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THE DYNAMICS OF ENERGY TRANSITION IN EUROPEAN COUNTRIES IN YEARS 2004-2021

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ABSTRACT: This study delves into the critical contemporary issue of global energy transition, focusing on European countries from 2004 to 2021. Its objective is to identify countries with similar rates of energy transition, utilising statistical measures and clustering techniques on Eurostat data. The paper explores energy efficiency, renewable sources, and energy import reliance. Findings show reduced primary energy consumption in EU-27, varied energy efficiency trends, and notable differences in renewables and import dependence. Clustering countries unveil diverse transition speeds. Policymakers can tailor effective strategies based on regional challenges and successes, fostering a nuanced understanding of economic, social, and environmental dynamics in the energy transition. This analysis offers valuable insights for informed policy-making in the complex landscape of global energy transformation.

KEYWORDS: energy efficiency, dependence on energy imports, renewable energy sources, energy transition

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Introduction

An important contemporary economic, industrial, and social issue today is the global energy transition. Energy transition refers to the global shift from fossil fuel-based energy systems to renewable and sustainable energy sources (Hosseini, 2020). It involves the transformation of energy production, distribution, and consumption patterns in order to mitigate climate change, reduce greenhouse gas emissions, and achieve a more sustainable and resilient energy future. The term energy transition is often used in the context of discussing policy frameworks, technological advancements (Baur et al., 2022), economic implications, social acceptance, and environmental impacts associated with the shift towards clean energy alternatives (Evensen et al., 2018). Energy transition processes are having a key impact on the development of world economies. The systematic and dynamic development of the energy transition is driven by the development of new technologies, an increase in the population's standard of living, and a change in consumption patterns (Piekut, 2021).

The contemporary energy markets are very important for economies. That fact is evident in business investment, the share of the energy sector in GDP, as well as expenditures on energy-related research and development (Inglesi-Lotz, 2019). The renewable energy sector and energy security have also been gaining importance in recent years due to the armed conflict in Ukraine. An increase in energy efficiency and the development of renewable energy is linked to the goals of sustainable development (Lyeonov et al., 2019), where the greatest emphasis is placed on environmental care and the transition from classical energy sources to renewable and non-carbon sources. Thanks to the development of renewable energy, there is a reduction in energy imports, which improves the country's energy security.

Energy transition is a broad concept that takes into account numerous aspects. The study considers three aspects of energy transition, i.e. energy efficiency, application of renewable energy sources and reliance on energy imports. The objective of the study is to identify the changes that have occurred in selected aspects of energy transition in European countries between 2004 and 2021 and to delimitate groups of countries with comparable speeds of change in energy transition. This paper aims to give further insight into the development of European countries' energy transition and offer new insights to help fill existing gaps in the literature.

For the objective thus formulated, the following research questions regarding European countries were posed:

- What progress in improving energy efficiency has been made?
- What progress in increasing renewable energy sources in the energy mix has been made?
- What does becoming independent of energy imports represent?

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The following research hypothesis was put forward: The speed of energy transition varies across European countries, and on this basis, it is possible to distinguish the groups of countries showing similar progress in terms of energy market changes.

For the appropriate development of modern economies, it becomes necessary to have constant observation and analysis of the energy markets' development and operability which, among others, is evident in EU documents. Particularly important in this context seems to be the analysis of the energy efficiency development and modification of the application of renewable energy sources application, as well as making countries independent of energy imports (Chen et al., 2021; Chen et al., 2023). Analyses designed to identify development trends occurring in energy markets also appear relevant.

Continuous tracking of progress in the application of energy carriers in the economies is becoming a compulsory task in the face of consumer health and environmental protection. The information on the consumption of energy carriers can be helpful for the development of regional policies and offer great cognitive interest.

This study is necessary for several reasons. Understanding energy transition dynamics is crucial, given the global emphasis on transitioning to sustainable and renewable energy sources. Policymakers require insights into the progress and variations in energy transition across countries. The diversity in the speed and efficiency of energy transition efforts poses challenges for policymakers. The study offers information that can inform policy decisions related to energy efficiency, renewable energy development, and reducing import dependency. Understanding these variations is crucial for formulating effective policies that are tailored to the specific needs and challenges of each group of countries.

By identifying groups of countries with similar rates of energy transition, policymakers can tailor their policies to address the unique challenges and opportunities within each group.

The inclusion of countries from different regions with varying economic strengths, historical backgrounds, and geographic characteristics enables a comprehensive analysis of energy transition dynamics across the continent. The sample allows for the identification of regional patterns and trends. Policymakers can use this information to develop region-specific policies that consider shared challenges and opportunities. The sample encompasses countries with varying levels of success in energy transition. This allows for a comparison of different approaches and strategies, facilitating the identification of factors contributing to success or hindrance. The policies derived from the study can be generalisable to countries with similar characteristics to those within the identified clusters.

An overview of the literature

The literature review aims to present the problem of the lack of a unified definition of energy transition and draw attention to the diversity of approaches and priorities associated with this concept. Three components of energy transition are considered: energy efficiency, renewable energy sources, and dependence on energy imports.

The systematisation of the literature presented in the Scopus database reveals a rapidly growing trend in publication activity since 2008, as depicted in Figure 1.

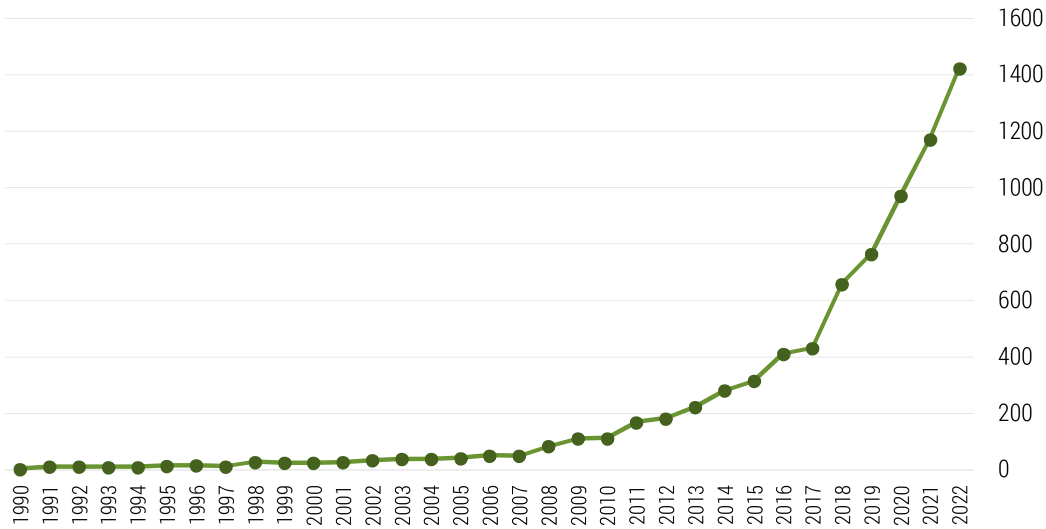

Figure 1. The dynamic of publication activity on Energy transition in social sciences, 1990–2022

Source: author's work based on Scopus (2023).

Despite such an impressive number of publications, it is difficult to find a single definition of energy transition. Pastukhova and Westphal (2020) conducted a literature review and found that neither a comprehensive definition nor a theoretical framework for the concept of energy transition is currently available. This situation is due to the lack of common understanding between (inter) national actors. The energy transition is most often defined from an extensional point of view, e.g. through its components, such as the increasing share of renewable energy sources in the total energy mix, energy efficiency, fossil fuel phasing-out (Ferroukhi et al., 2020) and nuclear power (German Federal Government), electrification of the transportation sector, development of CO_2 capture

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and storage technologies (Norway, Saudi Arabia). An important observation here is that the set of these components varies between countries, regions and organisations according to their respective programs. In other words, the global community suffers from a lack of a uniformly agreed-upon energy transition program (Pastukhova & Westphal, 2020).

Political approaches to energy transition are based on a set of paradigms, the essential of which is often defined as energy security. Traditionally, in the EU and OECD countries, energy security has been defined through the strategic energy triangle, which consists of three goals: security of supply, sustainability and economic efficiency. On the other hand, the World Energy Council emphasises that countries face the energy trilemma of simultaneously addressing security of supply, environmental sustainability and energy justice (Pastukhova & Westphal, 2020).

The concept of energy transition is widely used as a normative concept and is often adapted to specific political goals or as the basis for specific measures and steps. Therefore, international forums such as the G20 and the World Energy Council promote multiple energy transitions, i.e. structural changes in each individual state's energy system in accordance with its respective goals and economic and resource potential (Quitzow et al., 2019; Carrington & Stephenson, 2018).

The energy transition can be conceptualised through three components:

- Economic, which means new investment opportunities and eco-jobs or the export of low-carbon technologies,
- industrial, which means the modernisation of the economy and the transition to digitalisation and advanced, less polluting and less energy-consuming technologies,
- social, which includes measures forclimate protection and for the benefits to public health (Młynarski, 2019).

In the present article considers three components of energy transition: energy efficiency, renewable energy sources and energy imports. The motivation to include these elements was based on the research conducted by scholars from Germany, Turkey, and the United States (Gielen et al., 2019), which indicated that energy efficiency and renewable energy technologies are the main elements of that transition. Higher energy efficiency and a much higher share of renewable energy are the two core pillars of energy transition.

Furthermore, in other scientific studies, it has been emphasised that the increase in the use of renewable energy and the improvement of energy efficiency are key solutions for supporting the energy transition (Gielen et al., 2019; Bali Swain et al., 2022; Kost et al., 2019). Additionally, the studies draw on empirical data and analyses, enhancing the credibility of their findings.

Incorporating perspectives from researchers from different countries provides a global perspective on energy transition, acknowledging regional variations and priorities. The emphasis on energy efficiency and renewable energy

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sources aligns with the broader goals of sustainable development and decarbonisation. A limitation of such a research approach might be the fact that the scope of the studies, while valuable, is limited to three specific aspects of the energy transition, potentially overlooking other relevant factors.

Thus, the improvement of energy efficiency in the country's economy is one of the vital goals of both energy and environmental policies. Energy efficiency, according to the definition found in the Law on Energy Efficiency (Obwieszczenie, 2021), is the ratio of the achieved magnitude of the functional effect of a facility, technical device or installation under typical conditions of its use or operation, to the amount of energy consumed by that facility, technical device or installation, or as a result of the performed service necessary to achieve that effect. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency indicates that energy efficiency is the measure of the efficiency of energy consumed in economic activities. Energy efficiency is one of the best ways to meet these challenges. It increases the security level of the EU's energy supply by lowering primary energy consumption and reducing energy imports. It also contributes to lowering greenhouse gas emissions in a cost-effective manner, consequently mitigating the effects of climate change. Shifting to a more energy-efficient economy should also lead to faster spread of innovative technological solutions, improve industrial competitiveness in the EU, stimulate economic growth, and create high-quality jobs in sectors related to energy efficiency. These provisions show that reducing the EU's energy intensity is a top political priority. Increasing energy efficiency is one of the most important directions for sustainable economic development in industrial and social structures (Manuela & Slusarczyk, 2019).

Another important factor supporting the energy transition is the intensification of renewables in the mix of energy used in economies. The 23 April 2009 Renewable Energy Directive laid down that 20% of the EU's total energy consumption must mandatorily come from renewable sources by 2020.

In July 2021, in the European Green Deal implementation package, the European Commission proposed an amendment (RED II) to the Renewable Energy Directive so as to align its renewable energy targets with the new climate goals. The Commission proposed increasing the binding renewable energy target in the EU's energy mix to 40% by 2030 and promoted the use of renewable fuels such as hydrogen in industry and transport by defining additional targets.

In May 2022, after the Russian aggression against Ukraine, the Commission proposed a new amendment (RED III) under the REPowerEU plan to accelerate the transition to clean energy in accordance with the gradual reduction of dependence on Russian fossil fuels. The Commission proposed installing heat pumps, increasing the capacity of photovoltaic systems, and importing renewable hydrogen and biomethane to increase renewable energy sources to 45% by 2030.

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Regardless of the decarbonisation policy implemented by the EU-28 over the last decades, fossil fuels (i.e., coal, oil, gas) and their products are still the predominant energy sources utilised in the EU-28 (De Rosa et al., 2022).

The Glasgow Climate Pact represents a pivotal international initiative aimed at expediting the transition to renewable energy and achieving net-zero emissions by 2050, aligning with the Sustainable Development Goals. In 2022, during the COP27 conference, the emission targets established at COP26 were reaffirmed. COP27's primary focus was on promoting the adoption of renewable energy sources as part of the broader trajectory toward a fossil fuel-free future (Ma et al., 2023).

Another critical aspect of the energy transition pertains to ensuring energy security for economies by reducing reliance on energy imports. Energy import dependency is quantified as the proportion of energy that an economy must import and is expressed as a percentage, defined as the ratio of net energy imports to gross available energy. A negative dependency rate indicates a surplus of energy exports, while a dependency rate exceeding 100 percent signifies energy stockpiling (Nordic Statistics database, 2022). European nations, however, exhibit a significant dependence on fossil fuel imports (Martins et al., 2019), resulting in reduced energy security.

Enhancing energy supply security necessitates reducing import reliance, bolstering domestic production, diversifying energy sources, exploring alternative energy options, advancing technological innovations in the field, and implementing effective energy demand management strategies (Pacesila et al., 2016; De Rosa et al., 2022).

The problem of energy security, in particular, was accentuated in 2022. The war in Ukraine exacerbated energy uncertainty both in Europe and around the world, which affected the anxiety of governments and societies (Umar et al., 2022; Zuk & Zuk, 2022). This problem had an impact on decision-making at the highest levels of government. In 2022, the European Commission launched the EU's new external energy strategy, which aimed to support a global, clear and equitable energy transition for sustainable, secure and affordable energy (Kuzemko et al., 2022; Giuli & Oberthür, 2023). Later that year, the UK government announced a new energy security strategy designed to reduce the risk for British businesses and households in the fossil fuel energy market with simultaneous economic decarbonisation (Papadis & Tsatsaronis, 2020). The US Department of Energy, in turn, released a comprehensive plan to ensure energy security, increase the country's energy independence and transition towards clean energy by enhancing a sustainable supply chain (Gawusu et al., 2022; Tian et al., 2022).

Ensuring energy security is key to avoiding disruptions in economic activities, maintaining the growth momentum (Murshed, 2018; Nepal & Paija, 2019), and maintaining a proper standard of living (Piekut, 2020; Wang et al., 2022; Rao et al., 2022).

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The improvement in energy efficiency (EE) and increasing consumption of renewable energy sources (RES) in manufacturing play a key role in pursuing sustainable development in European countries and contribute to the transition to a low-carbon economy (Miskinis et al., 2023). These factors also lead to a reduction in fuel imports and, as a result, an increase in energy security for economies.

The proposed solutions for supporting energy transition across various studies exhibit both commonalities and differences, reflecting the complex and multifaceted nature of the challenge. Across studies, there is a shared emphasis on improving energy efficiency and increasing the share of renewable energy sources, highlighting these as fundamental pillars of energy transition. Researchers consistently advocate for policy interventions to promote sustainable energy practices, aligning with global initiatives like the European Green Deal.

The proposed solutions vary depending on regional priorities. Some proposals emphasise specific technological solutions, such as the use of hydrogen or biomethane, highlighting the diversity of approaches to achieving renewable energy goals.

Despite the differences, the studies collectively underscore the urgency of transitioning to cleaner energy sources. The diversity in proposed solutions reflects the need for context-specific strategies while emphasising shared global goals. Effective energy transition requires a combination of technological innovation, policy coherence, and international cooperation.

Research Methods and Preliminary results

To attain the research objective outlined in this paper and execute the tasks at hand, the researcher had to employ several statistical measures and methods. The subsequent research tasks were aligned with the research questions.

The model construction was based on two steps.

Evolution of Energy Transition Indicators (Step 1): Monitoring the evolution of selected indicators of energy transition in European countries required several statistical measures and methods. The empirical model's construction involved the following steps:

- aggregating data from the Eurostat Energy balance sheets database for individual countries,
- calculating the average rate of change in selected indicators in each country. The slope coefficient from regression analysis was employed, where the independent variable was the study year, and the dependent variable was a selected aspect of energy transition (energy efficiency, energy import, share of renewable energy sources) between 2004 and 2021,
  generating a ranking of countries in terms of selected variables.

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Country typing (Step 2): Identification of European country types in terms of energy transition changes involved the following steps:

- the Ward clustering method and establishing the optimal number of clusters,
- carrying out clustering with the Ward method,
- the application of the k-means method – description and labelling of clusters.

Cluster analysis using Ward's method with the square of Euclidean distance as a measure of distance and the k-means method was applied to distinguish groups of countries with similar speed of change in energy transition indices. Cluster analysis has already been employed successfully for grouping countries in several similar research areas, such as renewable energy (Ntanos et al., 2018), climate change (Puertas & Marti, 2021) or sustainable development (Megyesiova & Lieskovska, 2018).

Three variables were selected for grouping countries in terms of the average annual dynamics of change: a) energy efficiency, b) the share of renewables, and c) the share of imported energy.

For cluster analysis, sample representativeness and co-linearity are key issues. The lack of representativeness can lead to falsification of the cluster structure. To allow the generalisation of the results to the entire population, the sample must be drawn randomly. It must be assumed that the applied Eurostat data were representative. Collinearity, in turn, occurs when independent variables are highly correlated with one another. In such a case, the cluster arrangement may also be unrealistic, as collinear variables may have a greater impact on similarity (distance) measures. The selected variables were subjected to correlation analysis. There were no strong correlations between the variables used in the correlation analysis. The results are presented in Table 1.

Table 1. Correlation coefficients between variables used in cluster analysis

Variables	energetic efficiency	dependence on imports	renewable energy sources
energeti cefficiency	1,000000		
dependence on imports	0,0684	1,000000	
renewable energy sources	0,0111	0,2446	1,000000

Source: author's work based on Eurostat (2023, 2023a, 2023b).

The utilisation of Ward's method cluster analysis provided a solution to the query regarding the ideal number of country groups (Jung et al., 2003). Plotting the clustering distances against the clustering steps revealed a distinct spike occurring at approximately 10. Consequently, the dendrogram was truncated at this threshold, resulting in the formation of five clusters comprising countries (see Figure 2 and Figure 3). It is worth mentioning that Ward's method, employed for determining the optimal number of clusters, has also been adopted by other researchers (Liang et al., 2010; Jaslam et al., 2022).

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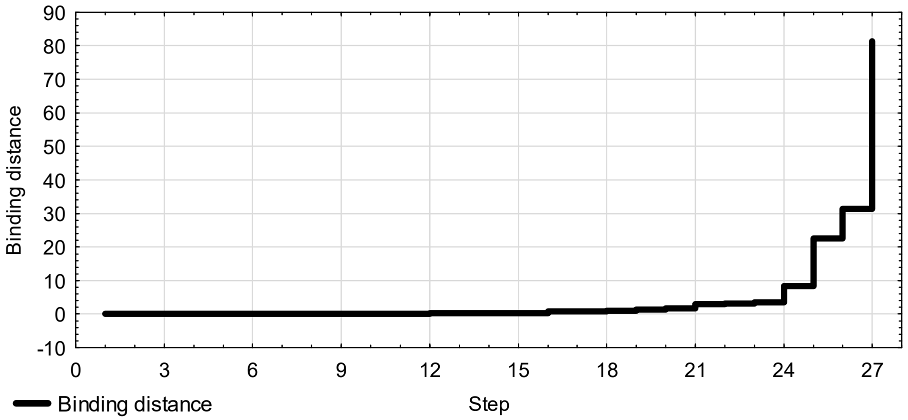

Figure 2. Results binding distance according to binding steps

Source: author's work based on Eurostat (2023, 2023a, 2023b).

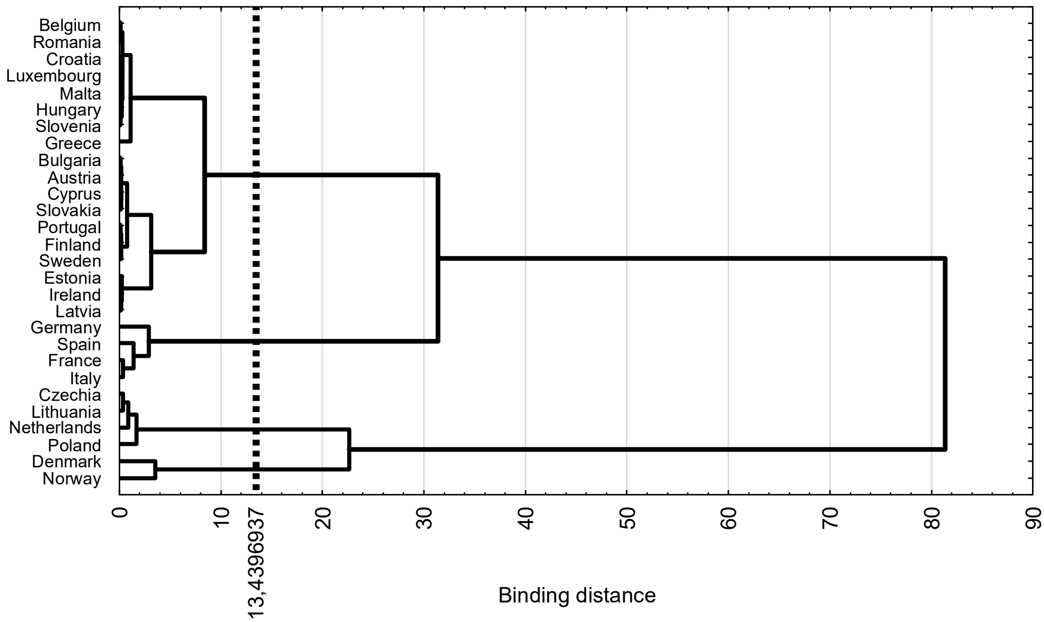

Figure 3. Results of the hierarchical grouping of similarities between the European countries in Energy transition in 2021 using Ward's method

Source: author's work based on Eurostat (2023, 2023a, 2023b).

Cluster analysis was then carried out with a k-means method. The number of clusters was determined from the distribution generated by Ward's method. The k-means method is widely used in data analysis in various domains. The advan-

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tage of the k-means method is the intuitiveness and simplicity of the basic computational idea. The object of analysis is a set of n objects (e.g., territorial units, countries) described by m characteristics (so-called diagnostic variables). The purpose of the analysis is to find the optimal division of the initial set of objects into k subsets, with the quality criterion for the division being the maximisation of the sum of the intergroup variance of the diagnostic variables (equivalently – the minimisation of the intragroup variance). In the k-means method, the distances between objects are computed using either the Euclidean distance or its squared counterpart (the algorithm's inherent nature ensures identical results in both cases).

The k-means algorithm comprises the following steps:

1. Begin with the initial division of a given set of objects into k subsets, typically created by assigning each element to the "closest" pre-selected representative of one of the k groups.
2. Calculate the centres of gravity for each group in the space of diagnostic variables.
3. Assign each element to the nearest centre of gravity, and then return to step 2 if at least one element has been reassigned to a different group. The k-means method's algorithm can be considered as a kind of "inverse" of variance analysis. It allows us to discover a partition of the studied population into k groups that maximises intergroup variance and, consequently, the F-statistic.

Results of the research

Between 2004 and 2021, primary energy consumption in EU-27 countries dropped by more than 12%, i.e. from 1,493.60 Mtoe (million tonnes of oil equivalent) to 1,309.01 Mtoe. In terms of energy consumption in Europe, among the countriesanalysed, Germany (in 2021 nearly 267 Mtoe) was the largest market, followed by France (224 Mtoe), Italy (145 Mtoe) and Spain and Poland (above 100 Mtoe in both cases). Malta (in 2021 – 0.8 Mtoe) and Cyprus (2.3 Mtoe) were positioned at the other end of the scale.

During the aforementioned period, there was a statistically significant increase in energy efficiency in most of the European countries under analysis. On an annual average, in EU-27, primary energy consumption decreased by 12.75 Mtoe. In Poland, in the period under review, there was a decrease in the energy efficiency of the entire economy; on average, primary energy consumption increased by 0.72 Mtoe per year. However, in six countries, no changes in energy efficiency were demonstrated, i.e., Bulgaria, Estonia, Latvia, Austria, Hungary, and Norway (Table 2).

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Table 2. Analysis of trends in energy efficiency of European countries in 2004-2021

Specification	Energy efficiency in Mtoe		Linear trend analysis results		
	2004	2021	B	R^2	p
EU-27	1493.6	1309.0	-12.75	0.813	0.0000
Belgium	52.4	48.8	-0.357	0.540	0.0005
Bulgaria	18.2	18.6	-0.063	0.138	0.1287
Czechia	43.1	39.6	-0.267	0.704	0.0000
Denmark	20.0	16.2	-0.273	0.844	0.0000
Germany	323.7	267.0	-3.156	0.816	0.0000
Estonia	5.2	4.5	-0.032	0.091	0.2231
Ireland	14.8	13.9	-0.079	0.271	0.0268
Greece	29.7	20.3	-0.676	0.919	0.0000
Spain	132.8	112.1	-1.393	0.653	0.0001
France	259.2	224.4	-2.151	0.767	0.0000
Croatia	8.9	8.3	-0.082	0.633	0.0000
Italy	177.7	145.3	-2.646	0.880	0.0000
Cyprus	2.4	2.3	-0.018	0.234	0.0417
Latvia	4.4	4.5	-0.008	0.083	0.2466
Lithuania	8.6	6.6	-0.139	0.531	0.0006
Luxembourg	4.7	4.2	-0.033	0.594	0.0002
Hungary	24.9	24.9	-0.090	0.180	0.0793
Malta	0.9	0.8	-0.012	0.565	0.0003
Netherlands	71.4	60.8	-0.621	0.804	0.0000
Austria	31.2	31.6	-0.043	0.791	0.2582
Poland	87.0	104.0	0.720	0.574	0.0003
Portugal	24.2	19.5	-0.235	0.641	0.0001
Romania	37.3	33.1	-0.367	0.561	0.0003
Slovenia	7.0	6.3	-0.062	0.653	0.0001
Slovakia	16.9	16.3	-0.090	0.406	0.0045
Finland	36.6	31.5	-0.294	0.666	0.0000
Sweden	50.5	43.8	-0.284	0.457	0.0021
Norway	26.4	25.0	-0.089	0.055	0.3651

Source: author's work based on data from Eurostat (2023).

Moving on to the economic implications of the research results. The overall decline in primary energy consumption in EU-27 countries suggests a positive trend. Lower energy consumption can lead to cost savings for both households and industries. Improved energy efficiency can contribute to reduced environmental impact. Poland experienced an increase in primary energy consumption, posing economic challenges. This may result in higher energy costs for industries and potentially impact the overall economic efficiency. Addressing this decline may be crucial for economic competitiveness and sustainability.

In 2021, the greatest share of renewable energy sources in total energy was observed in the Nordic countries, i.e., Norway, Sweden, Finland (from 43.1% to 74.1%), and Latvia (42.1%). It can be concluded that these countries have reached or are about to reach the target set in 2022 under the REPowerEU plan. In the year under analysis, the smallest share of the RES concerned the economies of countries such as Luxembourg, Malta, the Netherlands, Ireland, and Belgium; energy from renewable sources ranged from 11.7% to 13.0%.

Between 2004 and 2021, the share of renewables in total energy increased statistically significantly in all European countries under review. The highest growth speed was recorded in the Nordic countries, i.e. in Denmark, the average annual share in renewables increased by 1.31%, in Sweden by 1.22%, in Norway by 1.01%, and in Finland by 0.99%. The smallest average annual increase was reported in Slovenia (0.32 %) and Romania (0.47%) (Table 3).

Table 3. Renewable Energy Resources in final consumption Energy in European countries in 2004-2021

Specification	Share of RES in energy consumption in %		Linear trend analysis results		
	2004	2021	B	R^2	p
EU-27	9.6	21.8	0.66	0.967	0.0000
Denmark	14.80	34.70	1.31	0.87	0.0000
Sweden	38.40	62.60	1.22	0.97	0.0000
Estonia	18.40	38.00	1.06	0.91	0.0000
Norway	58.40	74.10	1.01	0.95	0.0000
Finland	29.20	43.10	0.99	0.96	0.0000
Greece	7.20	21.90	0.93	0.96	0.0000
Portugal	19.20	34.00	0.88	0.95	0.0000
Cyprus	3.10	18.40	0.84	0.93	0.0000
Italy	6.30	19.00	0.78	0.93	0.0000
Spain	8.30	20.70	0.73	0.96	0.0000
Latvia	32.80	42.10	0.73	0.84	0.0000

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Specification	Share of RES in energy consumption in %		Linear trend analysis results		
	2004	2021	B	R^2	p
Lithuania	17.20	28.20	0.72	0.94	0.0000
Malta	0.10	12.20	0.71	0.92	0.0000
Ireland	2.40	12.50	0.70	0.94	0.0000
Bulgaria	9.20	17.00	0.67	0.66	0.0007
Austria	22.60	36.40	0.67	0.86	0.0000
Germany	6.20	19.20	0.66	0.97	0.0000
Slovakia	6.40	17.40	0.63	0.89	0.0000
France	9.30	19.30	0.61	0.95	0.0000
Belgium	1.90	13.00	0.60	0.92	0.0000
Czechia	6.80	17.70	0.60	0.91	0.0000
Poland	6.90	15.60	0.57	0.93	0.0000
Luxembourg	0.90	11.70	0.56	0.84	0.0000
Netherlands	2.00	12.30	0.54	0.79	0.0000
Croatia	23.40	31.30	0.51	0.86	0.0000
Hungary	4.40	14.10	0.47	0.56	0.0004
Romania	16.80	23.60	0.47	0.75	0.0000
Slovenia	18.40	25.00	0.32	0.75	0.0000

Source: author's work based on data from Eurostat (2023a).

The Nordic countries, experiencing significant growth in renewable energy, demonstrate a commitment to sustainable and environmentally friendly practices. This can positively influence their economic standing, create jobs, and attract investments in the renewable energy sector. Countries with the smallest share of renewables, such as Luxembourg, Malta, the Netherlands, Ireland, and Belgium, may face challenges in achieving sustainability goals and might be dependent on traditional energy sources.

Moving on to the dependence on energy imports in European countries. In Europe, the vast majority of countries are net importers of energy. In 2021, Malta, Cyprus and Luxembourg were almost entirely import-dependent, with rates between 89.5% and 97.1%. The lowest energy dependency rates in 2021 were recorded by Estonia (1.4%), Iceland (15.2%), Sweden (21.2%), Romania (31.6%), and Denmark (32.6%). On the other hand, in 2021, Norway exported 6 times the country's consumption. It is worth noting that Denmark was net exporter of energy, between 1999 and 2012. As part of a plan to phase out fossil fuel extrac-

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tion by 2050, Denmark has brought an end to new oil and gas exploration in the Danish North Sea since 2013 (Nordic Statistics database, 2022).

In Belgium, Greece, Croatia, Hungary, Malta, Romania, and Norway, there have been no significant statistically observed changes in energy import dependency. The discussed indicator has decreased in Bulgaria, Estonia, Ireland, Spain, France, Italy, Cyprus, Luxembourg, Austria, Portugal, Slovakia, Finland, and Sweden. On the other hand, energy import dependency has increased in the Czech Republic, Denmark, Germany, Lithuania, the Netherlands, and Poland (Table 4).

Table 4. Analysis of trends regarding the dependence on energy imports in European countries from 2004-2021

Specification	The dependence on energy imports in %		Linear trend analysis results		
	2004	2021	B	R^2	p
EU-27	56.9	55.5	-0.009	0.001	0.9065
Belgium	79.8	70.8	-0.153	0.072	0.2813
Bulgaria	48.3	36.1	-0.830	0.618	0.0001
Czechia	25.3	40.0	0.91	0.786	0.0000
Denmark	-47.1	32.6	5.2	0.951	0.0000
Germany	61.2	63.5	0.285	0.634	0.0001
Estonia	30.1	1.41	-1.737	0.866	0.0000
Ireland	91.6	77.0	-1.416	0.632	0.0001
Greece	72.3	73.8	0.302	0.132	0.1387
Spain	77.7	69.1	-0.681	0.695	0.0000
France	50.9	44.2	-0.389	0.806	0.0000
Croatia	51.9	54.5	0.160	0.066	0.3048
Italy	84.4	73.5	-0.656	0.870	0.0000
Cyprus	95.5	89.5	-0.421	0.464	0.0018
Latvia	69.4	38.3	-1.606	0.792	0.0000
Lithuania	45.5	73.3	1.46	0.509	0.0009
Luxembourg	97.9	92.5	-0.268	0.724	0.0000
Hungary	61.0	54.1	-0.125	0.017	0.6091
Malta	99.8	97.1	-0.130	0.116	0.1662
Netherlands	32.1	58.4	1.88	0.551	0.0004
Austria	71.5	52.0	-0.701	0.476	0.0015
Poland	14.7	40.4	1.41	0.762	0.0000

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Specification	The dependence on energy imports in %		Linear trend analysis results		
	2004	2021	B	R^2	p
Portugal	83.9	66.9	-1.00	0.742	0.0000
Romania	30.0	31.6	-0.095	0.010	0.6907
Slovenia	51.4	48.6	-0.146	0.127	0.1469
Slovakia	68.2	52.6	-0.515	0.376	0.0068
Finland	54.7	38.0	-0.882	0.859	0.0000
Sweden	37.3	21.2	-0.769	0.718	0.0000
Norway	-702.5	-616.6	3.35	0.131	0.1402

Source: author's work based on data from Eurostat (2023b).

Countries achieving positive energy transition outcomes can serve as models for effective policies. Policymakers can leverage successful strategies to enhance energy efficiency, promote renewables, and reduce import dependency.

The clustering of countries according to the speed of energy transition in 2004-2021

The grouping of countries resulted in the emerging 4 clusters, consisting of two to eleven countries. The clusters were arranged according to similar speeds of change in the energy transition indicators analysed, starting with the cluster of countries displaying the greatest achievements. The following names were assigned to the respective clusters: walk (the slowest gait), trot, canter, and gallop (the fastest gait).

Cluster A, which was given the label "gallop", included Norway and Denmark. The specific nature of these countries determined their placement in one cluster. Among the analysed countries, Norway is the only country characterised by net energy exports. Denmark was a net exporter of energy between 2004 and 2012, but regulations introduced since 2013 resulted in the necessity to import energy. In 2021, about one-third of Denmark's energy used was imported. Along with Sweden and Estonia, these countries experienced the highest speed of growth in renewables. During the analysed seventeen-year period, in Denmark, the share of renewables in total energy consumption increased by nearly 20 pp (from 15% to 35%), and in Norway by nearly 16 pp (from 37% to 54%).

Cluster B, designated as "canter", included eleven countries (Bulgaria, Estonia, Ireland, Cyprus, Latvia, Luxembourg, Austria, Portugal, Slovakia, Finland, and Sweden). These countries revealed a relative stabilisation in the speed of the energy efficiency index changes, with a relatively highest reduction in energy imports. Dependence on energy imports in the analysed cluster in 2004 ranged from 30% in Estonia to 98% in Luxembourg, but it declined in 2021, ranging from just over 1% in Estonia to nearly 93% in Luxembourg. The cluster also

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showed a relatively high growth rate of energy from renewables. In 2004, renewables provided about 1% of energy in Luxembourg to 38% in Sweden, and seventeen years later, the RES share was from 12% in Luxembourg to 63% in Sweden. Interestingly, Cluster B included countries being on opposite sides of the rankings. Sweden, Finland, Estonia, Latvia, and Austria are the countries with a high percentage of energy from RES, low dependence on energy imports, and improved energy efficiency. In contrast, Cyprus, Ireland, Luxembourg, and Bulgaria are the countries with a low share of RES in energy consumption, thereby also with a relatively high share of energy import dependence, and also with the least favourable dynamics in the energy efficiency transition. In the period 2004-2021, a common feature of the countries in this cluster was an intensive trend in changing the existing state of energy transition to a more efficient one. These changes were accomplished by increasing the share of renewable energy sources in the energy mix and, thus, greater independence from energy imports.

In cluster C with the "trot" label, which included Germany, Spain, France and Italy, the highest speed of growth in energy efficiency with a relatively average tempo of import reduction and a relatively average speed of growth in the RES development were observed.

These are the countries with the highest gross final energy consumption in the EU, considering their size (area, population) (Sahin, 2021; Krikštolaitisa et al., 2022).

The last cluster, D, with the weakest energy transition performance, which was assigned the name "walk," included the Czech Republic, Lithuania, the Netherlands, Poland, Belgium, Greece, Croatia, Hungary, Malta, Romania and Slovenia. These countries had a low speed of growth in energy efficiency between 2004 and 2021, and Poland was the only one among all the analysed countries to show a drop in energy efficiency. Most of the countries grouped in cluster D reported an increase in dependence on energy imports. Only Belgium, Hungary, Malta, Romania, and Slovenia showed stabilisation in the tempo of change in reliance on energy imports. The increase in energy from renewables was the slowest among the emerged clusters, averaging 19% in 2021. Against this background, however, Lithuania and Croatia stood out, with a higher share of energy from renewables.

Discussion

The political discussion on energy transition in the European Union (EU) is a complex issue encompassing various aspects related to politics, economy, environment, and energy security (Mentes, 2023). One of the key aspects of this political debate is climate policy. EU member states engage in discussions about the need to increase climate ambitions, involving stricter goals for greenhouse gas emission reduction and promotion of more sustainable economic practices (Dominioni, 2022; Mišík & Oravcová, 2022). The discussion includes differences

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in strategies regarding energy transition among individual member states. Countries with different energy sources (e.g., Nordic countries with a dominance of renewable energy and Central European countries dependent on coal) seek to align with common goals. From our own research, it emerged that the pace of energy transition, even in countries with similar geopolitical positions, varies.

The analysis revealed four groups of countries with regard to the speed of change in selected energy transition indicators. One of the clusters was formed by the largest EU countries, i.e. Germany, Spain, Italy and France. Germany distinguished itself from these largest countries in achieving the highest speed of change (Malko, 2014). Several studies point to Germany's success in expanding photovoltaic technology. The right policies pursued by the authorities of this country are emphasised, i.e. long-term, stable, coordinated management of public funds directed to innovation in photovoltaic technology and a high level of cooperation between industry, universities and research institutes (Wen et al., 2021).

In the group with the worst performance in terms of the speed of change in the indicators responsible for the energy transition, some of the countries are located in Central and Eastern Europe and years ago used to be in the bloc of socialist countries. The energy sector of the Central and Eastern European (CEE) countries at the beginning of the 20th century had some common features, i.e. the highest energy consumption to produce a unit of GDP and the highest operating costs of the energy system among the EU countries. It is indicated that accession to the EU has led to an increase in energy efficiency in these countries (Marinas et al., 2018). However, some weaknesses in the energy policies of the CEE countries are revealed. In the mentioned countries, the need exists to increase the share of renewable energy in the energy mix. The study found (Marinas et al., 2018) that Lithuania, Hungary, and Slovakia (belonging in this analysis to a cluster with relatively fast changes) are the countries most vulnerable to a negative shock in the energy sector. Consequent implementation of RES solutions undoubtedly increases the chances for the CEE countries to achieve the EU energy policy goals. However, these countries will have to change the solutions that have been practised for years and are characteristic of a centrally planned economy – based on a single energy source (e.g. Poland – coal, Lithuania – nuclear energy) (Leal-Arcas et al., 2020; Piekut, 2021a). Countries in the area are also not as well prepared financially and technologically when compared to Western European countries. Nevertheless, due to the increasing "moralised" and monetised energy issues, energy transition is becoming fashionable in these countries (Hou, 2021).

The increasing awareness of consumers directing their energy choices toward renewable energy sources and the implementation by the governments of the energy and environmental policy obligations imposed by the European Commission are leading to an acceleration of energy transition in the countries of Central and Eastern Europe. It is pointed out (Marinas et al., 2018) that a sig-

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nificant role is played by the promotion of operating in harmony with nature, combined with the instrumental system supporting environmentally friendly solutions.

Malta and Ireland also ranked in the cluster with the slowest tempo of change. It is worth noting that island countries have their own peculiarities when it comes to energy. Islands tend to be immobilised in imports of expensive fossil fuels in isolated markets, which results in a low diversity of fuel mix and high carbon and other emissions relative to their economic growth (Ioannidis & Chalvatzis, 2017). In addition, their economies and lifestyles are often dependent on the tourism industry and connections with the continental countries. The islands cannot capitalise on the potential of renewable energy, especially solar and wind, due to poor grid infrastructure. Islands, due to their remote location, experience energy isolation and shortages (Kuang et al., 2016; Ioannidis & Chalvatzis, 2017). When an island is neither a producer nor a net exporter of fossil fuels, it is highly susceptible to energy shortage threats. The development of renewable energy sources directly affects energy independence, improving overall energy security and sustainability prospects. Locally generated renewable energy has the additional advantage of reducing their dependence on imports (Alves et al., 2019; Ioannidis & Chalvatzis, 2017).

Primary energy supply diversity in Malta and Cyprus has improved only slightly in the last decades. A major drop in Malta's diversity back in 1993 was caused by the abandonment of coal as an energy source, which left the country relying only on fuel oil (Ioannidis & Chalvatzis, 2017; Menegaki & Tsagarakis, 2015). Malta has the potential for renewable energy sources as it enjoys a high amount of sunshine with average daily radiation intensity.

Renewable energy sources can enhance energy security by reducing dependence on countries supplying energy resources. Renewable energy is widely considered more environmentally friendly than traditional sources because it generates fewer greenhouse gas emissions and other pollutants (Cergibozan, 2022; Rabbi et al., 2022). Political discussion on these matters mainly focuses on mitigating climate impact and improving air quality. Policymakers often emphasise the role of renewable energy sources in achieving sustainable development goals, especially in the context of reducing carbon dioxide emissions, promoting clean technologies, and protecting biodiversity.

In terms of the ranking of countries in terms of the share of renewable energy sources in energy consumption, the Nordic countries are at the top. These countries also have the fastest growth rate of RES in primary energy consumption. As Danish researchers have pointed out (Halsnæs et al., 2021), the Nordic energy system is currently dominated by renewables, primarily by hydropower, with the other part (about a third) coming from nuclear and fossil fuels. When compared to the rest of Europe, the Nordic countries possess renewable energy resources such as hydropower and bioenergy. Finland and Denmark are leading countries in the application of bioenergy. In terms of climate, geography and industry, Fin-

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land and Sweden have several features in common. Both countries have extensive and partially untapped biomass forest resources and a long history of forest management. Increased use of biomass for energy purposes is possible due to increased harvesting of wood from forests (Ranta et al., 2020). Nordic countries still have the potential to improve the management of existing resources. The planned increase in the share of renewable energy under the Paris Agreement will be particularly in wind power and, to a lesser extent, biomass, both of which are presumed to significantly increase the volatility of energy supply in Scandinavia, particularly in Sweden, as nuclear power is replaced (Halsnæs et al., 2021).

It is also worth mentioning that although energy security plans and strategies are clearly in line with the United Nations Sustainable Development Goals, the transition to affordable, cleaner, sustainable and secure energy sources involves some challenges. One of these challenges is ensuring the financial resources required to develop new energy technologies (Polzin et al., 2021). New energy technologies can be cost-effective in the long run, but their initial cost is usually significant (Liu & Feng, 2023). It has also been indicated that corporate (Knoefel et al., 2018) and national (Liu et al., 2021) governance can play a significant role as a catalyst or inhibitor for the effectiveness of environmental, macroeconomic or macro prudential policies in terms of energy transition.

The results of the presented research indicate countries' efforts to adhere to the principles set by the existing EU policy, albeit revealing varying levels of progress in achieving the established goals.

Conclusions

The conducted research has enabled the accomplishment of the research objective and answering the research questions. The research hypothesis, stating that the speed of energy transition varies across European countries, was positively verified, and on this basis, it is possible to identify groups of countries with similar progress in terms of changes in the energy market between 2004 and 2021. Four clusters of countries with varying degrees of energy transition were distinguished.

Changes implemented in European countries prove that the energy transition is in progress. However, this transition is proceeding with different dynamics. Undoubtedly, indicators with either a geographic or historical character play a role in a country's energy transition, but government policies also have a negligible impact. This is because different speeds of change in the distinguished energy transition indicators have been noted in countries with similar geographical (island countries) or historical (Eastern Bloc countries) conditions. Thus, for example, Cyprus achieved a higher speed of change than Malta and Ireland between 2004 and 2021, both in the improvement of energy efficiency and in the increasing of the share of renewables in energy consumption as well as in becom-

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ing independent on fuel imports. In contrast, Central and Eastern European countries such as Estonia, Latvia, Bulgaria, and Slovakia implemented the changes faster under the analysed energy transition indicators than the Czech Republic, Poland, Hungary, Romania, and Slovenia.

The Nordic countries have turned out to be the most intensive and the most successful in energy transition. In these countries, the development of the renewable energy market is resulting in increasing independence from fuel imports and, in Norway's case, even exports. The weakest results in terms of progress in the energy transition development were observed for the island countries, the Benelux and some of Central and Eastern Europe countries. These countries displayed a weaker performance on the analysed criteria as early as at the beginning of the research period.

Moving on to the practical implications of this research. The research provides valuable insights for policymakers and stakeholders in understanding the progress and variations in energy transition across European countries. It can inform policy-making decisions regarding energy efficiency improvements, renewable energy development, and reducing import dependency.

The social implications are as follows. The findings have social implications as the energy transition affects various aspects of society, including environmental sustainability, energy affordability, and energy security. The identified clusters can help identify best practices and policy approaches that can drive positive social impacts.

The main limitation of this analysis is that it is a dynamic study that requires regular updates with new statistical information. The political orientation of a country's leaders usually influences the country's evolution and engagement in sustainable development issues (particularly in Nordic countries) (Wu et al., 2023). Therefore, any change in government can alter the situation in the country and affect the pace of ongoing changes. All of this underscores the need for further adjustment of conclusions to the multifaceted situation.

In turn, the originality and value of this research are as follows. This research contributes to the understanding of energy transition dynamics in European countries, specifically focusing on energy efficiency, renewable energy utilisation, and import reliance. The clustering analysis provides a novel approach to grouping countries with similar rates of energy transition, offering insights into the diverse energy landscapes of European nations. The findings hold value for policymakers, researchers, and stakeholders interested in sustainable energy consumption and environmental protection.

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Marlena PIEKUT

TEMPO TRANSFORMACJI ENERGETYCZNEJ W KRAJACH EUROPEJSKICH W LATACH 2004-2021

STRESZCZENIE: Niniejsze badanie skupia się na kluczowym współczesnym zagadnieniu globalnej transformacji energetycznej, koncentrując się na krajach europejskich w latach 2004-2021. Jego celem jest zidentyfikowanie krajów o podobnych tempach przejścia energetycznego, wykorzystując statystyczne miary i techniki grupowania na danych z Eurostatu. Artykuł eksploruje trzy aspekty transformacji energetycznej: efektywność energetyczną, odnawialne źródła energii i zależność od importu energii. Wyniki wskazują na spadek zużycia energii pierwotnej w UE-27, zróżnicowane trendy efektywności energetycznej oraz istotne różnice w odnawialnych źródłach i zależności od importu. Grupowanie krajów ujawnia różne tempo transformacji. Decydenci polityczni mogą dostosowywać skuteczne strategie, uwzględniając regionalne wyzwania i sukcesy, sprzyjając wyważonemu zrozumieniu dynamicznych relacji ekonomicznych, społecznych i środowiskowych w procesie transformacji energetycznej. Analiza ta oferuje cenne spojrzenie na potrzeby podejmowania decyzji w kontekście skomplikowanego krajobrazu globalnej transformacji energetycznej.

SŁOWA KLUCZOWE: efektywność energetyczna, uzależnienie od importu energii, odnawialne źródła energii, transformacja energetyczna

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