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EUROPEAN UNION ENERGY INDEPENDENCE IN 2013-2022 IN LIGHT OF ITS ENERGY POLICY

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Purpose: The study analyses the energy independence of European Union member states from 2013 to 2022. Its specific objective was to analyse the development of renewable energy sources in the European Union between 2013 and 2022.
Design/methodology/approach: The authors investigated a hypothesis that the energy independence of European Union member states gradually increased between 2013 and 2022. The research employs such quantitative methods as dynamics analysis and EU member state clustering with zero unitarisation (a multivariate analysis method).
Findings: More than half of EU countries increased their energy dependency rate in 2022 compared to 2013. The metric for the Netherlands and Denmark has increased thrice since 2013, reaching the highest level among all countries. In contrast, Estonia, Sweden, and Romania had the lowest energy dependency rates of 6.2%, 26.8%, and 32.4%, respectively, in 2022.
Research limitations/implications: The study is founded on a single index as a prologue for a more in-depth investigation of the issue, which should consider a broader range of indicators, such as the price competitiveness of other energy sources. Therefore, the article is a starting point for further discussion on energy security as an important factor in economic security.
Originality/value: The study is founded on a single index as a prologue for a more in-depth investigation of the issue, which should consider a broader range of indicators, such as the price competitiveness of other energy sources. Therefore, the article is a starting point for further discussion on energy security as an important factor in economic security.
Keywords: energy independence, renewable energy sources, sustainable energy industry, sustainable development, European Union.
Category of the paper: research paper.

1. Introduction

Efforts are made today to eliminate the adverse environmental impact of economic development. It is evident in the struggle to balance environmental well-being, social development, and economic growth (Firlej et al., 2024). Global energy consumption grows by the year. Energy from coal and other fossil fuels is harmful to the environment. The European Union (EU) is proceeding with a plan to decarbonise member states and reach energy autarky by 2050. The means to this goal is energy from renewable sources, renewable energy, or RE (European Council meeting, 2019). The recent energy policy of Poland was founded on hard and brown coal. This has led to a low contribution from renewable energy sources (RES) to Poland's energy mix. The EU energy policy provides for individual member states to gradually increase the share of renewable energy (Wysocka, 2023).

The development of renewable energy sources has a significant impact on changes in energy prices. Firstly, the development of renewable energy sources causes a decrease in the costs of energy production. Thanks to technological progress in the field of renewable energy infrastructure, the cost of generating energy from these sources is decreasing. In EU countries such as Sweden, Finland and Latvia, wholesale energy prices are lower, especially during mass production such as sunny days. The development of renewable energy sources also has an impact in terms of dependence on conventional energy sources, mainly fossil fuels. RES can reduce imports of natural gas or coal (Seroka, 2022).

The development of renewable energy sources also has a significant impact on the economy. The RES sector generates new jobs, especially in the production and maintenance of energy farms (Generowicz, 2019). Countries with a high share of RES in the total energy mix are less sensitive to economic crises, mainly due to energy self-sufficiency (Katarzyński, Przekota, 2024). A greater number of investments in renewable energy sources affects the development of technology, which directly translates into innovation and competitiveness of the economy (Wojtaszek, 2022).

The energy and climate transition involves innovation and the latest technologies. Research and development efforts aim at tapping the national potential in technology, intellectual capital, and competitive advantage. Poland intends to spend 2.5% of its GDP on climate and energy research in 2030 (National Energy and Climate Plan).

The energy dependency rate is the degree to which a national economy relies on energy imports to satisfy its consumption needs (Braun, 2018). An analysis of energy security should consider such factors as the size and diversification of the country's fuel stock, supply system condition and supply infrastructure ownership, the degree of diversification and use of national and international energy source suppliers, and fuel storage capabilities (Mazurkiewicz, 2008).

The 2030 Agenda for Sustainable Development was adopted in 2015. It sets seventeen Sustainable Development Goals (SDGs) (Transforming our world). The main objective of the EU climate policy is to secure the production and use of sustainable energy. Access to sources of stable, sustainable, and innovative energy at an affordable price is encapsulated in SDG7 (Ensure access to affordable, reliable, sustainable and modern energy for all) (Report of the Inter-Agency…; Ensure access to affordable, reliable, sustainable and modern Energy).

Energy is the central factor ensuring energy security and the proliferation of renewable energy. The EU has made substantial progress in the use of RES in industry and transport (SDG7 Affordable and clean energy). EU member states consider the expansion of the renewable energy sector as the key to energy security. This approach is driven by the fear of a shortage of conventional energy sources in the early twenty-first century (Tomala, 2024). The EU climate and energy policy is shaped mainly by the SDGs. The European Commission undertook to implement the 2030 Agenda in the European Green Deal and Delivering on the UN's Sustainable Development Goals — A comprehensive approach (EU approach to SDGs implementation).

In addition to adopting the 2030 Agenda, the EU has its independent and targeted climate policy. The EU energy legislation is adapted to the 2030 goals by means of Directive 2012/27/EU. Directive 2018/2002 from November 2018 amended the 2012 directive, expanding the goals in the 2030 horizon (Directive (EU) 2018/2002).

In July 2021, the EU presented a new legislative package for the climate policy, Fit for 55. The 2030 objective is to reduce greenhouse gas emissions by 55% compared to 1990. Simultaneously, it was decided that the entire Europe should be climate-neutral by 2050. Apart from climate, the package addresses building energy-related issues, such as zero-emission buildings (Fit for 55; European Commission, 2019).

Conventional energy sources for electricity production can be replaced only by more sustainable energy technologies (Rizzi et al., 2014). Global warming and climate change are caused by excessive consumption of fossil fuels for energy purposes (Ang, Salem, Kamarol, Das, Nazari, Prabaharan, 2022). This entails a growing pressure towards renewable energy: solar energy, hydropower, wind power, geothermal energy, bioenergy, and hydrogen power (Michalcewicz-Kaniowska, Zajdel et al., 2022). The goal is to overcome the environmental crisis regarding electricity generation (Santika et al., 2019).

The study analyses the energy independence of European Union member states in 2013 and 2022. Its specific objective is to investigate the development of renewable energy sources in the European Union between 2013 and 2022. The input data come from secondary sources, official statistics time series from Eurostat, the International Renewable Energy Agency (IRENA), and Statistics Poland. The authors investigated a hypothesis (H1) that the energy independence of European Union member states steadily increased from 2013 to 2022.

2. Methods

The analysis for 2013–2022 is founded on official statistics from Eurostat, for example. The spatial scope of the analysis are European Union member states. The time series under scrutiny are energy intensity, energy import dependency rate, and share of renewable energy in gross final energy consumption. The study looks into the dynamics of changes with rates of increase $\left(\Delta_{t/(t-1)} = y_t - y_{t-1}\right)$ and ratios $\left(i_{t/(t-1)} = \frac{y_t}{y_{t-1}}\right)$.

The synthetic index of energy security in the EU in light of its energy policy makes use of a multivariate analysis method. First, the authors selected the variables (Table 1) and determined their profiles (BTB – bigger the better, STB – smaller the better).

Table 1.
Diagnostic variables selected for the analysis

Label	Variable	Profile
X_1	energy intensity [kgoe/1000PPS]	STB
X_2	energy dependency rate [%]	STB
X_3	share of renewable energy in gross final energy consumption [%]	BTB

Source: original work based on Eurostat.

The variables were chosen considering data availability and factual analysis. Values of the primary numerical measures are summarised in Table 2.

Table 2.
Statistics for the diagnostic variables for 2013 and 2022

Variable	2013				2022			
	max.	min.	mean	CV	max.	min.	mean	CV
X_1	241.00	84.30	144.44	0.26	155.60	34.70	96.01	0.29
X_2	97.60	12.30	55.26	0.46	99.00	6.20	61.06	0.36
X_3	50.20	3.50	19.02	0.60	66.00	13.10	25.73	0.49

CV: coefficient of variation.

Source: original work based on Eurostat.

All the variables exhibit variation over 10%. The coefficient of variation of X1 grew slightly between 2013 and 2022. Conversely, the CV of variables X2 and X3 declined. The second step was to standardise the variables using the following formula (Kądziołka, 2021, p. 72):

$$z_{ij} = \begin{cases} \dfrac{\max\limits_i x_{ij} - x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}, & X_j - STB \\ \dfrac{x_{ij} - \min\limits_i x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}, & X_j - BTB \end{cases}$$

where: x_{ij}, z_{ij} are actual and normalised values of X_j for country i, respectively, $z_{ij} \in [0,1]$.

In the third step, the authors calculated the value of the synthetic variable Qi with the following formula:

$$Q_i = \frac{1}{4}\sum_{j=1}^{3} z_{ij}$$

where: Q_i is the value of the synthetic variable for country i, $Q_i \in [0,1]$.

The highest value of Q_i means the object performed the best in the EU member state energy policy evaluation regarding energy security.

Using the method reported above, the authors ordered EU member states by Q_i. The investigated regions were grouped according to the following equations (Luty, Zioło, 2022):

- Group I: $Q_i \in (\max_i Q_i - A; \max_i Q_i]$.
- Group II: $Q_i \in (\max_i Q_i - 2A; \max_i Q_i - A]$.
- Group III: $Q_i \in (\max_i Q_i - 3A; \max_i Q_i - 2A]$.
- Group IV: $Q_i \in (\min_i Q_i; \max_i Q_i - 3A]$.

where: Q_i is the value of the synthetic variable for country i; $A = \frac{1}{4}(\max_i Q_i - \min_i Q_i)$.

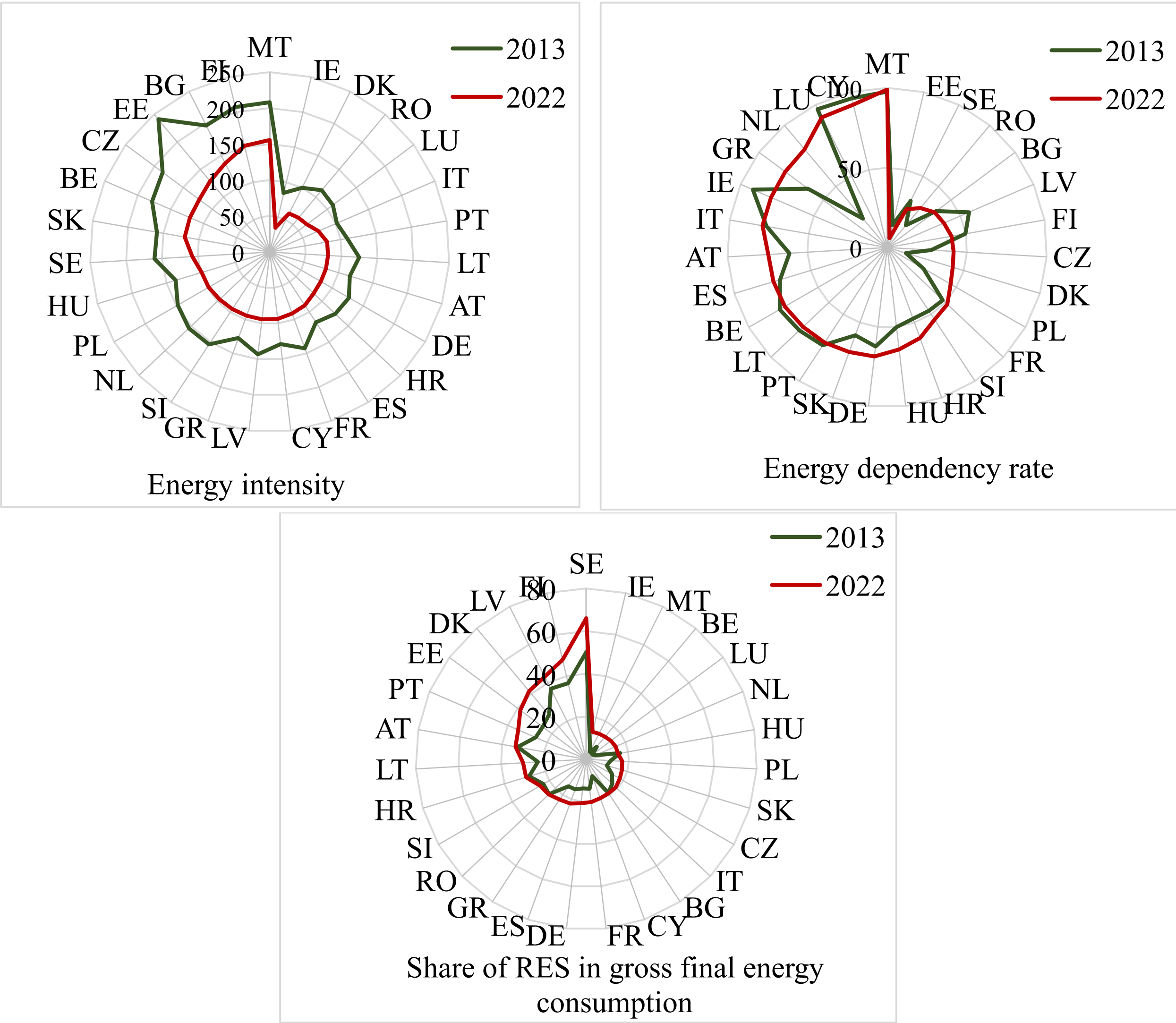
3. Results

Energy intensity reflects the amount of energy necessary to generate a unit of gross national product. It is expressed as kilograms of oil equivalent (kgoe) per thousand euros in purchasing power standards (1000 PPS). The EU mean value of energy intensity for 2022 was 86,5 kgoe per 1000 PPS. Only ten EU member states had energy intensity below the EU average in 2022. The least energy-intensive economies in that year were Romania (62.4), Denmark (60.2), and Ireland (34.7). Poland was the tenth most energy-intensive economy in the EU (98.3 kgoe per 1000 PPS in 2022). The ranking leaders were Bulgaria (137.9), Finland (152.1), and Malta (155.6).

Conversely, Estonia, Sweden, and Romania had the lowest energy import dependency rates of 6.2%, 26.8%, and 32.4%, respectively, in 2022. Poland was the ninth most energy-independent EU member state, even though its energy dependency rate skyrocketed by 75% between 2013 and 2022. The most energy-dependent EU member states in 2022 were Luxembourg (91.3%), Cyprus (92%), and Malta (99%) (figure 1).

The share of RES grew in every investigated country over the period of interest. In 2022, countries with the best shares of RES in total energy were Latvia (43.3%), Finland (47.9%), and Sweden (60%). In Poland, only 16.9% of the total energy was sourced from RES in 2022.

The lowest portions of renewable energy were found in Belgium (13.8%), Malta (13.4%), and Ireland (13.1%). The share of RE in the total EU energy in 2022 was 23%.



Labels for EU member states: Austria (AT), Belgium (BE), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Greece (GR), Spain (ES), Netherlands (NL), Ireland (IE), Lithuania (LT), Luxembourg (LU), Latvia (LV), Malta (MT), Germany (DE), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Sweden (SE), Hungary (HU), Italy (IT).

Figure 1. Changes in the metrics of energy security in EU member states from 2013 to 2022.

Source: Original work based on Eurostat.

The most energy-secure EU member states in 2013 were Romania, Sweden, and Denmark at the top. The lowest-ranked states were Cyprus, Belgium, and Malta (figure 2). In 2013, Poland was the seventh most energy-secure EU member state.

The landscape changed slightly in 2022. Sweden became the most energy-secure country, followed by Denmark. The third most energy-secure country was Latvia. Poland went down to the 14th position in 2022. Ireland and Estonia were the leaders in energy security improvement in 2022. In contrast, the Netherlands and Hungary neglected their energy security the most in 2022.

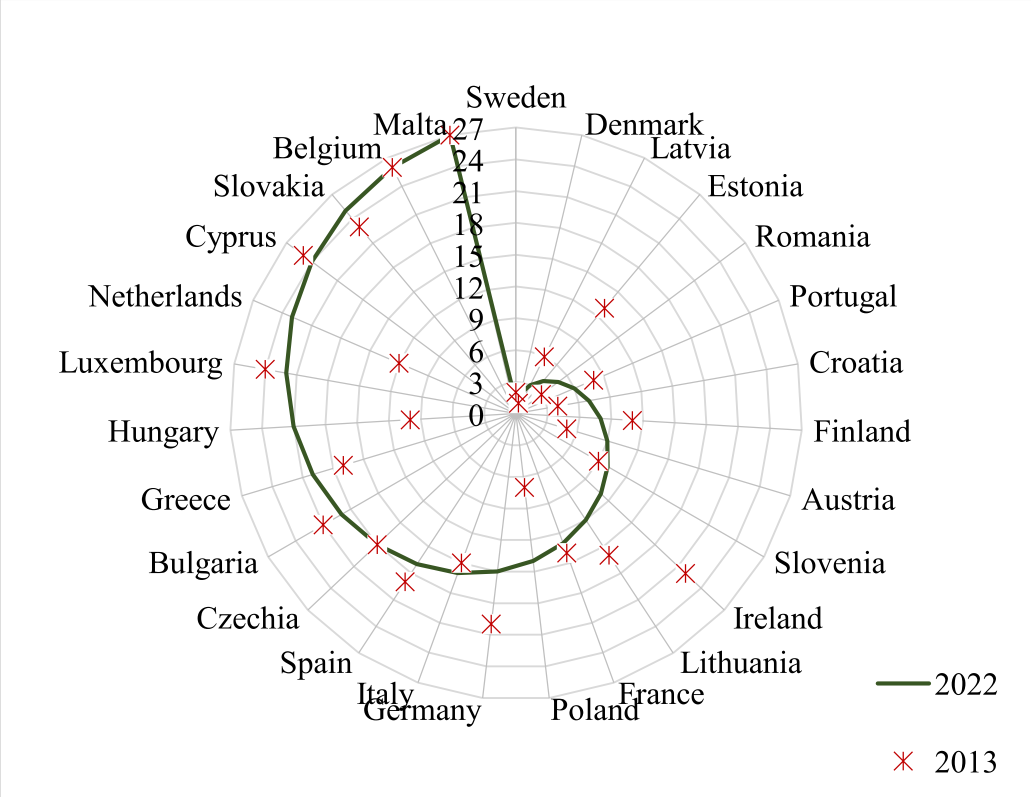


Figure 2. Ranking list of EU member states' energy security in 2022 and 2013.

Source: Original work based on Eurostat.

The authors classified EU member states into four groups regarding energy security, considering three metrics: energy intensity (X1), energy dependency rate (X2), and share of RES in gross final energy consumption (X3). The first group exhibits outstanding energy security. These five countries have a high share of RE, a minimal energy dependency rate, and small or average energy intensity.

The second group covers countries with adequate levels of energy security. They exhibit average energy intensity and share of RES and a small value of energy dependency rate. There were nine such EU countries.

The third group contains countries with average energy security levels. Their energy intensity is high, RES share average, and energy import dependency rate high. It is the largest group of all.

The fourth group of two EU member states demonstrates very low levels of energy security. These countries import over 90% of their energy. They also have very energy-intensive economies and very low shares of RE in their mixes.

Energy intensity declined in all EU member states between 2013 and 2022. Romania, Estonia, and Ireland were the most successful in this regard. The metric decreased by 45%, 47%, and 59% in Romania, Estonia and Ireland, respectively (Table 3). More than half of the EU member states grew more energy-dependent in 2022. The greatest increase of over three times compared to 2013 was in the Netherlands and Denmark.

Table 3.
EU member state groups according to energy security in 2022 and metric increases compared to 2013

Group	EU member state	Increase and ratio for X_1		Increase and ratio for X_2		Increase and ratio for X_3	
Group I	Sweden	-52.6	0.67	-6.0	0.82	15.8	1.31
	Denmark	-39.6	0.60	30.6	3.49	14.4	1.53
	Latvia	-49.0	0.66	-17.2	0.69	6.3	1.17
	Estonia	-99.4	0.53	4.3	1.06	13.1	1.52
	Romania	-50.1	0.55	14.1	1.77	0.2	1.01
Group II	Portugal	-28.3	0.74	-2.0	0.97	9.0	1.35
	Croatia	-41.4	0.67	12.9	1.27	1.4	1.05
	Finland	-55.2	0.73	-8.8	0.82	11.3	1.31
	Austria	-35.0	0.70	13.2	1.22	1.0	1.03
	Slovenia	-58.9	0.62	6.5	1.14	1.8	1.08
	Ireland	-49.6	0.41	-12.4	0.86	5.6	1.75
	Lithuania	-43.2	0.65	-3.2	0.96	6.9	1.30
	France	-51.6	0.64	3.9	1.08	6.4	1.46
	Poland	-49.5	0.67	19.7	1.75	5.4	1.47
Group III	Germany	-45.3	0.64	6.2	1.10	7.0	1.51
	Italy	-28.1	0.72	2.5	1.03	2.4	1.14
	Spain	-28.5	0.76	4.3	1.06	7.0	1.46
	Czechia	-63.4	0.66	14.2	1.51	4.3	1.31
	Bulgaria	-58.9	0.70	-1.2	0.97	0.2	1.01
	Greece	-33.0	0.74	17.8	1.29	7.4	1.48
	Hungary	-37.6	0.72	14.1	1.28	-1.0	0.94
	Luxembourg	-45.2	0.59	-5.8	0.94	10.9	4.11
	Netherlands	-58.4	0.62	56.6	3.39	10.3	3.19
	Cyprus	-35.0	0.73	-4.1	0.96	11.0	2.31
	Slovakia	-39.4	0.75	11.2	1.19	7.4	1.73
Group IV	Belgium	-57.1	0.68	-3.7	0.95	6.1	1.79
	Malta	-52.8	0.75	1.4	1.01	9.6	3.53

Source: original work based on Eurostat.

4. Discussion

The National Energy and Climate Plan for 2021–2030 (NECP) is the pivotal document for the Polish energy sector and other sectors of the country's economy (National Energy and Climate Plan). According to the NECP, Poland can reduce greenhouse gas emissions by 35% compared to 1990. To this end, all sectors should be decarbonised. According to forecasts, Poland will reach a 29.8% share of RES in the total energy mix in 2030 (National Energy and Climate Plan). Investments in RES help countries curb fossil fuel and energy import dependency, reducing exposure to oil and gas price shocks. This approach improves both energy security and control over national resources (Chen et al., 2021). The latest events in Europe (the COVID-19 pandemic and war in Ukraine) stress-tested the continent's energy security. They have led to supply chain disruptions, CO2 emissions trading speculations (the COVID-19 pandemic) (Horky et al., 2023) and energy price increases (the Russian gas sabotage) (Sattich et al., 2022).

Oil consumed in Poland is sourced mainly from Russia. The difficult geopolitical position of the country calls for diversification of the supply chain, leading to higher prices. Poland may be less dependent on its eastern neighbour but will remain dependent on imports. The planned nuclear power plant will offer a stable supply of energy in Poland (also regarding renewable energy) (Pangsy-Kania, Wierzbicka, 2022). The advantages of nuclear energy include high performance, zero emissions, and full decarbonisation.

Poland's energy independence and security require that the options of oil and natural gas imports from politically stable countries be investigated. Also, the condition of hard coal mining will impact Poland's energy security as coal remains the country's primary source of energy.

5. Summary

Poland's energy policy is founded on increased RE supply to decarbonise the economy. A nuclear power station is planned for the future. Transport needs more RE, and the energy efficiency of the entire economy has to improve. For this, it is critical to reduce coal dependency. Poland's economic policy is set to increase energy security and reduce energy import dependency (Poland 2022 - Energy Policy Review).

The country's energy independence is central to its energy security. More focus is required on energy infrastructure, which affects energy security regarding the distribution, transmission, and storage of carriers and energy (Gomółka, Kasprzak, 2023).

Due to the increasing political instability related to the armed conflict in Ukraine, the EU energy policy should aim at improving energy independence or diversifying imports of energy carriers from politically volatile countries. It is critical for economic and energy security. Renewable energy sources are believed to be less risky for energy security and independence. Their downside is lower predictability compared to nuclear energy, for example. European Union's dependency on a single supplier of natural gas and oil, Russia, threatens the energy security of the entire Community. Despite its high energy independence, Poland still extensively relies on imports of energy carriers from Russia.

The main objective of the research, which was to analyze the energy dependence of the European Union countries in 2013-2022 was achieved. Also the side objective, which was to analyze the development of renewable energy sources in the European Union in 2013-2022. The hypothesis that the energy dependence of the European Union countries systematically decreased in the years 2013-2022 was verified negatively.

The article is a starting point for further considerations in the field of energy dependency and development of renewable energy sources, extending future research to other countries or time range. The analysis of the European Union's energy independence encounters certain limitations such as the changing energy policies of the European Union members.

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