Entrepreneurial Business and Economics Review

2024, Vol. 12, No. 4

10.15678/EBER.2024.120405

Access to sources of stable, sustainable, and modern energy as a goal of sustainable development in the European Union: Are the Scandinavian countries leading the energy transition?

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ABSTRACT

Objective: The objective of the article is to classify European Union (EU) member states according to similarity in the area of sustainable development goal 7 (SDG7) of the United Nations (UN) Agenda 2030 on affordable and clean energy.

Research Design & Methods: We conducted a hierarchy of EU countries using the linear ordering method due to the level of achievement of sustainable development goal 7 based on indexes available in the Eurostat database for the years 2015 and 2021. We preceded the selection of the method for ordering objects by applying several procedures (Hellwig method (HELLWIG); Technique for order of preference by similarity to ideal solution (TOPSIS); standardized value Sums method (SSW); zeroed unitarization method (IUCN) proposed in the literature. Next, we used a procedure to support the selection of the method based on the measure of inter-ranking comparisons. Moreover, we singled out high-performing countries and countries that require increased attention and support to facilitate the transition to a greener energy economy.

Findings: The article presents the ranking of countries by level of achievement of SDG 7 in 2021 and 2015 using the IUCN method. The hypotheses that proclaim the Scandinavian countries (Sweden and Denmark) as leaders in the implementation of SDG7 in the European Union and forming the cluster with the highest degree of SDG7 implementation were verified positively. The results obtained for each group of countries indicate strong development disparities among member countries in the area of clean and accessible energy in its various aspects.

Implications & Recommendations: The econometric optics proposed in the study and its results can help classify EU member states in terms of achieving SDG7 for researchers and policymakers. Scholars may supplement the proposed research approach with further measures of clean and accessible energy beyond the SDG7 monitoring indexes. Such indexes could include energy prices, which affect the scale of energy poverty, or the level of greenhouse gas emissions on which environmental well-being depends, among others.

Contribution & Value Added: The study narrowed the knowledge gap on the choice of the linear ordering method for objects, often used in socio-economic research. The use of an original research approach different from previous work for the new timeframe supports filling the research gap in empirical studies concerning the classification of European Union member states in terms of SDG7 implementation.

Article type:	research article
Keywords:	sustainable development; clean energy; accessible energy; SDG 7; EU countries; classification; typology; sustainable development goal; sustainable energy management
JEL codes:	O13, P18, Q42

Received: 30 January 2024 Revised: 10 June 2024 Accepted: 14 June 2024

Suggested citation:

Firlej, K.A., Firlej, Ch., & Luty, L. (2024). Access to sources of stable, sustainable, and modern energy as a goal of sustainable development in the European Union: Are the Scandinavian countries leading the energy transition?. *Entrepreneurial Business and Economics Review,* 12(4), 75-95. https://doi.org/10.15678/EBER.2024.120405

INTRODUCTION

The concept of sustainable development is a response to the destructive impact of human economic activity on environmental well-being. This concept has evolved over the years. Initially, it assumed the need to eliminate the negative impact of economic development on the environment. Today, scholars view it through the prism of a balance between respect for environmental well-being, social development, and economic growth. Graczyk (2017) indicates that in the context of sustainable development, sustainable energy development is of particular importance. It is the process of sustainable, safe, and efficient provision of energy for sustainable development. Patterson (2009) defines sustainable energy as energy consumption and production that meet the needs of parents without depriving children of the opportunity to meet their needs in the future. Lorek (2007) notes that the implementation of measures to support sustainable energy requires the implementation of sustainable energy policies, which we should aim at maintaining a balance between meeting social needs, energy security, economic competitiveness, and environmental protection.

The realisation of the concept of sustainable development in terms of economic practice is the document Agenda 2030 (*Transforming our world: The 2030 Agenda for Sustainable Development, 2015)* by the United Nations (UN). The document includes 17 major sustainable development goals, under which the UN identified a total of 169 tasks. It is a follow-up document (*Agenda 21*, 1992) covering the 21 millennium development goals presented by the UN at a conference in 1992 and enshrined in the UN Millennium Declaration in 2000 (Millennium Development Goals and Beyond, 2015). Scholars see sustainable development goals as an opportunity for global society due to the shift in focus in global politics and the possibility of putting the world on a sustainable growth path.

Among all the 17 sustainable development goals identified in the 2030 Agenda, the one that directly addresses the issue of energy management is Goal 7 aimed at ensuring access to affordable, reliable, sustainable and modern energy for all (*Transforming our world: the 2030 Agenda for Sustainable Development, 2015)*. Energy is a sector that can play an important role in mitigating climate change because of its potential to transform into clean energy (Muntean *et al.*, 2021). The first task identified under this goal is to increase the availability of clean and affordable energy (7.1). Energy availability is an important determinant of economic development (Marcillo-Delgado *et al.*, 2019), supports poverty alleviation and sustainable industrialisation and urbanisation (Chirambo, 2018), determines the satisfaction of human needs, and is essential in many areas, such as transportation, heating and cooling, electricity for equipment and production processes, for example (Chovancová & Vavrek, 2022). The second task is to increase the share of renewable energy sources in the global energy mix (7.2), whose role is particularly important in terms of creating sustainable development, reducing negative climate change by reducing carbon emissions, and strengthening energy security (Swain & Karimu, 2020). The third task assumes a doubling of the growth rate of global energy efficiency (7.3). Energy efficiency and renewable energy sources complement a sustainable energy economy (Salvarli & Salvarli, 2020). Increasing energy efficiency translates into lower energy requirements for renewable energy development and availability, reducing the burden of obtaining each (McCollum, 2017) and reducing the negative impact of energy on environmental well-being.

Another task (7.A.) includes the need to increase international cooperation for research on clean energy technologies, more advanced, and less environmentally damaging fossil fuel technologies, energy efficiency, and promoting the undertaking of investments in energy infrastructure and environmentally friendly energy technologies (*Transforming our world: the 2030 Agenda for Sustainable Development, 2015)*. Conducting research and development activities is important in terms of creating innovation in the energy sector (Bointner, 2014). Energy innovation is particularly important in the context of combating climate change and reducing greenhouse gas emissions (Mallett, 2015). The final task is to expand infrastructure and modernise technologies that enable access to modern and sustainable energy services (7.B.) (*Transforming our world: the 2030 Agenda for Sustainable Development, 2015)*. The premise of developing infrastructure and sustainable energy services in all countries is the result of the close connection between SDG7 and the Fourth Industrial Revolution (Muntean *et al.*, 2021).

The energy transition of European Union member states based on the concept of sustainable energy corresponds to the goals set under SDG7. Continuing to make progress in the area of clean and accessible energy, supporting decarbonisation and, thus, environmental well-being, will require the pursuit of a well-considered energy policy. Meeting the challenges facing the European Union in pursuing energy policy and building a sustainable energy economy requires simultaneous consideration of many areas, such as energy security, meeting social needs, the competitiveness of the economy, and concern for environmental well-being.

The European Union's energy policy is grappling with several energy challenges, including reducing dependence on fossil fuel imports, increasing energy efficiency, developing renewable energy sources, and decarbonising or integrating energy markets. Measures aimed at creating an integrated energy market and ensuring energy security and stability in the energy sector are at the core of the European Union's energy policy. As agreed in 2014 (with a review conducted in 2018), the energy goals for 2030 are to increase the percentage of renewable energy in total energy consumption to 32%, increase energy efficiency by 32.5%, and realise interconnections covering no less than 15% of the EU's electricity systems (Energy policy: General principles 2023). Noteworthy, the REPowerEU Plan (2022) indicates a desire to increase the share of renewables in global energy consumption to 45% in 2030. The energy package Fit for 55: Delivering the EU's 2030 Climate Target on the way to climate neutrality (2021) indicates the need to reduce net emissions by no less than 55% by 2030, compared to 1990 levels, and to make Europe the first climate-neutral continent by 2050. These targets are in the nature of commitments set out in the first European climate law, as well as providing opportunities in the areas of innovation, investment and jobs. The intensification of actions taken within the European Union's energy policy framework supports the implementation of the tasks set under SDG7.

Previous research on the progress of clean and accessible energy in the European Union in light of SDG7 is limited to one selected ordering method. The research problem is the question of which ordering method is optimal for classifying EU member states in terms of achieving SDG7. We made a hierarchy of EU countries using the linear ordering method due to the level of achievement of SDG Goal 7 based on indexes available in the Eurostat database for 2015 and 2021. The choice of the method of ordering objects was preceded by the application of several procedures (HELLWIG, TOPSSIS, SWW, IUCN) proposed in the literature, and then we used a procedure to assist in the choice of the method based on the measure of inter-ranking comparisons. Moreover, we singled out high-performing countries along with countries that require increased attention and support to facilitate the transition to a greener energy economy. The use of an original research approach different from previous work for the new timeframe supports filling the knowledge gap in the selection of a linear ordering method for objects, often used in socio-economic research. We aimed to classify the European Union member states according to their similarity in the area of sustainable development goal 7 of the UN 2030 Agenda on affordable and clean energy. The empirical data included in the study comes from the Eurostat database (2023) and covers the years 2015-2021. We chose this period because of the data availability for the SDG 7 implementation period to date.

The article is organised into several chapters. The next section will include a literature review and hypotheses development, which presents the state of knowledge to date on assessing the progress of SDG7 implementation in European Union member states. The next section will include research methodology, which will present the indexes and linear ordering methods used to assess the progress of SDG7 in European Union member countries. The next section will present results and discussion, including the rankings of European Union countries in terms of SDG7 implementation in 2015 and 2021, rankings of countries according to the value of selected indexes in 2021, and groups of similar countries in terms of SDG7 implementation levels. The last part of the work will present conclusions, the implications for economic practice, limitations, and potential future research directions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The development of affordable and clean energy is particularly important, because it also determines the achievement of selected goals in areas of the economy other than energy. The interactions between

SDG7 and the other sustainable development goals have been the subject of many studies, the results of which can be a valuable resource for researchers and those responsible for implementing these goals. Maduarai Elavarasan *et al.* (2021) postulate the view that one of the foundations for the implementation of the other SDGs is to shape sustainable development based on SDG7. Nillson *et al.* (2016) point to examples of how SDG7 interacts with selected SDGs. For example, increasing coal burning to improve energy access (SDG7), would have devastating impacts on environmental well-being by accelerating climate change and ocean acidification (SDG13, SDG14), as well as worsening community health (SDG3). In contrast, engaging agricultural land for bioenergy production (SDG7) could negatively impact food security (SDG2) and the end of poverty (SDG1), albeit reversible. In contrast, the supply of energy to homes positively affects education, but improving education does not directly determine energy, so it is a one-way interaction. Le Blanc (2015) indicates interactions between SDG7 and poverty (SDG1), inequality (SDG10) and responsible consumption and production (SDG12). He also notes the lack of consideration of the link between energy and economic infrastructure in the sustainable development goals.

The literature covers the classifications of European Union member states in the area of affordable and clean energy. The completed studies resulted in a division of EU economies into clusters or a classification according to the degree of implementation of SDG7. These studies were characterised by variation, for example, in terms of the econometric methods used, the selection of variables or the period considered. The results obtained in studies that have divided member countries into clusters vary in terms of the number of clusters, from dividing them into 4 clusters (Firoiu *et al.*, 2021), to distinguishing five clusters (Włodarczyk *et al.,* 2021), to distinguishing 11 clusters (Rybak *et al.,* 2021). Chovancová and Wawrek (2022) presented different research optics, where determining the best and worst countries allowed for comparison with other countries (Table 1).

Firoiu *et al.* (2021) analysed the dynamics of the implementation of the goals of the seventh sustainable development goal in the European Union member countries in 2015 and 2019. The empirical study resulted in five clusters covering the European Union countries in 2019. Within the first cluster (A_2019), they identified 10 countries. Among others, they were characterized by the highest average value of energy productivity in the EU and an average value of dependence on energy imports higher than the EU average. The second cluster (B_2019) included five countries. Among others, it was characterised by the lowest average value of energy productivity in the European Union and slightly higher than the EU average values of the share of renewable energy in total energy consumption and dependence on energy imports. In cluster three (C_2019), Firoiu *et al.* identified eight countries identified. This cluster was characterised, among others, by the lowest average value of dependence on energy imports and the highest average value of renewable energy in total energy consumption among the European Union countries. In contrast, the fourth cluster (D_2019) brought together 4 countries and was characterised, among others, by the highest average value of dependence on energy imports and the lowest share of renewable energy in total energy consumption. The study indicated an increase in the commitment of EU member countries to the seventh sustainable development goal and observed an increase in the number of top-performing countries from 4 in 2015 to eight in 2019.

Rybak *et al.* (2021) conducted a study on the progress in the integration of energy markets in the European Union member states. The analysis resulted in a division into 10 clusters in 2019. Bulgaria was classified in cluster 0, which had the lowest energy productivity level and the highest population unable to heat their homes due to poverty levels among EU member states. On the other hand, Cyprus and Estonia were assigned to separate clusters due to their exceptionally high levels of dependence on energy imports among EU countries. Ireland was placed in a separate cluster due to its highest level of energy productivity. Cluster eight included two of the 4 Visegrad Group countries, Poland and the Czech Republic, plus Slovenia and Romania. Characteristics of this cluster included similar levels of energy productivity and dependence on energy imports. On the other hand, Cluster 9 included countries with similar levels of dependence on energy imports. Cluster 10 brought together EU leaders in terms of, among others, the share of renewable energy in total energy consumption. In conclusion, the formation of the mentioned clusters was mainly due to the different energy mix of EU member states, energy productivity, dependence on energy imports, and the population being unable to heat their homes due to poverty levels. Rybak *et al.* (2021) observed the main differences between the countries of the 'old' and 'new' European Union.

Table 1. The overview of selected studies on the implementation of SDG7 in European Union member states

Firoiu *et al.* (2021)	
Research period	2015, 2019
Variables	primary energy consumption, final energy consumption, energy productivity, share of renewable energy in gross final energy consumption, energy import dependency, population unable to keep the home adequately warm by poverty status
Selected results	the year 2019: *Cluster A*: BE, DE, GR, HU, IE, IT, NL, PT, SK, ES; *Cluster B*: AT, HR, LV, PL, SI; *Cluster C*: BG, CZ, DK, EE, FI, FR, RO, SE; *Cluster D*: CY, LT, LU, MT
Research method	Hierarchical cluster analysis
Rybak *et al.* (2021)	
Research period	2000, 2019
Variables	primary energy consumption, primary energy consumption per capita, final energy consumption, final energy consumption per capita, final energy consumption in households per capita, energy productivity, share of renewable energy % 2005, energy import dependency, energy import dependency oil and petroleum, energy import dependency solid fossil fuels, energy import dependency natural gas, population unable to keep the home adequately warm by poverty status % 2005, greenhouse gas emissions intensity of energy consumption
Selected results	year 2019: *Cluster 0*: BG; Cluster *1:* CY; Cluster *2:* DK; Cluster *3:* EE; Cluster *4:* DE, FR; *Cluster 5*: IE; Cluster *6:* LU; Cluster *7:* MT, GR; Cluster *8:* PL, CZ, SI, RO; Cluster *9:* LT, LV, PT, ES, IT, BE, NL, HR, HU, AT, SK; Cluster *10*: SE, FI
Research method	Surface trend analysis, hierarchical cluster analysis
Włodarczyk *et al.* (2021)	
Research period	2019
Variables	energy productivity, the share of renewable energy in transportation, the share of renewable energy in electricity, the share of renewable energy in heating and cooling, energy import dependency, greenhouse gas emissions intensity of energy consumption
Selected results	year 2019: *Cluster A*: AT, DE, GR, IE, IT, PT, ES; *Cluster B*: BE, CY, LT, LU, MT; *Cluster C*: BG, HR, EE, RO, SI; Cluster *D*: CZ, FR, HU, NL, PL, SK; Cluster *E*: DK, FI, LV, SE.
Research method	Hierarchical cluster analysis
Chovancová and Wawrek (2022)	
Research period	2010-2017
Variables	primary energy consumption per capita, final energy consumption per capita, energy productivity, production of renewable energy, energy import dependency by products, population unable to keep the home adequately warm by poverty status, total greenhouse gas emissions including land-use change and forestry
Selected results	Classification: SE, AT, DK, FI, LV, HR, SI, EE, FR, RO, ES, CZ, DE, SK, PL, UK, HU, IE, IT, NL, PT, GR, LT, BE, MT, BG, CY, LU
Research method	The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

Note: AT: Austria, BE: Belgium, BG: Bulgaria, CY: Cyprus, CZ: Czechia, DE: Germany, DK: Denmark, EE: Estonia, ES: Spain, FI: Finland, FR: France, GR: Greece, HR: Croatia, HU: Hungary, IE: Ireland, IT: Italy, LT: Lithuania, LU: Luxembourg, LV: Latvia, MT: Malta, NL: Netherlands, PL: Poland, PT: Portugal, RO: Romania, SE: Sweden, SI: Slovenia, SK: Slovakia
Source: own study based on Firoiu *et al.*, 2021; Rybak *et al*., 2021; Włodarczyk *et al*., 2021; Chovancova & Wawrek, 2022.

In their study, Włodarczyk *et al.* (2021) investigated the relationship between sustainability and renewable energy sources in European Union member states. Based on the empirical analysis, they identified five clusters in 2019. Cluster 1 (A_2019) included 7 countries. The characteristic feature of this cluster was the highest average energy productivity relative to the other clusters, as well as above EU average results regarding, among others, average values of dependence on energy imports or the share of renewable energy in energy consumption. Another cluster (B_2019) included 5 countries, and the distinguishing feature of this cluster was the highest average value of dependence on energy imports. In contrast, the distinguishing feature of yet another cluster (C_2019) was, among others, the lowest average value of energy productivity compared to the other clusters. On the other hand, Cluster D_2019 included six countries and was the cluster with the lowest average share of renewable energy in heating and cooling relative to the other clusters. The last cluster E_2019, included 4 countries and its average value of renewable energy share in energy consumption in all areas (electricity, transportation, heating and cooling) was the highest relative to the other clusters.

The article by Chovancová and Wawrek (2022) assessed the progress of the seventh sustainable development goal in the European Union from 2010 to 2017. Based on a multi-criteria assessment, the highest-ranked European Union member country was Sweden, which was due to its results in the area of renewable energy production. Nevertheless, the results in terms of energy productivity were far from ideal, which indicated that even the top-ranked country in 2017 has some room for improvement. On the other hand, the lowest-ranked country was Luxembourg, which was due to, among others, a high percentage of energy consumption per capita or household, high dependence on energy imports, and total greenhouse gas emissions. Despite its last place, the country scored positively in terms of the percentage of the population that is unable to adequately heat their homes due to their poverty status. Concluding, none of the EU economies have fully succeeded in considering the indexes and the reasons for this are the variation in geographical or cultural conditions and the policy priorities of individual countries.

The compilation of the studies included in Table 1, shows variation in terms of the final set of criteria for classifying EU Member States in terms of the degree of SDG7 implementation. Nevertheless, some repetition is apparent in the selected SDG7 areas. All studies used indicators on energy productivity, renewable energy, and energy import dependency. However, Firoiu *et al.* (2021), Rybak *et al.* (2021), Włodarczyk *et al.* (2021), included the indicator population unable to keep home adequately warm by poverty status as a measure of energy poverty. The aforementioned indicators are characterised not only by their interaction but also by their complementarity in the ongoing energy transition.

Interpretations of energy productivity include the amount of economic product produced per unit of energy consumed. Improved energy productivity implies a reduction in energy consumption and is synonymous with reduced carbon dioxide production (Zhou *et al.*, 2024) which positively impacts environmental well-being (Aydin & Erdem, 2024). Improved energy productivity through reduced energy consumption implies relatively high economic output (Ding *et al.*, 2021). From an economic point of view, energy productivity is also equated with a measure of the savings that can be made through non-conventional energy sources (Huaman & Xiu Jun, 2014). Renewable energy sources are a remedy for depleting fossil fuel resources, which currently have a leading position in the global energy market (Østergaard *et al.*, 2022). Unfortunately, fossil fuels have a negative impact on the well-being of the environment, making it necessary to replace them with another energy source. In this situation, the most cost-effective alternative is the development of renewable energy sources (Olabi & Abdelkareem, 2022). Renewable energy sources play a special role in developing a sustainable energy economy by improving access to energy for society, reducing pollution, and supporting poverty reduction, and local socio-economic development activities (Algarni *et al.*, 2023). By reducing production costs, renewable energy sources can determine production growth and job creation and support improved energy security (Carfora *et al.*, 2022). Energy security is inextricably linked to the level of dependence on fossil fuel imports. In the context of the war in Ukraine, the independence of EU member states from imports of conventional energy sources from Russia is an absolute priority (Firlej & Stanuch, 2023). A solution to support the security of supply and meet energy demand can be the development of renewable energy sources (Firlej *et al.*, 2024). In the context of the implementation of SDG7, in addition to energy productivity, renewables, and dependence on fossil fuel imports, the issue of energy poverty, among others, is relevant. One indicator of fuel poverty is the population being unable to keep home adequately warm by poverty status. Improvements in this area can be reflected in a reduction in citizens' medical costs, a higher quality of life and an increased interest in becoming economically active among the population (Biernat-Jarka *et al.*, 2021). A search of the literature suggests a particularly high level of clean and accessible energy development in the Scandinavian countries that are members of the European Union. Sweden and Denmark were ranked first and third among European Union countries in the work of Chovancová and Wawrek (2022). In contrast, in two separate studies (Firoiu *et al.*, 2021; Włodarczyk *et al.*, 2021), Sweden and Denmark were in the same clusters, both of which had, among others, the highest average share of renewable energy sources in total energy consumption and the lowest average greenhouse gas emissions. In contrast, in the study by Rybak *et al.* (2021), Sweden formed a cluster alongside Finland within which SDG7 was considered achieved.

Moreover, global studies also confirm the high level of development of a sustainable energy economy in Sweden and Denmark. In the Energy Transition Index classification presented in the Fostering Effective Energy Transition (2023) report, Sweden and Denmark were ranked first and second, respectively. The compilation covered 120 countries worldwide. The final score consisted of results obtained in the areas of system performance (equitable, secure, sustainable) and transition readiness (regulatory framework and investment, enabling factors). Sweden and Denmark were also ranked in the top two positions also in the Energy Trilemma Index presented in the World Energy Trilemma Index (2022) report. The classification included 127 countries of the world and was based on performance in categories such as energy security, energy equity, and environmental sustainability. In the area of energy security, the highest ranking among EU countries went to Finland (the third place) and Sweden and Denmark were ranked fourth and 14th, respectively. On the other hand, within the energy equity category, Luxembourg was the winner and Denmark and Sweden were ranked 11th and 19th, respectively. In the area of environmental sustainability, Sweden, Denmark and Finland were the best, ranking first, second, and third respectively.

The research results on the development of a sustainable energy economy in Sweden and Denmark was characterised by a high level of similarity while indicating the leading positions of both countries both within the European Union and globally. These prior empirical results led us to hypothesise:

H1: The Scandinavian countries are among the clusters with the highest degree of SDG7 implementation in the European Union.

H2: The Scandinavian countries are leading the way in the implementation of SDG7 in the European Union.

RESEARCH METHODOLOGY

We aimed to classify European Union member countries according to their similarity in the area of sustainable development goal 7 of the UN 2030 Agenda on clean and affordable energy. We based the classification of European Union member countries in terms of achieving SDG7 on selected official indicators of this goal (Figure 1). We based the analysis of the progress of European Union member countries in terms of achieving Sustainable Development Goal 7 on affordable and clean energy on selected indicators (Figure 1). We obtained the statistical material used in the study from the Eurostat database (Eurostat, 2022). The time scope of the study covered the years 2015 and 2021. The statistical material used in the study came from the Eurostat database (Eurostat, 2022) and covered all 27 European Union member states. The time scope of the study covered the years 2015 and 2021. The study period coincided with the first (2015) year of Agenda 2030 and (2021) the year for which the latest data were available at the time of the econometric study. In the course of the analysis, we aimed to answer the question of which ordering method is optimal for classifying EU member states in terms of achieving SDG7.

The selection of diagnostic features was guided by statistical analysis in addition to content analysis, considering the appropriate level of feature variability (coefficient of variation of at least 0.10; quotient of extreme values of at least 2) (Figure 2). We also identified the features' nature. Thus, we included the following variables in the set of stimulants (*S*): X_1, X_2, X_3, X_4, X_5, we included the remaining variables in the set of destimulants (*D*). We assumed that each variable contributes the same portion of information to the evaluation of the studied objects. The weights of all variables were the same and equal to one. Changes in the adopted indexes from 2015 to 2021 were generally insignificant (Figure 2). During the analysed period, all indexes that were stimulants increased and all indexes that were destimulants (except X_9) decreased.

An important issue in the construction of a ranking due to the level of a complex phenomenon, which is what we are dealing with, is the choice of an ordering method. In particular, in ordering methods based on a synthetic variable, an important step is the normalisation of diagnostic characteristics and the method of construction of the synthetic variable. The study used a procedure to help choose one of several methods recommended in the literature, presented in Kukuła and Luty (2015). In the literature, we can find many proposals for these methods and discussions on the criteria for their selection. This issue was described by, among others Hellwig (1968), Hwang and Yoon (1981), Kukuła (2000), Ishizaka and Nemery (2013), Walesiak (2014), Izonin *et al.* (2022).

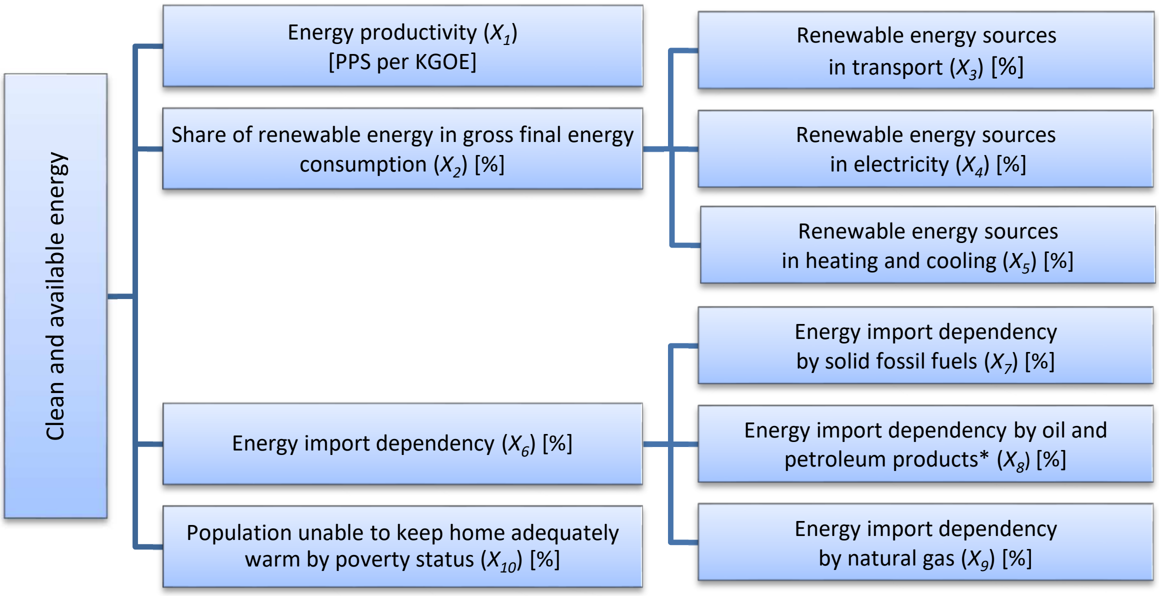
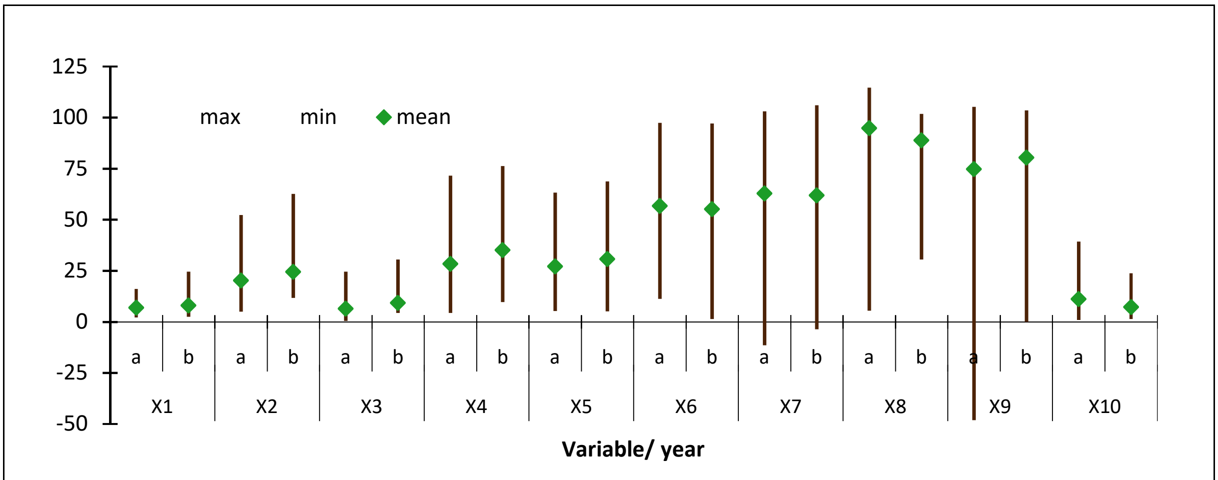


Figure 1. Selected indicators for the classification of European Union member states in terms of the achievement of SDG7

Note: KGOE – kilograms of oil equivalent; PPS: purchasing power standard; *: excluding biofuel.
Source: own elaboration.



Specification		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
a	SD	3.17	11.58	5.29	18.22	15.88	24.88	41.75	20.46	43.56	10.25
	CV	0.46	0.57	0.8	0.64	0.59	0.44	0.66	0.22	0.58	0.91
b	SD	4.4	12.03	5.08	18.33	16.53	22.07	40.48	15.83	28.33	6.72
	CV	0.55	0.49	0.54	0.52	0.54	0.40	0.65	0.18	0.35	0.91

Figure 2. Descriptive statistics for the variables in the years 2015 (a) and 2021 (b)

Note: Designations as in Table 1. SD: standard deviation, CV: coefficient of variation.
Source: own elaboration based on the results.

In the first stage of the study, we selected four linear ordering procedures (Table 3).

Table 3. Chosen linear ordering methods

Method	Synthetic variable	Normalisation	
		Stimulant	***Destimulant***
HELLWIG	$Q_i = 1 - \frac{d_i^+}{d_0}$	$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}$	$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}$
TOPSIS	$Q_i = \frac{d_i^-}{d_i^- + d_i^+}$	$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$	$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$
SSW	$Q_i = \frac{1}{m}\sum_{j=1}^{m} z_{ij}$	$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}$	$z_{ij} = \frac{\bar{x}_j - x_{ij}}{S_j}$
IUCN	$Q_i = \frac{1}{m}\sum_{j=1}^{m} z_{ij}$	$z_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}$	$z_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}$

Note: Q_i- the value of the synthetic measure for the object i $(i = 1,..,n)$; x_{ij}, x_{ij}, z_{ij} – actual and normalised values of the trait j (j=1,..,m) for the object i; $\bar{x}_j, \bar{x}_j, S_j$ - arithmetic mean,, standard deviation of the trait j; $\bar{d}, S_d$ – arithmetic mean, standard deviation d_i^+: $d_0 = \bar{d} + 2S_d$; $d_i^+ = \sqrt{\sum_{j=1}^{m}(z_{ij} - z_j^+)^2}$; $d_i^- = \sqrt{\sum_{j=1}^{m}(z_{ij} - z_j^-)^2}$; $z_j^+ = \begin{cases} \max_i z_{ij}, X_j \in S \\ \min_i z_{ij}, X_j \in D \end{cases}$; $z_j^- = \begin{cases} \min_i z_{ij}, X_j \in S \\ \max_i z_{ij}, X_j \in D \end{cases}$

TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution; SSW: Standardized Value Sums Method; IUCN: Zeroed Unitarization Method.

Source: own study.

In the second stage of the analysis, among the rankings made (thus the methods used), we used the one that was most similar to the others selected, *i.e.* the one for which $\bar{u}_p$ was the largest when:

$$\bar{u}_p = \frac{1}{v-1}\sum_{\substack{q=1 \\ p\neq q}}^{v} m_{pq}\ ,\ p, q = 1,2,\ldots, v \tag{1}$$

in which v – number of rankings; $m_{pq} m_{pq} = 1 - \frac{2\sum_{i=1}^{n}|c_{ip} - c_{iq}|}{n^2 - z}$ such that: c_{ip}, c_{iq}, – i object's position in the rankings of p and q respectively; $z = \begin{cases} 0,\ n \in P \\ 1,\ n \notin P \end{cases}$; P – the set of even natural numbers; $m_{pq,}\ m_{pq} \in [0,1]$.

The chosen method was the basis for the preparation and interpretation of the ranking of EU countries by the phenomenon under study in 2021 and 2015.

RESULTS AND DISCUSSION

Based on selected SDG 7 indexes (Figure 1), we prioritized. EU countries according to the value of synthetic measures using the four ordering procedures described in Table 3. The resulting ordering arrangements differ (Figure 3).

For each pair of the presented order systems, we estimated the values of the measure m_{pq} and $\bar{u}_p$ (Table 2).

In the problem under consideration, the ranking of countries obtained from the synthetic trait determined by the IUCN method was closest to all other determined rankings ($\bar{u}_p$ = 0.846) (Table 4).

Figure 4 shows the ranking of countries by level of achievement of SDG 7 in 2021 and 2015 using the IUCN method. The Spearman determined rank correlation coefficient was 0.941, indicating a strong positive correlation of ordinal systems. In 2015, Denmark, Sweden, and Romania were ranked highest and Belgium, Cyprus and Malta – lowest. In 2021, Denmark, Estonia, and Sweden had the highest ranks and Lithuania, Luxembourg, and Belgium – the lowest. In 2021, relative to 2015, 10 countries improved their position. These were Sweden, Slovenia, Latvia, Portugal, Ireland, Greece, Slovakia, Cyprus, Malta and Belgium. In contrast, the position of nine countries deteriorated over the same period. These were Romania, Croatia, Poland, the Czech Republic, Italy, Bulgaria, Spain, Luxembourg and Lithuania. In 2021, in relation to 2015, the position of eight countries has not changed. These were Denmark, Sweden, Austria, Finland, Germany, the Netherlands, Hungary, and France.

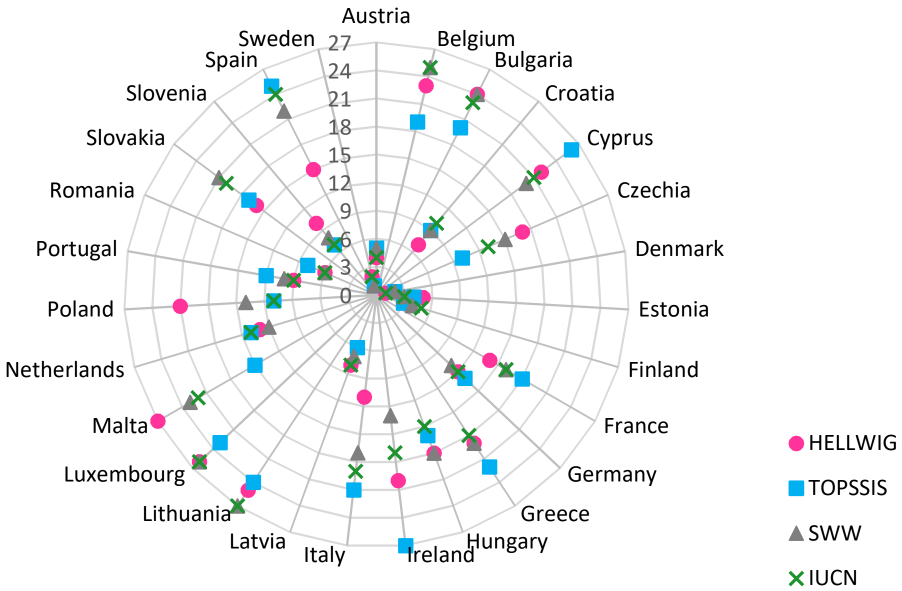


Figure 3. Ranks of European Union countries in terms of their level of SDG 7 achievement in 2021 according to the ordering methods shown in Table 2

Source: own elaboration based on results.

Table 4. Measure values m_{pq} and $\bar{u}_p$ determined according to formula (1)

Method	HELLWIG	TOPSSIS	SWW	IUCN	$\bar{u}_p$
HELLWIG	1.000	0.725	0.835	0.813	0.791
TOPSSIS	–	1.000	0.775	0.813	0.771
SWW	–	–	1.000	0.912	0.841
IUCN	–	–	–	1.000	0.846

Note: Designations as in Table 2

Source: own study based on the results.

In 2021, Ireland (24.45), Denmark (16.89) and Luxembourg (12.82) were the best performers on Index X_1 – energy productivity (PPS per KGOE) (Table 5). In contrast, Bulgaria (2.47), Malta (4.31) and Estonia (4.47) were the worst performers in the same year. In 2021, the average value of this index in the EU-27 was 8.01 (Figure 2). In 2021 relative to 2015, the value of index X_1 increased in 26 countries and decreased in one.

In 2021, under Index X_2 – the share of renewable energy in gross final energy consumption (%), the highest values belonged to Sweden (62.6%), Finland (43.1%), and Latvia (42.1%). In contrast, the lowest values occurred in countries such as Luxembourg (11.74%), Malta (12.15%), and the Netherlands (12.28%). In 2021, the average value of this index in the EU-27 countries was 24.49%. In 2021, relative to 2015, the value of index X_2 increased in 21 countries and decreased in six. In 2021, index X_3 – renewable energy sources in transport (%) had the highest value in Sweden (30.43%), Finland (20.51%), and Estonia (11.24%) and the lowest in Ireland (4.30%), Greece (4.31%), and Poland (5.67%). In 2021, the average value of this index in the EU-27 countries was 9.39%. In 2021, relative to 2015, the value of index X_3 increased in 23 countries and decreased in four. The analysis of the value of index X_4 – renewable energy sources in electricity (%) in 2021 in the EU-27 countries allowed us to identify the EU leaders in this area: Austria (76.19%), Sweden (75.70%), and Denmark (62.65%), as well as the last-ranked countries: Malta (9.66%), Hungary (13.66%) and Luxembourg (14.22%). In 2021, the average value of this index in the EU-27 countries was 35.19%. In 2021, relative to 2015, the value of index X_4 increased in 20 countries and decreased in seven. The analysis of the value of index X_5 – renewable energy sources in heating and cooling (%) in 2021 in the EU-27 countries makes it possible to identify the highest ranked: Sweden (68.64%), Estonia (61.32%), Latvia (57.38%) and those countries with the lowest values, *i.e.* Ireland (5.17%), the Netherlands (7.72%), Belgium (9.24%). In 2021, the average value of this index in the EU-27 countries was 30.74%. In 2021, relative to 2015, the value of index X_5 increased in 18 countries and decreased in nine.

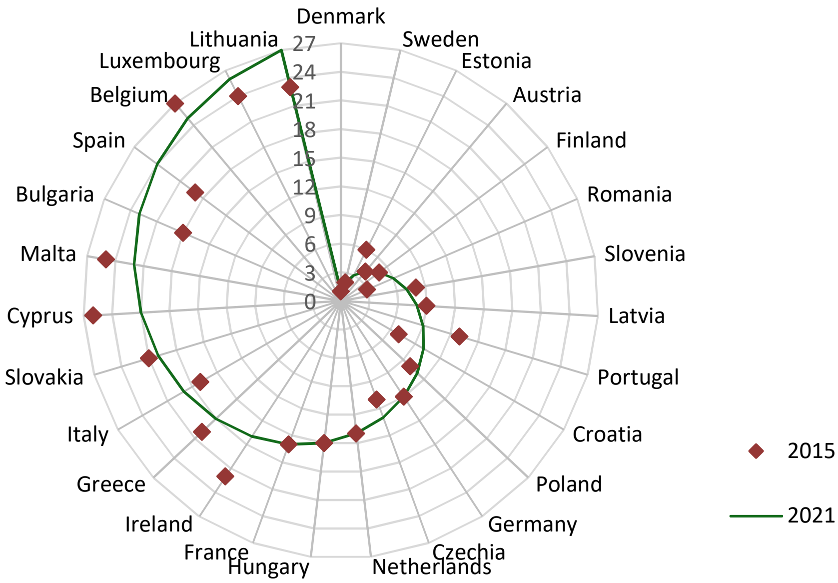


Figure 4. Rankings of European Union countries in terms of the level of achievement of SDG 7 in 2021 and 2015 by IUCN methods

Source: own elaboration based on the results. Method designations as of Table 3.

Table 5. Country rankings by value of selected indexes in 2021

Variable	Ranking*
X_1	IE, DK, LU, IT, DE, AT, SE, FR, ES, CY, NL, PT, GR, SI, BE, HR, FI, RO, LT, LV, SK, HU, PL, CZ, EE, MT, BG
X_2	SE, FI, LV, EE, AT, DK, PT, HR, LT, SI, RO, GR, ES, FR, DE, IT, CY, CZ, SK, BG, PL, HU, BE, IE, NL, MT, LU
X_3	SE, FI, EE, SI, MT, DK, BE, IT, AT, ES, NL, SK, PT, FR, DE, LU, RO, BG, CZ, CY, HR, LT, LV, HU, PL, GR, IE
X_4	AT, SE, DK, PT, HR, LV, ES, DE, RO, FI, IE, IT, GR, SI, NL, EE, BE, FR, SK, LT, BG, PL, CY, CZ, LU, HU, MT
X_5	SE, EE, LE, FI, LT, PT, DK, CY, HR, AT, SI, MT, GR, BG, RO, FR, CZ, PL, IT, SK, HU, ES, DE, LU, BE, NL, IE
X_6	MT, LU, CY, IE, GR, IT, LT, BE, ES, PT, DE, NL, HR, HU, SK, AT, SI, FR, PL, CZ, LV, FI, BG, DK, RO, SE, EE
X_7	IE, ES, HR, AT, NL, CY, LU, IT, EE, SE, LV, BE, LT, SK, FR, FI, DE, HU, RO, CZ, DK, SI, BG, GR, PT, MT, PL
X_8	LT, LU, SI, CY, SK, IE, PT, MT, DE, FR, BG, CZ, PL, BE, ES, FI, LV, GR, AT, HU, NL, IT, HR, SE, RO, EE, DK
X_9	MT, LT, ES, PT, EE, LU, SE, LV, BE, FI, SI, GR, BG, FR, IT, CZ, DE, PL, HR, IE, SK, HU, AT, NL, DK, RO, CY
X_{10}	BG, LT, CY, GR, PT, ES, RO, IT, MT, FR, SK, HR, HU, LV, BE, DE, IE, PL, DK, LU, NL, CZ, EE, AT, SI, SE, FI

Note: Designations as in Table 1. *: by value in descending order. AT: Austria, BE: Belgium, BG: Bulgaria, CY: Cyprus, CZ: Czechia, DE: Germany, DK: Denmark, EE: Estonia, ES: Spain, FI: Finland, FR: France, GR: Greece, HR: Croatia, HU: Hungary, IE: Ireland, IT: Italy, LT: Lithuania, LU: Luxembourg, LV: Latvia, MT: Malta, NL: Netherlands, PL: Poland, PT: Portugal, RO: Romania, SE: Sweden, SI: Slovenia, SK: Slovakia.
Source: own study based on the results.

In 2021, index X_6 – energy import dependency (%) obtained the highest values in countries such as Malta (97.06%), Luxembourg (92.47%), Cyprus (89.52%) and the lowest values belonged to Estonia

(1.41%), Sweden (21.22%), Romania (31.65%). In 2021, the average value of this index in the EU-27 countries was 55.24%. In 2021, relative to 2015, the value of index X_6 increased in nine countries and decreased in 18. In 2021, index X_7 – energy import dependency by solid fossil fuels (%) obtained the highest values in countries such as Ireland (105.92%), Spain (105.66%), Croatia (100.71%) and Austria (100.19%). In contrast, we observed the lowest values in Poland (-3.61%), Portugal (4.54%), and Greece (9.6%). In 2021, the average value of this index in the EU-27 countries was 61.96%. In 2021, relative to 2015 overall (excluding Malta – no data available), the value of the X_7 index increased in 14 countries and decreased in 12. In 2021, index X_8 – energy import dependency by oil and petroleum products (excluding biofuel) (%) obtained the highest values in such countries as Lithuania (101.70%), Luxembourg (99.85%), Slovenia (99.55%). In contrast, we observed the lowest values in Denmark (30.56%), Estonia (54.91%), and Romania (68.18%). In 2021, the average value of this index in the EU-27 countries was 88.92%. In 2021, relative to 2015 overall, the value of the X_8 index increased in five countries and decreased in 22. In 2021, index X_9 – energy import dependency by natural gas (%) obtained the highest values in such countries as Malta (103.48%), Lithuania (100.82%), Spain (100.07%). In contrast, we observed the lowest values in Romania (22.80%), Denmark (27.76%) and the Netherlands (33.62%). In 2021, the average value of this index in the EU-27 countries was 80.42%. In 2021, relative to 2015 overall, the value of index X_9 increased in 12 countries, decreased in 11 and remained unchanged in four.

In 2021, index X_{10} – population unable to keep the home adequately warm by poverty status (%) obtained the highest values in countries such as Bulgaria (23.7%), Lithuania (22.5%), and Cyprus (19.4%). In contrast, we observed the lowest values in Finland (1.3%), Sweden (1.7%), and Slovenia (1.7%). In 2021, the average value of this index in the EU-27 countries was 7.37% (Table 2). In 2021 relative to 2015 overall, the value of the X_{10} index increased in 4 countries, decreased in 21, and remained unchanged in two.

Furthermore, countries were divided by their level of achievement of SDG 7 (Table 6) according to the synthetic measure determined using the IUCN method in 2021 into four groups with levels:

– very high (group I): $Q_i \in \left(\max_i Q_i - 0{,}25R\,;\max_i Q_i\right]$;
– high (group II): $Q_i \in \left(\max_i Q_i - 0{,}5R\,;\max_i Q_i - 0{,}25R\right]$;
– medium (group III): $Q_i \in \left(\max_i Q_i - 0{,}75R\,;\max_i Q_i - 0{,}5R\right]$;
– low (group IV): $Q_i \in \left[\min_i Q_i\,;\max_i Q_i - 0{,}75R\right]$;

in which $R = \max_i Q_i - \min_i Q_i$.

Table 6. Groups of countries similar in terms of the level of implementation of SDG 7 in 2021

Group	**Country**
Group I	Denmark, Sweden
Group II	Estonia, Austria, Finland, Romania
Group III	Slovenia, Latvia, Portugal, Croatia, Poland, Germany, Czechia, Netherlands
Group IV	Hungary, France, Ireland, Greece, Italy, Slovakia, Cyprus, Malta, Bulgaria, Spain, Belgium, Luxembourg, Lithuania

Source: own study based on the results.

We determined basic numerical characteristics for diagnostic variables in groups of countries similar in terms of SDG 7, as shown in Table 7.

The first group (Table 6) consisted of only two countries. In 2021, the average value of the energy productivity index (PPS per KGOE) significantly exceeded the EU-27 average and more than doubled the average result of countries in the second group. The percentage of renewable energy in gross final energy consumption significantly exceeded the EU average. It was almost double the results obtained by countries classified in the third group, and almost three times for the results of countries assigned to the fourth group. Considering the structure of renewable energy source distribution, we draw special attention to the high average levels of renewable energy sources in electricity (%) and renewable energy sources in heating and cooling (%). On the other hand, the average values of the energy import dependency index (%) were more than twice as good as the EU average, which was mainly due to very good results in the energy import dependency by oil and petroleum products (excluding biofuel) indexes (%) and energy import dependency by natural gas (%). In the case of the energy import dependency by solid fossil fuels index (%), good results were also obtained, which, however, were not at such a good level as those of the EU leaders in this area (from the third group of countries). The largest disparity among the analysed groups was in the percentage of the population unable to adequately heat their homes due to poverty. The average value of this index in the first group of countries was three times lower than the EU-27 average, twice as low as the average for the third group of countries, and as much as four times lower than the average for the fourth group of countries (Table 7).

Table 7. Selected characteristics of indexes in groups in 2021

Specification	Statistics	Group I	Group II	Group III	Group IV
X_1	min	9.32	4.47	4.51	2.47
	max	16.89	9.69	9.99	24.45
	mean	13.11	6.40	6.78	8.47
X_2	min	34.72	23.60	12.28	11.74
	max	62.57	43.10	42.11	28.23
	mean	48.65	35.29	24.64	17.36
X_3	min	10.55	7.67	5.67	4.30
	max	30.43	20.51	10.64	10.58
	mean	20.49	12.19	7.85	7.77
X_4	min	62.65	29.34	14.54	9.66
	max	75.70	76.19	58.43	45.96
	mean	69.18	46.89	38.01	24.63
X_5	min	41.53	24.48	7.72	5.17
	max	68.64	61.32	57.38	48.63
	mean	55.09	43.47	30.21	23.40
X_6	min	21.22	1.41	38.33	36.14
	max	32.56	51.96	66.93	97.06
	mean	26.89	30.76	51.39	69.50
X_7	min	12.69	23.21	-3.61	0.00
	max	94.20	100.19	100.71	105.92
	mean	53.45	72.74	45.97	69.78
X_8	min	30.56	54.91	78.39	84.33
	max	71.57	95.50	99.55	101.70
	mean	51.06	77.14	93.22	95.72
X_9	min	27.76	22.80	33.62	0.00
	max	100.00	100.00	100.05	103.48
	mean	63.88	68.36	84.11	84.40
X_{10}	min	1.70	1.30	1.70	2.50
	max	2.80	10.10	16.40	23.70
	mean	2.25	3.78	4.98	10.74

Note: Designations as in Table 1 and Table 4.
Source: own study based on the results.

The second group included 4 countries. In 2021, the average value of the energy productivity index (PPS per KGOE) was significantly behind the average of the EU-27 countries and the lowest in relation to all other groups. In 2021, the average of the following indexes: share of renewable energy in gross final energy consumption (%); renewable energy sources in transport (%); renewable energy sources in electricity (%) and renewable energy sources in heating and cooling (%) in each case achieved the second best results in relation to the other groups. Thus, we may call this group a runner-up in the area of renewable energy consumption. In 2021, despite the weakest average performance of the index energy import dependency by solid fossil fuels, the countries of the second group achieved the second-best position among all groups in terms of average energy import dependency (%), to which the good performance of the indexes energy import dependency by oil and petroleum products (excluding biofuel) (%) and energy import dependency by natural gas (%) contributed significantly. In 2021, the average value of the index population unable to keep the home adequately warm by poverty status (%) indicated the good position of the analysed group in this area. This result was almost twice as good as the EU-27 average and nearly three times as good as the average of the fourth group countries.

The third group included eight countries. In 2021, the average value of the energy productivity index (PPS per KGOE) for this group was not much behind the average value of countries classified in the second group. In comparison with Groups 1 and 2, we recorded significantly weaker results for the average value of the following indexes: share of renewable energy in gross final energy consumption (%); renewable energy sources in transportation (%); renewable energy sources in electricity (%); energy import dependency (%). Moreover, in the case of the renewable energy sources in the transport index (%), the result was slightly better than that of the fourth group, which is the weakest in this area. An interesting situation occurred in the case of the energy import dependency index (%), the average value of which is the closest to the EU-27 average considering all the separate groups. Attention is drawn to the average value of the energy import dependency by solid fossil fuels index (%), which is the best when compared with the other groups. The situation is different in the case of the average value of the energy import dependency by natural gas index (%), which indicates a similarly weak position of the analysed group as is the case with the fourth group. On the other hand, the average value of the population unable to keep the home adequately warm by poverty status index (%) indicates a relatively not too bad position of the analysed group of countries. This result was significantly better than the EU-27 average and more than twice as good as the result obtained by the fourth group of countries.

The fourth group, comprising 13 countries, was the largest in terms of size. In 2021, the average value of the energy productivity index (PPS per KGOE) was close to the EU-27 average and was second only to the result obtained by the first group of countries. When compared with the other groups, the average values of the following indexes: share of renewable energy in gross final energy consumption (%); renewable energy sources in transport (%); renewable energy sources in electricity (%); energy import dependency (%) indicate the weakest position of the analysed group in these areas. Among the aforementioned indexes, only the renewable energy sources in the eating and cooling index (%) was higher than the EU-27 average. In the area of energy import dependency, the weakest results compared to other groups were achieved in the average value of indexes: energy import dependency (%); energy import dependency by oil and petroleum products (excluding biofuel) (%); energy import dependency by natural gas (%). The situation was not much better in the case of the index energy import dependency by solid fossil fuels, where the result obtained was better than in the case of the second group. Moreover, the average values of all indexes of energy import dependency fared worse than the results of the EU-27 average. The average value of the population unable to keep the home adequately warm by poverty status index (%) positions the analysed group in last place among all analysed groups. The result obtained was as much as four times weaker than the result of the first group and significantly weaker than the average of the EU-27 countries.

In our 2021 study, Denmark and Sweden comprised the group with the highest level of SDG 7 achievement. Our work confirmed their similarity in terms of the characteristics of the studied indicators (Firoiu *et al.,* 2021), in which both in 2015 and 2019, these countries were assigned to the same group, which was characterised in comparison with others by, among others, the highest average value of the share of energy from renewable sources, the lowest average value of energy import dependency (%). The group was also characterised by the lowest average level of greenhouse gas intensity, which we can associate with a broad focus on a clean energy economy. The same group also included Bulgaria, the Czech Republic, Estonia, Finland, France, and Romania, among others, which were assigned to separate country groups in our work. In a similar study, Włodarczyk *et al.* (2021) also assigned Denmark and Sweden in 2019 to the same group (which also included Finland and Latvia), indicating the highest average value of indexes in this group (relative to the other groups) for renewable energy sources in transportation (%); renewable energy sources in electricity (%) and renewable energy sources in heating and cooling (%), and the lowest average level of greenhouse gas intensity. On the other hand, in their study, Rybak *et al.* (2021) classified Denmark in 2019 as a separate site, arguing for the considerable variation in the countries studied in terms of the level of SDG7 achievement. They indicated the characteristics of the Danish economy's import dependency – low for oil, high for coal and below 0 for natural gas. In the same study, Sweden and Finland were placed in the same group. In another study (Chovancová & Wawrek, 2021), Sweden and Denmark ranked first and third, respectively, in a classification covering the average position of the EU-27 countries from 2010 to 2017 in terms of the level of multicriteria assessment covering a range of indexes for clean and accessible energy.

Despite the limited possibility of comparing the results of our study with those of other works due to differences in the choice of indexes, the period of the study or the econometric method, we may note numerous similarities. Denmark and Sweden were among the countries with a high average value of many indexes describing the development of clean and accessible energy. The results obtained in our study allowed for a positive verification of the research hypotheses proclaiming that the Scandinavian countries (Sweden and Denmark) were leaders in the area of progress towards clean and accessible energy in the European Union, as well as formed a cluster with the highest degree of implementation of the SDG7.

Denmark is an example of a country that has successfully implemented an energy transition toward clean and accessible energy for several decades. Changes in Denmark's implemented energy policy were largely determined by the oil crisis outbreak in the 1970s. In connection with the energy-inefficient and environmentally destructive structure of the energy sources, corrective measures were taken to reduce primary energy consumption, diversify the structure of its sources, and increase the efficiency of the energy sector. Denmark had already become energy-independent by the end of the twentieth century as a result of the exploitation of deposits of fossil fuel resources. Beginning in the last decade of the twentieth century, the development of renewable energy sources strongly supports Denmark's energy security. The country's energy policy transformation based on clean energy technologies allowed for the implementation of the concept of sustainable and balanced development (Frączek, 2015).

In Denmark, in 2021, the share of renewables in total energy consumption was 34.7% (compared to 30.5% in 2015), which was much better than the EU-27 average of 24.5%. In the same year, high participation of renewable energy in total energy consumption was recorded in the electricity (62.7%) and heating and heat (41.5%) sectors, while the transport sector was 10.5%. A comparison of the results with the EU-27 average, which was 35.2%; 30.7%, and 9.39%, respectively, within the indicated sectors (Table 1), shows significantly better results for Denmark (Eurostat, 2023). The high and, at the same time, one of the largest shares of renewable energy sources in total electricity consumption in the world was due, among others, to public support for the use of such sources. An important part of Denmark's energy policy was not only an emphasis on the development of renewable energy sources, but also high efficiency in the consumption of energy carriers (Frączek, 2015). The concern for energy efficiency is reflected in Denmark's National Energy and Climate Plan 2021-2030, which includes a number of measures aimed at supporting it both in private homes and businesses, as well as in public buildings. For example, Danish citizens can get funding to renovate their homes and switch to green heating. Meanwhile, business owners can count on support for measures aimed at energy savings. Municipalities and regions can take advantage of subsidies to improve energy efficiency and digitisation in buildings (European Commission, 2023).

Renewable energy development in Denmark is largely based on wind energy, which accounts for 26.2% of energy consumed in the total economy (Energy Institute Statistical Review of World Energy, 2023). The ability to develop wind energy at this scale is due to Denmark's geographic location with access to the North Sea, which is characterised by large shallow areas, high wind speeds, and low wind variability. These factors significantly support the development of wind energy, whose offshore capacity is one of the highest in the world (Energy Market Information Centre, 2023). The future of Danish wind energy is based on a political agreement on offshore wind farms, with a planned capacity of 9 GW with the possibility of reaching as much as 14 GW if offshore wind farmers decide to exercise the option in the agreement to build as much capacity as possible on land. Another major project is the planned construction of an energy island in the North Sea, with a minimum capacity of 3 GW in 2023 and 10 GW in 2040 (Directorate-General for Energy, 2023).

As a result of the energy crisis of the 1970s, Sweden has taken steps to move away from traditional fossil fuels and increase energy efficiency and energy independence. The potential for energy savings became a particularly important aspect of national policy (Legnér *et al.*, 2020). The implementation of clean energy technology solutions supported the Swedish public's understanding of the need to reduce the exploitation of natural resources in favour of more sustainable and harmonious development while maintaining the existing standard of living. The public sector supported this idea as exemplified by the preparation by municipalities of a sustainable economic system that was understandable to residents and had to be reflected in provincial and state-wide plans (Neterowicz, 2020). Sweden's energy transition is an excellent example of the focus of energy policy on sustainable, low-carbon energy systems, both at the national level through the construction of large-scale wind farms, hydropower and biomass, and at the community and household level through district heating plants and smart grids (Ring *et al.*, 2022). The implementation of smart grids was a milestone for building a clean energy economy, as it enabled Swedish households to take on the role of prosumers (Huang *et al.*, 2019).

In Sweden, in 2021, the participation of renewable energy sources in total energy consumption accounted for 62.57% (compared to 52.2% in 2015), consolidating its leadership in the European Union in this area with a significant advantage over second-ranked Finland (43.1%) and third-ranked Latvia (42.1%), as well as being more than double the EU-27 average. In the same year, Sweden's consumption of renewable energy sources was very high regardless of the area of consumption, with 75.7% in the electricity sector, 68.6% in heating and heating, and 30.4% in transportation. In each of the indicated sectors, Sweden achieved the best results in the European Union, which were much higher than the EU-27 average, which within the mentioned areas was respectively: 37.5%; 22.9%, and 9.1% (Eurostat, 2023). Sweden aims to increase the share of renewable energy sources in total consumption to 75% in 2030. The largest share of renewable energy consumption in Sweden is biofuels (53%), which are mainly used in industry and heating, although the highest growth rate in recent years has been observed in transportation (Draft updated NECP for Sweden, 2023). The structure of energy supply sources in Sweden supports a high level of energy productivity, as well as one of the lowest EU-27 energy import dependency by oil and petroleum products (excluding biofuel) and the lowest percentage of population unable to keep the home adequately warm by poverty status among EU economies.

On the one hand, Sweden's economic policy significantly supports the development of wind and biomass energy with subsidies, and on the other hand, imposes high taxes on nuclear and fossil fuels (Coal industry across Europe, 2017). The development of biomass energy would not have been possible without large-scale research and development projects, the creation of markets due to taxing fossil fuels, and the creation of district heating systems with wide coverage (Ydersbond, 2014). Sweden has the world's most developed energy mix and is the only country that has developed nuclear and renewable energy in parallel while reducing the share of fossil energy. Energy clusters formed by local communities play an important role in the Swedish energy system. Electricity generated in the clusters provides a source of supply for priority energy supply points (*e.g.* hospitals) when this energy is unavailable for some reason. Energy clusters generate not only electricity, but also heat and cooling, (Neterowicz, 2020). Another important link supporting the popularisation of renewable energy in Sweden is the natural conditions, which support, among others, the development of hydropower due to the presence of a large number of rapid rivers (Latoszek & Wojtowicz, 2020).

CONCLUSIONS

This article classifies the European Union member states in the area of achieving SDG7. The research focused on selected monitoring indicators for this objective, which included energy productivity, share of renewable energy in gross final energy consumption, energy import dependency, and population unable to keep the home adequately warm because of poverty status. We placed particular emphasis on measuring the area of share of renewable energy in gross final energy consumption, within which the structure of consumption in transportation, electricity, heating, and cooling was isolated. We placed more focus on measuring the area of energy import dependency, considering its structure, including solid fossil fuels, oil and petroleum products, and natural gas. Using an econometric apparatus including selected linear ordering methods, we ranked the European Union member countries in terms of the level of achievement of SDG7 in 2021, followed by a division into groups of similar countries in terms of the level of achievement of this goal. The classification of EU Member States in this area varies and we can notice large differences between the established groups. In comparison with the existing literature, our study displays originality in several respects. Firstly, in tabular form, we presented a detailed search of the existing literature on the classification of EU member states in terms of the implementation of SDG7. Secondly, we analysed in theoretical terms the interdependencies between SDG7 achievement indicators, pointing out, among others, their complementary nature. Thirdly, we identified the IUCN method as optimal in the context of ranking the European Union Member States in terms of the achievement of SDG7, which significantly supports filling the research gap in this area. We positively verified the hypotheses that proclaim the Scandinavian countries (Sweden and Denmark) as leaders in the implementation of SDG7 in the European Union and forming the cluster with the highest degree of SDG7 implementation. These results correspond with the work of Chovancová and Wawrek, (2021), Firoiu *et al.* (2021), and Włodarczyk *et al.* (2021), which showed a high level of similarity in the development of a sustainable energy economy between Sweden and Denmark. Sweden and Denmark's energy transformation was initiated due to the outbreak of the oil crisis in the 1970s. At that time, the focus was on shifting away from fossil fuels to clean energy sources, increasing energy efficiency, and striving for energy independence. Today, both countries' energy policies strongly focus on developing the production and consumption of renewable energy sources and increasing energy efficiency, which translates into energy security. The national energy and climate plans for 2021-2030 include numerous measures to support renewable energy development, which focus on wind energy.

The results obtained for each group of countries indicate strong development disparities among member countries in the area of clean and accessible energy in its various aspects. The econometric optics proposed in the study and its results can help classify EU member states in terms of achieving SDG7 for researchers and policymakers The proposed research approach could be supplemented with further measures of clean and accessible energy beyond the SDG7 monitoring indexes. Such indexes could include energy prices, which affect the scale of energy poverty, or the level of greenhouse gas emissions on which environmental well-being depends, among others. The results of our research indicate the countries that are best at building a sustainable energy economy, which could serve as a model in the area of energy policy actions for policymakers in countries catching up with development in this area. However, the implementation of solutions that have proven effective in countries with the highest level of development of a sustainable energy economy is not always possible for other countries to imitate. This has to do, for example, with local geographic conditions predisposing to a greater or lesser extent to the development of renewable energy sources and the attitude of society to changes resulting from the energy transition. This requires policymakers to take a pragmatic and holistic approach, which will consider several factors that determine the development of the energy sector in the actions taken for clean and accessible energy. The recognition of these factors can support the pursuit of a long-term energy policy for an effective energy transition. Depending on the established conditions for the development of the national economy, these measures can take different forms. On the one hand, these actions can be based on providing financial incentives and tax breaks for those interested in investing in renewable energy sources and improving energy efficiency. On the other hand, there can be measures that discourage the use of fossil fuel-generated energy, such as environmental levies and taxes. The energy transition can be achieved through a modern infrastructure that is open to innovative and advanced solutions such as smart grids and energy storage. Clean energy technologies can be of interest to energy R&D actors. Supporting this type of activity is important from the point of view of building a sustainable energy economy, as it not only supports the creation of solutions reducing greenhouse gas emissions, but also determines the reduction of energy costs by increasing its availability to the general public.

The limitations of the conducted research results from statistical data availability. As a result of the outbreak of war in Ukraine in 2022, the European Union has taken a number of measures to strengthen energy security and independence from fossil fuel imports from the Russian Federation, which should be reflected in the improvement of a number of indexes monitoring the implementation of SGD7. At the same time, the existing limitation provides an interesting prospect for further research, which may address the impact of measures taken under the energy security policy on building a sustainable energy economy for the European Union under the conditions of the war conflict in Ukraine.

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Acknowledgements and Financial Disclosure

The publication presents the result of the Project no 023/EER/2023/POT financed from the subsidy granted to the Krakow University of Economics and subsidy for research activities of the University of Agriculture in Krakow (no 010016-D012 and no 010017-DO12).

Conflict of Interest

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