7	26.0
Lithuania	65,300	2.80	20,000	21.4	1.14	7.1	35.4	24.8
Malta	316	0.52	28,890	20.3	0.65	3.4	31.2	19.0
Poland	312,696	37.75	15,060	17.0	1.39	3.4	26.8	17.3
Romania	238,397	19.12	12,620	23.7	0.47	5.6	34.3	30.4
Slovakia	49,035	5.45	18,110	18.9	0.9	6.8	20.9	14.8
Slovenia	20,273	2.11	24,770	20.3	2.14	4.8	23.0	15.0
Mean	88,036	7.92	19,294	21.73	1.20	5.6	29.9	21.3
CV**	0.98	1.26	0.28	0.17	0.43	0.30	0.17	0.27
CA***	1.76	2.32	0.18	0.56	0.46	−0.26	0.10	0.31

* GERD (gross domestic expenditure on R&D) – percentage of GDP in 2020; ** CV – coefficient of variation; *** CA – coefficient of asymmetry.
Source: own compilation based on Eurostat n.d.

The EU–13 are strongly differentiated in terms of their area. The following countries are the largest: Poland (312,696 km^2), Romania (238,397 km^2) and Bulgaria (110,910 km^2). In contrast, the smallest are Malta (316 km^2), Cyprus (9,251 km^2) and Slovenia (20,273 km^2). In terms of population, the leaders are Poland (37.75 million people), Romania (19.12 million) and Czechia (10.51 million). The least populated are Malta (0.52 million), Cyprus (0.9 million) and Estonia (1.33 million). The variation between countries in terms of population can be considered strong, with a variation coefficient of 1.26. However, the vast majority of countries have populations below the group average.

One of the most important indicators of a country's socio-economic development is GDP per capita. The countries with the highest levels are Malta (EUR 28,890 per capita), Cyprus (26,680) and Slovenia (24,770). Conversely, those with the lowest levels are Bulgaria (EUR 10,330 per capita), Romania (12,620) and Croatia (14,720). The variation coefficient, at the 0.28 level, indicates a weak variation among the EU–13.

Another economic indicator is the investment rate (% of GDP), which ranges from 16.3% in Bulgaria to 28.9 in Estonia. Thus, the diversity of countries can be considered weak.

One measure of a country's innovativeness is GERD (gross domestic expenditure on R&D) as a percentage of GDP. The leaders are Slovenia (2.14%), Czechia (1.99%) and Estonia (1.75%). In contrast, Romania (0.47%), Malta (0.65%) and Latvia (0.69%) have the lowest share of R&D expenditure in their GDP.

The EU–13 have a good labour market situation. The unemployment rate is relatively low, ranging from 2.8% (Czechia) to 7.6% (Latvia). On average, it stood at 5.6%, with six countries above the average (weak negative asymmetry).

Several indicators that define social development were also assessed. The Gini coefficient shows income disparity in a given society; the higher it is, the greater the disparity of incomes. The lowest values are found in Slovakia (20.9%), Slovenia (23.0%) and Czechia (24.8%). In contrast, the largest income disparities can be observed in Bulgaria (39.7%), Latvia (35.7%) and Lithuania (35.4%). The average value of the Gini coefficient was 29.9%.

The countries are also characterised by poor diversification in terms of the ratio of persons at risk of poverty or social exclusion, ranging from 11.9% (Czechia) to 32.1% (Bulgaria). The weak right-handed asymmetry indicates that most of the countries have lower poverty levels than the group average (Table 1).

The general statistical characterisation of the EU–13 shows that they form a fairly homogeneous collective. The question arises as to whether renewable energy use is also similar. The values of the share of renewable energy in gross final energy consumption between 2007 and 2021 are given in Table 2.

Table 2. Values of the share of renewable energy in gross final energy consumption (%) in selected EU countries, 2007–2021

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bulgaria	9.10	10.35	12.01	13.93	14.15	15.84	18.90	18.05	18.26	18.76	18.70	20.58	21.55	23.32	17.02
Croatia	22.16	21.99	23.60	25.10	25.39	26.76	28.04	27.82	28.97	28.27	27.28	28.05	28.47	31.02	31.33
Cyprus	4.00	5.13	5.92	6.16	6.25	7.11	8.43	9.14	9.90	9.83	10.48	13.87	13.78	16.88	18.42
Czechia	7.90	8.67	9.98	10.51	10.95	12.81	13.93	15.07	15.07	14.93	14.80	15.14	16.24	17.30	17.67
Estonia	17.14	18.81	23.01	24.58	25.52	25.59	25.36	26.13	28.99	29.23	29.54	29.97	31.73	30.07	38.01
Hungary	8.58	8.56	11.67	12.74	13.97	15.53	16.21	14.62	14.50	14.38	13.56	12.55	12.63	13.85	14.12
Latvia	29.62	29.81	34.32	30.38	33.48	35.71	37.04	38.63	37.54	37.14	39.01	40.02	40.93	42.13	42.11
Lithuania	16.48	17.82	19.80	19.64	19.94	21.44	22.69	23.59	25.75	25.61	26.04	24.70	25.47	26.77	28.23
Malta	0.18	0.20	0.22	0.98	1.85	2.86	3.76	4.74	5.12	6.21	7.22	7.91	8.23	10.71	12.15
Poland	6.90	7.69	8.68	9.28	10.34	10.96	11.45	11.61	11.88	11.40	11.06	14.94	15.38	16.10	15.62
Romania	18.20	20.20	22.16	22.83	21.74	22.83	23.89	24.85	24.79	25.03	24.45	23.88	24.29	24.48	23.60
Slovakia	7.77	7.72	9.37	9.10	10.35	10.45	10.13	11.71	12.88	12.03	11.47	11.90	16.89	17.35	17.41
Slovenia	19.68	18.65	20.77	21.08	20.94	21.55	23.16	22.46	22.88	21.98	21.66	21.38	21.97	25.00	25.00
UE–27	11.75	12.55	13.85	14.41	14.55	16.00	16.66	17.42	17.82	17.98	18.41	19.10	19.89	22.04	21.78

Source: own compilation based on Eurostat n.d.

Even a cursory assessment of the share of renewable energy in gross final energy consumption shows quite significant differences between the countries. In 2007, the indicator ranged from 0.18% (Malta) to 29.62% (Latvia). The European average (EU–27) was 11.75%, exceeded by six of the EU–13 (Latvia, Croatia, Slovenia, Romania, Estonia and Lithuania). However, by 2021, there were some significant changes in the level of renewable energy share in gross final energy consumption compared to 2007. There was a noticeable increase in all of the countries. In 2021, it ranged from 12.15% in Malta to 42.11% in Latvia, with an EU–27 average of 21.78%. RES leaders were Latvia, Estonia and Croatia. The bottom three countries in the ranking were Malta, Hungary and Poland, where the share of renewable energy in gross final energy consumption was almost one-third that of Estonia. Estonia saw the largest increase in 2021 compared to 2007 (by 20.87%), followed by Cyprus (14.42%) and Latvia (12.49%). In the study period, the ranking of the EU–13 in terms of the share of renewable energy in gross final energy consumption showed that four countries had improved by two places (Cyprus, Estonia, Lithuania, and Slovakia). Six countries (Bulgaria, Croatia, Czechia, Latvia, Malta and Poland) remained unchanged, while Romania and Slovenia fell by two places, and Hungary fell by four.

Changes in the share of renewable energy in gross final energy consumption in the EU–13 in 2007 and 2021 are presented in Figure 1.

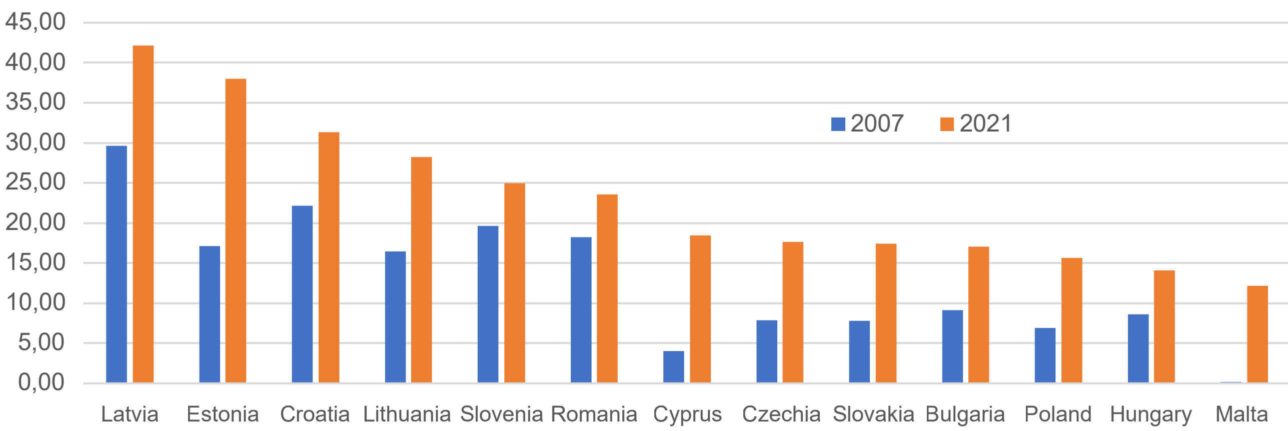

Figure 1. Values of the share of renewable energy in gross final energy consumption (%) in selected EU countries, 2007 and 2021

Source: own compilation based on own compilation based on Eurostat n.d.

The data in Figure 1 show that in 2021, compared to 2007, there had been significant progress in the use of renewable energy in all the countries studied. Pérez, Scholten, and Smith Stegen (2019) pointed out that Central and Eastern European countries are among those with similar energy experiences. Furthermore, similar political and economic conditions, including the period of recent economic transition, continue to influence the energy policy-making principles they have adopted. Nevertheless, as the results of the study show, despite such advances, the energy transition remains a huge challenge for them, both technologically and economically. This can also be seen in the debates and negotiations on EU energy policy. Central and Eastern European countries often criticise renewable energy sources for their instability and high sourcing costs while also arguing that these sources cannot fully replace fossil fuels.

Examining the entire research period of 15 years shows the average rate of change of the share of renewable energy in gross final energy consumption for the EU–13 and EU–27 countries. The results of the calculations, according to equation (2), are shown in Figure 2.

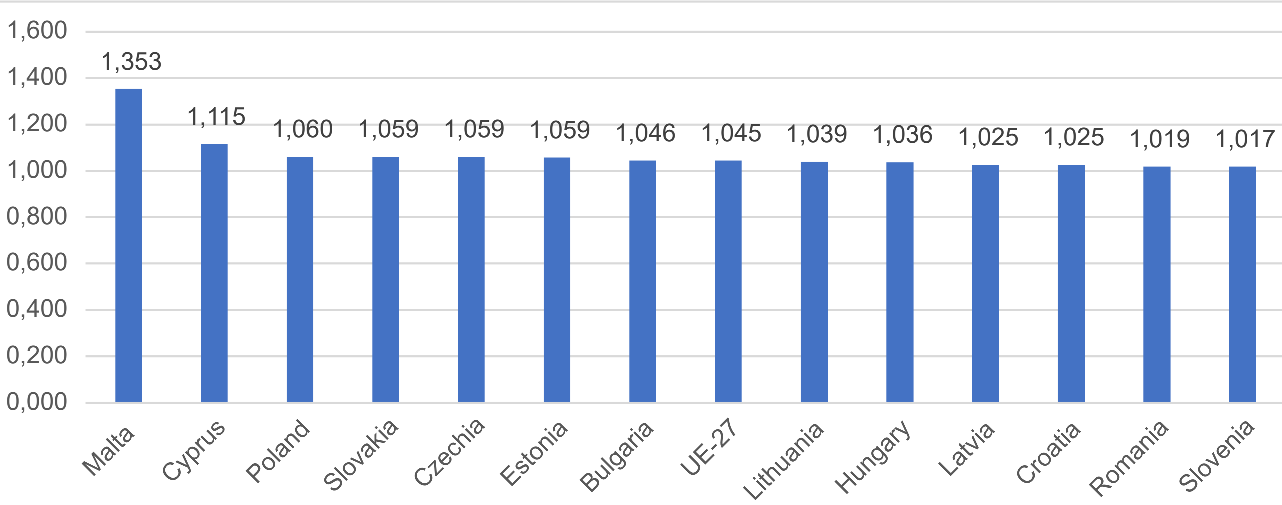

Figure 2. Average rate of change of the share of renewable energy in gross final energy consumption (%), 2007–2015

Source: own compilation based on Eurostat n.d.

Figure 2 shows that the rate of change in the share of renewable energy in gross final energy consumption was positive in all the countries studied. The highest rate of growth was achieved by Malta (a 35.3% average annual increase) and Cyprus (11.5%). Poland, Slovakia, Czechia, Estonia and Bulgaria also had growth rates higher than the EU–27 average. Nonetheless, the countries which stand out in terms of the rate of change of the share of renewable energy in gross final energy consumption are catching up but still far from the current RES leaders (Latvia, Estonia, Croatia).

The issues of energy transition in southeast European countries and the related problems were highlighted by Anastasiu et al. (2018), Năstase et al. (2018), and Koltsaklis et al. (2020). Using Romania as an example, they showed that countries in the region have great potential to diversify their energy sources, including the use of renewable sources. Romania can and does use a variety of renewable energy sources, including wind, solar, geothermal and hydropower. However, making full use of the sources requires investment and an appropriate, well-thought-out operational strategy.

Romanian energy policy, just like that of other countries in the region, is dominated by the use of non-renewable energy sources, primarily coal.

To ascertain whether the upward trend observed in the share of renewable energy in gross final energy consumption between 2007 and 2021 in the EU–13 will continue, an attempt was made to forecast it for the years 2022–2024. The time series of the variable from 2007 to 2021 showed an increasing trend for most of the countries and slight random fluctuations for some of them. An analytical approach using linear and non-linear trend functions may then be an appropriate forecasting method, assuming this trend of changes continues. Using the least squares method, the structural parameters of the linear trend function of the indicator of the share of renewable energy in gross final energy consumption over the period 2007–2021 were estimated for each of the 13 countries separately, determined by equation (3). The structural parameters were determined using equations (4) and (5), and the models were verified using the statistical measures and tests defined by equations (12)–(15).

If the verification of the estimated linear trend functions did not meet the desired criteria, non-linear trend functions, i.e. a second-degree polynomial model (equation (7)) or a third-degree polynomial model (equation (10)), were used. The final results of the trend model estimations for the EU–13 and EU–27 are presented in Table 3.

Table 3. Trend functions of the share of renewable energy in gross final energy consumption in the years 2007–2021 for selected EU countries

Country	Trend function equation	Standard Error	t-Stat	p-Value	R^2	We (%)
Bulgaria	$\hat{y}_t = 10.23 + 0.81\ t$	$S_{(a0)} = 1.08$ $S_{(a1)} = 0.12$	$t_0 = 9.43$ $t_1 = 6.78$	0.000000 0.000013	0.779	11.96
Croatia	$\hat{y}_t = 22.26 + 0.59\ t$	$S_{(a0)} = 0.59$ $S_{(a1)} = 0.07$	$t_0 = 37.39$ $t_1 = 8.95$	0.000000 0.000000	0.860	4.07
Cyprus	$\hat{y}_t = 2.23 + 0.93\ t$	$S_{(a0)} = 0.66$ $S_{(a1)} = 0.07$	$t_0 = 3.35$ $t_1 = 12.78$	0.005194 0.000000	0.926	12.61
Czechia	$\hat{y}_t = 8.06 + 0.67\ t$	$S_{(a0)} = 0.45$ $S_{(a1)} = 0.05$	$t_0 = 17.86$ $t_1 = 13.46$	0.000000 0.000000	0.933	6.02
Estonia	$\hat{y}_t = 18.29 + 1.08\ t$	$S_{(a0)} = 1.02$ $S_{(a1)} = 0.11$	$t_0 = 17.98$ $t_1 = 9.64$	0.000000 0.000000	0.933	6.95
Hungary	$\hat{y}_t = 3.79 + 3.89\ t - 0.43t^2 + 0.01t^3$	$S_{(a0)} = 1.17$ $S_{(a1)} = 0.61$ $S_{(a2)} = 0.09$ $S_{(a3)} = 0.004$	$t_0 = 3.25$ $t_1 = 6.37$ $t_2 = 4.91$ $t_3 = 3.96$	0.007748 0.000053 0.000468 0.002233	0.880	6.53
Latvia	$\hat{y}_t = 29.29 + 0.90\ t$	$S_{(a0)} = 0.73$ $S_{(a1)} = 0.08$	$t_0 = 40.18$ $t_1 = 11.27$	0.000000 0.000000	0.907	3.67

Country	Trend function equation	Standard Error	t-Stat	p-Value	R^2	We (%)
Lithuania	$\hat{y}_t = 16.81 + 0.77\ t$	$S_{(a0)} = 0.55$ $S_{(a1)} = 0.06$	$t_0 = 30.62$ $t_1 = 12.67$	0.000000 0.000000	0.925	4.41
Malta	$\hat{y}_t = -2.00 + 0.85\ t$	$S_{(a0)} = 0.38$ $S_{(a1)} = 0.04$	$t_0 = 5.29$ $t_1 = 20.49$	0.000146 0.000000	0.970	14.44
Poland	$\hat{y}_t = 6.66 + 0.61\ t$	$S_{(a0)} = 0.50$ $S_{(a1)} = 0.05$	$t_0 = 13.35$ $t_1 = 11.14$	0.000000 0.000000	0.905	7.95
Romania	$\hat{y}_t = 17.66 + 0.58\ t - 0.06\ t^2$	$S_{(a0)} = 0.58$ $S_{(a1)} = 0.17$ $S_{(a2)} = 0.01$	$t_0 = 30.60$ $t_1 = 8.05$ $t_2 = 6.25$	0.000000 0.000004 0.000042	0.902	2.80
Slovakia	$\hat{y}_t = 6.53 + 0.65\ t$	$S_{(a0)} = 0.71$ $S_{(a1)} = 0.08$	$t_0 = 9.18$ $t_1 = 8.36$	0.000000 0.000000	0.843	11.13
Slovenia	$\hat{y}_t = 19.44 + 0.30\ t$	$S_{(a0)} = 0.58$ $S_{(a1)} = 0.06$	$t_0 = 33.36$ $t_1 = 4.75$	0.000000 0.000376	0.635	4.90
UE–27	$\hat{y}_t = 11.44 + 0.69\ t$	$S_{(a0)} = 0.27$ $S_{(a1)} = 0.03$	$t_0 = 43.03$ $t_1 = 23.54$	0.000000 0.000000	0.977	2.89

Source: own calculations using Excel and Statistica.

The data in Table 3 show that for most of the countries studied and for the EU–27, a linear function was the appropriate analytical form of modelling the development trend of the share of renewable energy in gross final energy consumption over the period 2007–2021. It correctly described the course of the phenomenon, as indicated by the values of the verification measures, i.e. the standard error, t-statistic, p-value, coefficient of determination (R^2) and coefficient of random variation (*We*). Only for two countries, i.e. Romania and Hungary, was it incorrect. Thus, for Romania, a second-degree polynomial trend function was used, while for Hungary, a third-degree polynomial trend function was used, which met the verification criteria. Subsequently, for all trend models, the values of the structural parameters of the estimated trend models were statistically significantly different from zero, the coefficient of determination was close to one, and the coefficient of random variation was within the recommended limits (less than 10–15%).

The correctly verified linear and non-linear trend functions of the share of renewable energy in gross final energy consumption provided the basis for forecasting its values for 2022–2024 for the EU–13 and the EU–27. The point forecast values, together with the forecast errors, are shown in Table 4.

Table 4. Point forecasts and forecast errors for the share of renewable energy in gross final energy consumption, 2022–2024

Country	2022			2023			2024		
	y_T^*	S_{pT}	V_T	y_T^*	S_{pT}	V_T	y_T^*	S_{pT}	V_T
Bulgaria	23.17	2.27	9.81	23.98	2.32	9.70	24.79	2.38	9.61
Croatia	31.64	1.25	3.94	32.22	1.28	3.96	32.81	1.31	3.98
Cyprus	17.15	1.39	8.11	18.08	1.42	7.87	19.01	1.46	7.66
Czechia	18.74	0.94	5.04	19.41	0.97	4.98	20.07	0.99	4.93
Estonia	35.54	2.13	5.99	36.31	2.08	5.95	37.69	2.23	5.92
Hungary	14.70	1.45	9.85	16.09	2.01	13.70	18.07	2.82	19.17
Latvia	43.75	1.53	3.49	44.65	1.56	3.50	45.56	1.60	3.51
Lithuania	29.05	1.15	3.96	29.82	1.18	3.95	30.58	1.21	3.94
Malta	11.65	0.79	6.81	12.50	0.81	6.49	13.36	0.83	6.22
Poland	16.44	1.05	6.36	17.05	1.07	6.27	17.66	1.10	6.20
Romania	22.91	0.87	3.80	22.16	0.98	4.42	21.29	1.13	5.31
Slovakia	17.01	1.49	8.77	17.66	1.53	8.64	18.32	1.56	8.53
Slovenia	24.31	1.22	5.02	24.62	1.25	5.07	24.92	1.28	5.13
UE–27	22.45	0.56	2.48	23.14	0.57	2.46	23.83	0.58	2.45

Source: own calculations.

The data in Table 4 show that increases in the share of renewable energy in gross final energy consumption in subsequent years can be predicted for Bulgaria, Czechia, Croatia, Latvia, Lithuania, Hungary, and Poland, we well as the EU–27. Several countries are projected to have a lower value of the indicator in 2022 compared to the previous year (Estonia, Cyprus, Malta, Romania, Slovenia, Slovakia). In the following years, the share of renewable energy in gross final energy consumption is expected to increase again in these countries. Only for Romania is a slight decline projected.

Measures of forecast quality include absolute and relative ex-ante forecast errors (S_{pT} and V_T). For most countries, the relative error of the forecasts did not exceed 10%, indicating high precision. However, caution is advised for the forecast of the share of renewable energy in gross final energy consumption for Hungary in 2023 and 2024, where the forecast error limit was exceeded.

Interesting conclusions can be made when comparing the achieved share of renewable energy in gross final energy consumption in 2020 (Table 1) with and the projections for 2022–2024 (Table 4), alongside the national RES targets to be achieved in 2020 and 2030 (Table 5) for each of the 13 countries. Under current directives, each EU country is mandated to transition away from fossil fuels towards energy generation from RES. Each country is tasked with meeting specific RES energy production targets, depending on regional capacity and prior RES development.

Table 5. National commitments as to the RES share in gross final consumption of energy (%)

Country	National target/contribution for renewable energy: Share of energy from renewable sources in gross final consumption of energy (%)	
	2020	2030
Bulgaria	21.4	27.09
Croatia	20.0	36.4
Cyprus	13.0	22.9
Czechia	13.0	22.0
Estonia	25.0	42.0
Hungary	13.0	21.0
Latvia	40.0	50.0
Lithuania	23.0	45.0
Malta	10.0	11.5
Poland	15.0	21.0–23.0
Romania	24.0	30.7
Slovakia	14.0	19.2
Slovenia	25.0	27.0
UE–27	20.0	32.0

Source: own research based on European Commission 2020.

Based on the data in Tables 1, 4 and 5, it can be concluded that all the countries studied and the EU–27 achieved the 2020 target share of renewable energy in gross final energy consumption. However, the 13 countries studied and the EU–27 also set their own national targets, ranging from 10% in Malta to as high as 40% in Latvia. A major challenge for the EU as a whole, as well as the EU–13, will be to meet the national targets adopted for 2030. The increasing forecast values for the share of renewable energy in gross final energy consumption for 2022–2024 for most of the countries provide grounds for optimism, although there are concerns about Romania and Slovenia meeting the 2030 RES targets.

Conclusions

The management of renewable energy sources is now one of the most important branches of a country's economy, determining its socio-economic development. The volume and structure of production and energy consumption is an important element of the economic strategy pursued. It indicates the degree of modernity of technological, production and consumption solutions adopted in terms of the rationality of energy consumption and the pro-ecological orientation of a country's economic development (Gorczyca 2011).

The development of RES in many regions of the world contributes to their economic development while also improving environmental conditions. However, there are also some adverse effects, including the conversion of agricultural and forest land for energy crop production and environmental impacts through noise and landscape changes in the case of wind farms (Kruk 2012). Nevertheless, RES development is a kind of bridge linking economic, environmental and energy issues (Załuska, Piekutin, and Magrel 2018).

The article evaluated the 13 countries admitted to the EU in 2004 and later, i.e. Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia in terms of the level of renewable energy use. The indicator of the share of renewable energy in gross final energy consumption for the period 2007–2021 was assessed.

The results of the research, as well as those of other authors (e.g., Papież, Śmiech, and Frodyma 2018; Gaigalis and Katinas 2020; Koltsaklis et al. 2020; Daroń and Wilk 2021; Mišík 2022; Stec and Grzebyk 2022) confirm that the EU–13 countries attach great importance to obtaining and using energy from renewable sources. Over the 15-year research period, the use of renewable energy showed an increasing trend in most of the countries. In 2021, the leaders were Latvia (42.11%), Estonia (38.01%) and Croatia (31.33%). However, a lot of work still needs to be done by Malta, Hungary and Poland. In all of the countries, the change in the indicator of the share of renewable energy in gross final energy consumption between 2007 and 2021 was positive.

To assess whether the upward trend in the indicator will continue, we forecast it for 2022–2024 using linear and non-linear trend models. The forecasting method was an effective tool for building a forecast for the indicator, as indicated by the verification measures used. For most of the countries, the forecasts were highly and sufficiently precise, meaning the countries had a chance of meeting the RES targets set out in the EU directives. A comparison of the set forecasts of the indicator of the share of renewable energy in gross final energy consumption for 2022–2024 with the targets set by individual countries for 2020 shows that they have already been met, and the targets for 2030 also appear realistic.

The research is of great practical relevance, providing an overview of the RES situation in selected EU countries and the prospects for future years. It is becoming crucial to monitor development in this area and to set directions for the development of renewable energy sources. The level of development should be assessed as part of a long-term plan for the EU on how to increase the competitiveness of individual countries and the EU as a whole on the international stage. Using our analyses and calculations, it is possible to illustrate in detail the state of progress to date, as well as the prospects for further development.

The results of the research can also be useful, enabling the authorities or other decision-makers in these countries to identify which areas need to be improved to meet the targets set for the increasing use of RES. Countries that fall short of the targets could, for example, apply for assistance funds under EU cohesion policy or other programmes supporting RES. They could also benefit from the experiences of countries that are RES leaders.

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References

Aczel, A.D. (2000), *Statystyka w zarządzaniu*, Wydawnictwo Naukowe PWN, Warszawa.

Anastasiu, N., Simionescu, B.C., Popa, M.E., Mihai, M., Rusu, R.D., Predeanu, G. (2018), *Romanian coal reserves and strategic trends*, "International Journal Coal Geology", 198, pp. 177–182, https://doi.org/10.1016/j.coal.2018.09.011

Bekirsky, N., Hoicka, C.E., Brisbois, M.C., Camargo, L.R. (2022), *Many actors amongst multiple renewables: A systematic review of actor involvement in complementarity of renewable energy sources*, "Renewable and Sustainable Energy Reviews", 161, 112368, https://doi.org/10.1016/j.rser.2022.112368

Cieślak, M. (ed.) (2001), *Prognozowanie gospodarcze. Metody i zastosowanie*, Wydawnictwo Naukowe PWN, Warszawa.

Communication from the commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. The European Green Deal, COM/2019/640 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640 (accessed: 7.03.2023).

Daroń, M., Wilk, M. (2021), *Management of Energy Sources and the Development Potential in the Energy Production Sector – A Comparison of EU Countries*, "Energies", 14 (3), 685, https://doi.org/10.3390/en14030685

Devine-Wright, P. (2019), *Community versus local energy in a context of climate emergency*, "Nature Energy", 4, pp. 894–896, https://doi.org/10.1038/s41560-019-0459-2

Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market, Council of the European Union, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L00s77&from=ES (accessed: 10.02.2023).

Directive 2003/30/EC of the European Parliament and of the Council of 8th May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, Official Journal of the European Union 2003, L123, 42–46, https://eur-lex.europa.eu/eli/dir/2003/30/oj (accessed: 10.02.2023).

Directive 2009/28/EC of 23rd April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, Council of the European Union, Brussels, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF (accessed: 10.02.2023).

Directive 2018/2001/EU of the European Parliament and of the Council of 11th December 2018 on the Promotion of the Use of Energy from Renewable Sources, Brussels, https://eur-lex.europa.eu/eli/dir/2018/2001/oj (accessed: 8.02.2023).

European Commission (2020), *Individual assessments*, https://energy.ec.europa.eu/individual-assessments_en (accessed 10.03.2023).

Eurostat (n.d.), *Database*, https://ec.europa.eu/eurostat/data/database (accessed: 21.02.2023).

Frątczak, E. (2015), *Statistics for management and economics*, Warsaw School of Economics, Warsaw.

Gaigalis, V., Katinas, V. (2020), *Analysis of the renewable energy implementation and prediction prospects in compliance with the EU policy: A case of Lithuania*, "Renewable Energy", 151, pp. 1016–1027, https://doi.org/10.1016/j.renene.2019.11.091

Gorczyca, M. (2011), *Energy from renewable sources in Poland as compared to other EU countries*, "Energetyka i Ekologia", pp. 515–518, https://elektroenergetyka.pl/upload/file/2011/8/Gorczyca.pdf (accessed: 8.02.2023).

Hoicka, E.E., Lowitzsch, J., Brisbois, M.C., Kumar, A. (2021), *Implementing a just renewable energy transition: Policy advice for transposing the new European rules for renewable energy communities*, "Energy Policy", 156, 112435, https://doi.org/10.1016/j.enpol.2021.112435

Johansson, B. (2013), *Security aspects of future renewable energy systems – A short overview*, "Energy", 61, pp. 598–605, https://doi.org/10.1016/j.energy.2013.09.023

Koltsaklis, N.E., Dagoumas, A.S., Seritan, G., Porumb, R. (2020), *Energy transition in the South East Europe: the case of the Romanian power system*, "Energy Reports", 6, pp. 2376–2393, https://doi.org/10.1016/j.egyr.2020.07.032

Kruk, H. (2012), *Wykorzystanie źródeł energii a bezpieczeństwo energetyczne i ekologiczne Polski*, "Zeszyty Naukowe Akademii Morskiej w Gdyni", 72, pp. 23–39.

Kryszk, H., Kurowska, K., Marks-Bielska, R., Bielski S., Eźlakowski, B. (2023), *Barriers and Prospects for the Development of Renewable Energy Sources in Poland during the Energy Crisis*, "Energies", 16 (4), 1724, https://doi.org/10.3390/en16041724

Latkowska, B., Fitko, H., Stelmach, S. (2011), *Ocena właściwości paliwowych ubocznego produktu z produkcji bioetanolu*, "Inżynieria Ekologiczna", 25, pp. 222–230.

Łuczak, A., Kalinowski, S. (2022), *A multidimensional comparative analysis of poverty statuses in European Union countries*, "International Journal of Economic Sciences", XI (1), pp. 146–160, https://doi.org/10.52950/ES.2022.11.1.009

Mišík, M. (2022), *The EU needs to improve its external energy security*, "Energy Policy", 165, 112930, https://doi.org/10.1016/j.enpol.2022.112930

Molo, B. (2016), *Polityka Unii Europejskiej a rozwój odnawialnych źródeł energii w Niemczech*, "Rocznik Integracji Europejskiej", 10, pp. 121–142, https://doi.org/10.14746/rie.2016.10.8

Năstase, G., Şerban, A., Năstase, A.F., Dragomir, G., Alin Ionuț Brezeanu, A.I. (2018), *Air quality, primary air pollutants and ambient concentrations inventory for Romania*, „Atmospheric Environment", 184, pp. 292–303, https://doi.org/10.1016/j.atmosenv.2018.04.034

Ociepa-Kubicka, A. (2015), *Wykorzystanie biomasy w przedsiębiorstwach energetycznych*, "Proceedings of ECOpole", 9 (1), pp. 279–286, https://doi.org/10.2429/proc.2015.9(1)036

Olczak, K. (2016), *Polityka Unii Europejskiej w odniesieniu do odnawialnych źródeł energii – ramy prawne*, "Studia Prawno-Ekonomiczne", 101, pp. 87–97.

Papież, M., Śmiech, S., Frodyma, K. (2018), *Determinants of renewable energy development in the EU countries. A 20-year perspective*, "Renewable and Sustainable Energy Reviews", 91, pp. 918–934, https://doi.org/10.1016/j.rser.2018.04.075

Pérez, M., Scholten, P., Smith Stegen, K. (2019), *The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security*, "Energy Strategy Reviews", 26, 100415, https://doi.org/10.1016/j.esr.2019.100415

Rajchel, D., Walawender, A., (2018), *Renewable energy in the European Union and in Poland, including households*, [in:] S. Sitek (ed.), *„Stare i nowe" problemy badawcze w geografii społeczno-ekonomicznej*, z. 8, Polskie Towarzystwo Geograficzne Oddział Katowicki, Uniwersytet Śląski Wydział Nauk o Ziemi, Sosnowiec, pp. 161–176.

Stec, M., Grzebyk, M. (2022), *Statistical Analysis of the Level of Development of Renewable Energy Sources in the Countries of the European Union*, "Energies", 15 (21), 8278, https://doi.org/10.3390/en15218278

Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii (Dz.U. z 2015 r., poz. 478).

Van de Graaf, T. (2018), *Battling for a Shrinking Market: Oil Producers, the Renewables Revolution, and the Risk of Stranded Assets*, [in:] D. Scholten (ed.), *The Geopolitics of Renewables*, Springer, Cham, pp. 97–121, https://doi.org/10.1007/978-3-319-67855-9_4

Wawrzyniak, D. (2016), *Standard of Living in the European Union*, "Comparative Economic Research. Central and Eastern Europe", 19 (1), pp. 139–153, https://doi.org/10.1515/cer-2016-0008

Wiśniewska, M., Pusz, A., Rogalski, D. (2020), *Development of renewable energy sources (RES) in the European Union and Poland*, "Polish Journal for Sustainable Development", 24, pp. 101–112, https://doi.org/10.15584/pjsd.2020.24.2.12

Załuska, M., Piekutin, J., Magrel, L. (2018), *Efektywność ekonomiczna i energetyczna funkcjonowania biogazowni w zależności od zastosowanego substratu*, "Budownictwo i Inżynieria Środowiska", 9 (1), pp. 51–56.

Zeliaś, A., Pawełek, B., Wanat, S. (2003), *Prognozowanie ekonomiczne. Teoria, przykłady, zastosowania*, Wydawnictwo Naukowe PWN, Warszawa.

Żuk, P., Żuk, P. (2022), *National energy security or acceleration of transition? Energy policy after the war in Ukraine*, "Joule", 6 (4), pp. 709–712, https://doi.org/10.1016/j.joule.2022.03.009

Poziom wykorzystania energii odnawialnej w wybranych krajach Unii Europejskiej – statystyczna ocena zmian i perspektyw rozwoju

Poszukiwanie i wykorzystywanie ekologicznych źródeł energii to ważne kierunki działań Unii Europejskiej. W pracy dokonano porównania 13 wybranych krajów, przyjętych do UE w 2004 roku i później, w zakresie poziomu wykorzystania energii odnawialnej. Podstawowym wskaźnikiem oceniającym poziom wykorzystania OZE w wybranych krajach był udział energii odnawialnej w końcowym zużyciu energii brutto w latach 2007–2021. Dane statystyczne pobrano z bazy Eurostatu. Wyniki przeprowadzonych badań potwierdzają, że w latach 2007–2021 w większości badanych krajów UE nastąpiły pozytywne zmiany w zakresie wykorzystania energii odnawialnej. We wszystkich badanych krajach tempo zmian wskaźnika udziału energii odnawialnej w końcowym zużyciu energii brutto w latach 2007–2021 było dodatnie. Perspektywy rozwoju energii odnawialnej w badanej grupie krajów oceniono poprzez budowę prognoz wskaźnika udziału energii odnawialnej w końcowym zużyciu energii brutto na lata 2022–2024. Dla większości badanych krajów prognozy okazały się wysoce i dostatecznie precyzyjne, co daje szansę realizacji założonych celów OZE zawartych w dyrektywach unijnych.

Słowa kluczowe: energia odnawialna, Unia Europejska, metody prognozowania, perspektywy rozwoju