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ENSURING SUSTAINABLE ENERGY AS A SIGN OF ENVIRONMENTAL RESPONSIBILITY AND SOCIAL JUSTICE IN EUROPEAN UNION MEMBERS

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ABSTRACT: The article aims to measure and assess the degree of providing sustainable energy in the European Union (EU) countries in the context of social and environmental responsibility and social justice as well as in the context of implementation of the 7th goal of Agenda 2030. Providing people with access to sustainable energy and increasing energy efficiency in all sectors of the economy is necessary to achieve the goals of the concept of sustainable development, the Agenda 2030, the Europe 2020 strategy, and the European energy policy. Ensuring sustainable energy is also a sign of environmental responsibility and social justice. Accurate evaluation of achievements in this area is a relatively new issue, both in economic practice and in modern economics, therefore, there is a need to develop ways for measuring access to sustainable energy other than the usual analysis of time-series of data in individual years, on which current studies are based. Hence, an attempt was made to use two methods belonging to cluster analysis (Ward method and k-means) in order to more effectively assess the degree of sustainable energy provision undertaken by EU countries. This is a novel approach in this area as it directs the article towards the research trend focused on the operationalization of the concept of sustainable development. In the study, available statistical data on 8 indicators for SDG 7, reported by Eurostat and established by the UN, were used, covering the years 2010 and 2016. The study enabled the grouping of EU countries by the degree of provision of sustainable energy and, thus, the determining of their environmental responsibility and social justice in this area. The study shows that past EU achievements in providing sustainable energy are not particularly spectacular; there is no country where they were completely satisfactory, they were quite satisfactory in only 14 countries, averagely satisfactory in 9 countries, and unsatisfactory in 5 countries.

KEY WORDS: sustainable development; sustainable energy; environmental responsibility; social justice; European Union

Introduction

Providing people with access to inexpensive, clean, sustainable, and modern energy at an affordable price, which is the objective of Agenda 2030 (SDG 7), is one of the most important goals of the sustainable development concept as it determines the achievement of several other goals set within it as well as fulfilling the overriding goals of the concept, i.e. prosperity and justice (both inter and intra generation). To improve monitoring of its implementation, the UN has set indicators to determine the level of sustainable development in terms of availability of energy as well as of the development itself. This is something of a novelty in terms of enforcing the implementation of the goals set in Agenda 2030 (Kryk, 2019b, pp. 22-36). Further, the designated indicators are the basis for searching/application of more advanced methods for monitoring the performance of tasks by individual countries/groups of countries than ordinary statistical analysis, which until now has been the norm in this respect. Therefore, an attempt was made to utilize the Ward method and k-means to achieve the goal of the article, which is the measurement and assessment of the degree of providing sustainable energy in European Union (EU) countries in the context of implementation of the 7th goal of Agenda 2030 as well as environmental responsibility and social justice. The use of econometric methods to measure the provision of sustainable energy also meets the expectations of modern economics, as it contributes not only to widening the spectrum of analyzed issues and methods of operationalization of sustainable development but also to increasing the level of precision of calculations and conclusions. Therefore, we may say that the article supplements the recognized research gap. Articles on the need to use advanced econometric methods to operationalize sustainable development have also been written, inter alia, by Radovanovic, Ivanivic, Teodorovic (2011), Mardani and others (2017), Kumar and others (2017), (Kryk, 2019a).

The research body consists of EU member states, and the subject – the degree of providing sustainable energy, analyzed based on Eurostat data on 8 core indicators for SDG 7 of Agenda 2030, which is the point of reference in the article. The beginning of the research period is 2010, at which time discussions and actions were initiated to increase the availability of sustainable energy for societies. The end of the research period (2016) is determined by available data. The research description was preceded by a synthetic presentation of the essence of sustainable development in conjunction with the EU's commitment to achieving the 7th goal of Agenda 2030 and the concept of sustainable energy. The conducted research made it possible to assess the achievements of EU countries and group them according to the degree of ensuring sustainable energy as well as to formulate conclusions regarding

the implementation of SDG 7 together with environmental responsibility and social justice.

An overview of the literature

The beginnings of the concept of sustainable development date back to the 1970s and are associated with the reports of the Club of Rome, which revealed the ecological crisis and numerous environmental barriers to economic growth and socio-economic development, thereby making people aware that their activities could become the cause of the destruction of life on Earth. Attempts to find *the antidote* to the ecological problems of the world in the form of post-industrial concepts of economic growth and development gave rise to the belief that there is no other way of socio-economic development – both worldwide and in individual countries – than sustainable development (Kryk, 2003). The concept of sustainable development is very wide, covering many areas of human activities, and its essence is meeting the needs of the current generation without reducing the chances of future generations to meet them (this definition is included in the report of the Global Commission on Environment and Development "Our Common Future" (1987). Currently, it is one of the most important concepts of economic development.

The concept of sustainable development is winning more and more followers and, most importantly, is implemented in many countries, especially those with a well-developed market economy. The basis of the concept of sustainable development is focused on people as entities affecting the environment, our planet as an area (object) of people's impact, and method of action, i.e. partnership, as only integrated actions will allow us to achieve the goal of this concept; prosperity and peace in the world. These five elements have the following significance in the concept of sustainable development:

- People – we are determined to eliminate poverty and hunger in all their forms and dimensions and to provide all people with the opportunity to use their potential with dignity in a healthy environment and in accordance with the principle of equality.
- Our planet – we want to protect the Earth from deteriorating environmental conditions by sustainable consumption and production, sustainable management of natural resources, and by taking urgent action against climate change and supporting the needs of present and future generations. Climate change is affecting public health, food and water security, migration, and preserving peace and global security. Investing in sustainable development will help counteract climate change by reducing emissions and building disaster resilience. Actions taken on climate change will drive sustainable development and vice versa.

- Prosperity – we want to ensure a decent and satisfying life for all the people, and ensure that economic, social, and technological development is in harmony with nature.
- World peace – we are building peaceful and inclusive societies, free from fear and violence. There is no sustainable development without peace, and there is no peace without sustainable development.
- Partnership as a method of implementing the concept means that we will mobilize the resources needed to implement this concept by revitalizing the global partnership for sustainable development in a spirit of enhanced global solidarity, a partnership focused in particular on the needs of the poorest and the most vulnerable groups, and in the cooperation of all countries, parties and people around the world (United Nations, 2015; Latoszek, 2016, pp. 25-26).

In contemporary socio-economic conditions, M. Prasopchoke's approach should be considered as particularly important in the process of disseminating the concept of sustainable development, which tries to make the ruling classes aware that economic growth cannot consist only in the growth of GDP, production, employment or income, but must at least maintain the current level of social, relational, and natural capital, which will ensure intergenerational/social justice (and development in the future). Therefore, the assumptions for sustainable growth should be considered appropriate from a macroeconomic point of view (Buszko, 2012, p. 177).

F. Piontek understands sustainable development in a similar way, according to whom it is "a lasting improvement in the quality of life of contemporary and future generations by shaping the right proportions between three types of capital: economic, human and natural" (Piontek, 2000, pp. 117-189). Usually, the abbreviation 3xP is mentioned, derived from the first letters of the English words: *planet, people,* and at then, *profit*. This order suggests an emphasis primarily on preserving the Earth's resources, not threatening the environment, and profit comes only at the very end.

Peggy F. Barlett and Geoffrey W. Chase – as in the Bruntland report – argue that sustainable development is about meeting the current needs of society in such a way that the next generations will also be able to meet their own needs (Niesenbaum, 2005, pp. 775-777). In the concept of sustainable development – as H. Komiyama and K. Takeuchi say (2006, pp. 1-6) – strong emphasis has been placed not only on the elimination of barriers for growth, poverty, implementation of innovative solutions, and increase of intangible assets but also on environmental protection and the possibility of renewing resources, which is of particular importance in the new global conditions. Thus, sustainable development is activity that favors the natural environ-

ment, does not take place at the expense of the next generation, and is set in the globalization reality.

An interesting global initiative of the second decade of the 21st century is the UN Resolution *Transforming our world: the 2030 Agenda for Sustainable Development* (2015), which is a global program for sustainable development which sets a universal, global framework for action to eradicate poverty and achieve sustainable development by 2030. The agenda includes a set of 17 ambitious goals and 169 goal-related and complementary tasks. One of the goals is to guarantee universal access to cheap, reliable, modern, and sustainable energy (SDG 7) by 2030 by:

- ensuring universal access to affordable, reliable, and modern energy services,
- significant increase in the share of renewable energy in the overall energy mix,
- doubling the global energy efficiency improvement rate,
- development of infrastructure and modernization of technologies for providing modern and sustainable energy services in all developing countries, in particular in the least developed countries, small island developing countries, inland developing countries, in accordance with their respective support programs,
- strengthening international cooperation to facilitate access to clean energy and technology, including renewable energy, greater energy efficiency, and advanced, clean fossil fuel technologies, and supporting investment in energy infrastructure and clean energy technologies.

Actions aimed at ensuring access to sustainable energy are important from the point of view of both social justice (giving people the chance of access to the achievements of civilization, development, and prosperity) and environmental protection (affecting not only the environment condition but also intra- and intergenerational justice). Hence, undertaking these actions and effects not only reflect the degree of implementation of SDG 7 but also are a sign of environmental responsibility and social justice.

The concept of sustainable energy must first be explained as there are few attempts to define it broadly in the literature (Prandecki, 2014a). It is primarily associated with the application of renewable energy sources (Pawłowski, 2011, p. 242), which is an over-simplification. Most often, authors paraphrase the previously quoted definition of sustainable development from Bruntlad, describing sustainable energy as "energy consumption and supply that meets our needs without compromising our children's ability to meet their needs" (Patterson, 2009; Lemaire, 2010; Tester et al., 2005). They, therefore, emphasize the issue of sustainability of energy availability. In turn, LG Action points out that sustainable energy is associated not only with

the issue of sustainability but also with the authorization for use of energy sources causing slight damage to the environment and human health (2012). This extension of the definition is vital because there are no energy sources that would be completely harmless to the environment. For some authors, the above-mentioned definition has become the basis for equating sustainable energy with a sustainable energy system. This was taken up by Prandecki (2014b), who defines such a system as a conversion of primary energy into electrical and heat energy and its delivery to the final recipient in a way that meets the needs of current and future generations, taking into account the economic, social, and environmental aspects of human development. According to the author of this article, equating a sustainable energy system with sustainable energy also does not exhaust the entire spectrum of issues that can be included in its definition as well as its reduction only to renewable energy sources. This can be demonstrated, for example, by the variety of subjects forming acts from the EU package "*Clean Energy for all Europeans*" (2016), which also fails to show a clear definition of sustainable energy. Therefore, it would be worthwhile, at least for future reference, to formulate its complete definition to ensure uniformity of understanding and comparability of data and information provided on this issue.

The European Union is known for its high commitment and experience in the implementation of sustainable development, which is anchored in the highest-ranking documents, including: Treaty on European Union (2012), strategy for sustainable development (COM (2009) 400 final), "Europe 2020" strategy (COM 2010) and others. EU has also played an important role in shaping Agenda 2030, which is fully in line with the European vision and is a global action program for global sustainable development based on the objectives of this concept. The EU was one of the leading forces that led to the adoption of Agenda 2030. It is fully committed to its implementation and determined to act as a precursor in the implementation of this program and the objectives of sustainable development in cooperation with the Member States in accordance with the principle of subsidiarity. That is why the EU adopted in 2016 the action program for sustainable development entitled *Next steps for a sustainable European future European action for sustainability* (COM 739 final 2016). It is implemented in two ways. The first direction of works is to completely integrate the goals of sustainable development within European policy with the priorities of the European Commission. The second direction is to develop a long-term vision and the main points of the sectoral policy after 2020 as part of the preparation for the long-term implementation of the sustainable development goals. With regard to this work, a long-term vision was created to establish a prosperous, modern, competitive and climate-neutral EU economy by 2050 (COM 773 final 2018). This vision paves

the way for a structural change in the European economy, stimulating sustainable growth and job creation. On the other hand, with regard to the first direction, the identification has shown that under the current EU policies, all 17 sustainable development objectives are being implemented. Moreover, they are included in all 10 of the Commission's priorities for 2015-2019. These are: (1) employment, economic growth and investments; (2) the single digital market; (3) energy union and climate; (4) internal market: (5) a deepened and fairer economic and monetary union; (6) a balanced and progressive trade policy to exploit the opportunities of globalization; (7) justice and fundamental rights; (8) migration; (9) stronger position in the international arena; (10) democratic changes. An important role in the process of implementing a number of sustainable development goals is played by the "Europe 2020" strategy and its assumptions regarding sustainable energy and climate to be implemented by 2020: increase of energy efficiency by 20%, increase of up to 20% share of energy from renewable sources in total energy consumption, reduction of greenhouse gas emissions to 20% compared to 1990. In the document *Towards a Sustainable Europe by 2030* (COM 22 final 2019), this strategy was pointed out as a way for achieving, among others, Goal 7 of the Agenda 2030. Namely:

- "The process of **separating economic growth** from energy inputs and related **greenhouse gas emissions**. In 1990–2017, greenhouse gas emissions fell by 22%, while GDP increased by 58%. Since 2000, the energy productivity and the intensity of greenhouse gas emissions have been improving almost uninterruptedly in the EU.
- The EU seeks to achieve its target value for energy efficiency, set at 20% by 2020. In 2005–2016, primary energy consumption in the EU decreased by 9.9%, and final energy consumption by 7.1%.
- The EU is on track to achieve the 2020 target of a 20% share of renewable energy in final energy consumption. In the last decade, the use of renewable energy has grown steadily in the EU – from 9% to 17% of gross final energy consumption (in 2005-2016). The main driver of this growth was the predictable EU regulatory framework, more efficient technologies, falling costs of renewable energy technologies and more market-oriented support.
- The EU continues to meet its demand for energy mainly by importing fuels from non-EU countries. The EU dependence on import is 53.6% and has practically remained unchanged between 2006 and 2016, while energy production has decreased by 14% during this period. In the same period, there was a constant decrease in primary energy consumption – by about 10%.

- The EU has made progress in increasing access to affordable energy. In recent years, the percentage of households that can not afford to heat the house to the right temperature has decreased. In 2017, 8.1% of the EU population complained about the lack of access to affordable energy – which is less by 2.8 percentage points than in 2007."

The trends presented, based on data analysis in the form of time-series, suggest that changes in the provision of sustainable energy by EU countries are satisfactory (Kryk, 2019a). Whereas, the research performed using the Ward method and k-means shows less satisfactory results, which are presented later in the article.

Research methods

Observation of the implementation of tasks that were aimed at achieving the goals of sustainable development set out in the Agenda 2030, including ensuring access to sustainable energy, is based on the most common tool available, being indicators. According to T. Borys (2005), an indicator refers to a certain state of a phenomenon. The most important feature of each indicator is the comparability of its values, which allows the positioning of a given object (e.g. country), compared with others. Sustainable development indicators are tools that are intended for monitoring implemented changes, providing information on the level of implementation of tasks in the field of sustainability and the current state of the environment. The use of the indicator as a medium has become quite popular due to its multidimensionality, accessibility, readability, unambiguity, and comparability. Indicators assigned to specific orders (economic, environmental, social) or sustainable development goals create the possibility of constructing economic models, forecasting, and monitoring/assessing the implementation of changes. Determination of indicators for the implementation of the 7th goal of Agenda 2030 by the UN has created the possibility of using multidimensional exploration techniques to measure its implementation (e.g. Hellwig, 1968; Shen, Tzeng, 2018), GDM (Jajuga et al., 2003; Walesiak, 1993), consisting predominantly of cluster analysis. Hence, this article uses two such cluster analysis methods (the Ward method and k-means) to determine the degree of providing sustainable energy by EU countries, their environmental responsibility, and social justice.

The term "cluster analysis" was coined by R. Tryon (1939) and then further developed by R. Cattell (1944, pp. 169-184) and the use of cluster methods has increased significantly over the past 30 years (Gore, 2000). The purpose of cluster analysis – also known as data clustering or non-model classification – is to combine the examined elements into similar groups in such a

way that the degree of association of objects belonging to the same group is as large as possible and as small as possible with objects from other groups (Statistica PL, 1997; Kisielińska, Stańko, 2009, p. 68). In the non-model classification, there is no information on the belonging of objects to classes, classification is based on the distances between the objects. Cluster methods can be used to group different objects based on their values in the data set and to discover data structures, but without providing an explanation or interpretation of the reason behind their existence. All dependencies are found only on the basis of input variables. Cluster analysis is a set of different algorithms that assign objects to clusters according to well-defined similarity rules. It is important that, unlike a number of other statistical procedures, cluster analysis is most often used when the hypothesis is not prioritized in terms of data structure, but rather is in the exploratory phase of the research. Among various methods used to analyze clusters, the two most common ones have been selected that will enable the article's goal to be achieved.

The first method used is the Ward method, which is classified among the hierarchical, agglomerative methods. It uses the rule of minimizing variance (Migut, 2009). The methods employed in this group do not require any previous assumption as to the resulting number of clusters – at the end of the analysis, the chart (dendrogram) can be cut off at the proper height and then interpreted (Lotko, Lotko, 2015, p. 5) – this has been done in this study.

Table 1. Set of variables

Variable mark	Type of variable	Variable name
x_1	D	Primary energy consumption [million tons of oil equivalent – TOE]
x_2	D	Final energy consumption [million tons of oil equivalent – TOE]
X_3	D	Final energy consumption in households *per capita* [kg of oil equivalent]
X_4	S	Energy productivity [Euro per kilogram of oil equivalent – KGOE]
X_5	S	Share of renewable energy in gross final energy consumption by sector [%]
X_6	D	Energy dependence by-product [% of imports in total energy consumption]
x_7	D	Population unable to keep home adequately warm by poverty status [% of the population]
x_8	D	Greenhouse gas emissions intensity of energy consumption

D – destimulant, S – stimulant

Source: author's own work based on Eurostat.

The second grouping method – the k-means method – belongs to the group of non-hierarchical methods. They are fast in terms of calculation times but require the input of the assumed number of clusters at the beginning, which may affect the results of grouping (Salamaga, 2010).

In this article, the Ward method was used to identify the number of clusters (number of groups of EU countries), and the k-means method was then used to group cases and interpret the results based on the average value of each variable in each cluster.

To measure the achievement of the 7th goal of the UN Agenda 2030, 8 indicators have been established. These were adopted in this article as variables against which 28 EU countries were examined (table 1).

Before grouping, the variable destimulants were converted into stimulants and normalized using the zero unitarization method according to the following formula (Kukuła, 1999, p. 13):

$$x'_{ij} = \frac{\max\limits_i x_{ij} - x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}, \tag{1}$$

where:
x'_{ij} – value of converted variable,
x_{ij} – diagnostic variable value for the country,
j – variable number.

Then, the stimulants were normalized and deprived of the identifier, using the formula:

$$x'_{ij} = \frac{x_{ij} - \max\limits_i x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}}. \tag{2}$$

Variables standardized by this method take values from the range [0,1]. For each diagnostic variable, the least favorable state is valued by the number zero (being min x_{ij} for stimulant and max x_{ij} for destimulant). However, the condition considered to be the most favorable (max x_{ij} for stimulant and min x_{ij} for destimulant) is estimated by the largest number in the range of variation of normed variables, i.e. unity.

Using the above methods, European Union countries were grouped in terms of the degree of providing sustainable energy, and thus the implementation of the principle of environmental responsibility and social justice in connection with the SDG 7 of Agenda 2030. The beginning of the research period is 2010 when the United Nations report "The Global Partnership for Development: Time to Deliver" (2011) informed of the difficulties in supply-

ing energy to a significant part of the Earth's population. This information was the basis for the formulation of the 2011 UN opinion on the need to increase efforts to ensure wider public access to energy and the 7th goal in the New Agenda, which is the subject of the article. The end of the research period (2016) is determined by available data.

Results of the research

Calculations and charts in this section were derived using Statistica version 13.1. The dendrogram prepared using the Ward method (figure 1) presents the clusters of EU Member States in the field of ensuring sustainable energy obtained in the next steps in 2010.

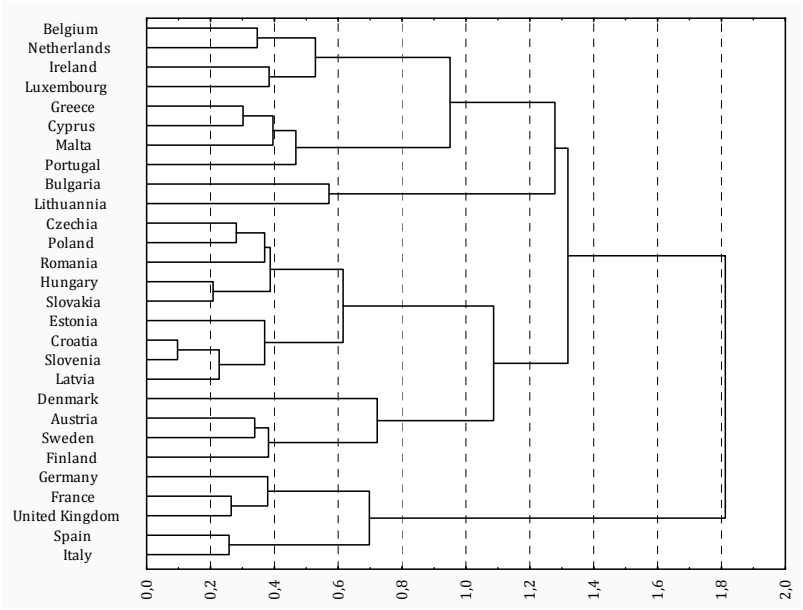


Figure 1. Dendrogram of clusters of EU countries in the field of ensuring sustainable energy determined by the Ward method (2010)
Source: author's own work.

Analysis of figure 1 shows that with a cut-off of 0.8, we obtain a clear and logical division into 6 groups. In this condition:

- 1st group: Italy, Spain, United Kingdom, France, Germany,
- 2nd group: Finland, Sweden, Austria, Denmark,
- 3rd group: Latvia, Slovenia, Croatia, Estonia, Slovakia, Hungary, Romania, Poland, Czechia,

- 4th group: Lithuania, Bulgaria,
- 5th group: Portugal, Malta, Cyprus, Greece,
- 6th group: Luxembourg, Ireland, Netherlands, Belgium.

The division into six groups was adopted in the grouping using the k-means method as the initial value of the number of clusters. The results of grouping EU countries by this method are shown in table 2 and figure 2.

Table 2. Clusters of EU countries in the field of ensuring sustainable energy determined by the k-means method in 2010 and 2016

2010		2016	
Cluster elements	**Distance from the center of cluster**	**Cluster elements**	**Distance from the center of cluster**
Cluster 1		Cluster 1	
Belgium	0.184814	Belgium	0.171062
Spain	0.122939	Czechia	0.088108
Italy	0.220052	Estonia	0.189681
Netherlands	0.233038	Croatia	0.089577
Austria	0.198091	Latvia	0.146819
Portugal	0.351651	Hungary	0.091497
Cluster 2		Netherlands	0.160064
Bulgaria	0	Poland	0.133063
Cluster 3		Romania	0.142325
Ireland	0.269652	Slovenia	0.054797
Greece	0.059351	Slovakia	0.127734
Cyprus	0.094806	Cluster 2	
Lithuania	0.560238	Bulgaria	0.203475
Luxembourg	0.377806	Greece	0.126121
Malta	0.297849	Cyprus	0.140249
Slovakia	0.210114	Lithuania	0.114690
Cluster 4		Portugal	0.142030
Denmark	0	Cluster 3	
Cluster 5		Ireland	0.124702
Germany	0.095808	Luxembourg	0.186237
France	0.027457	Malta	0.224063
United Kingdom	0.090601	Cluster 4	

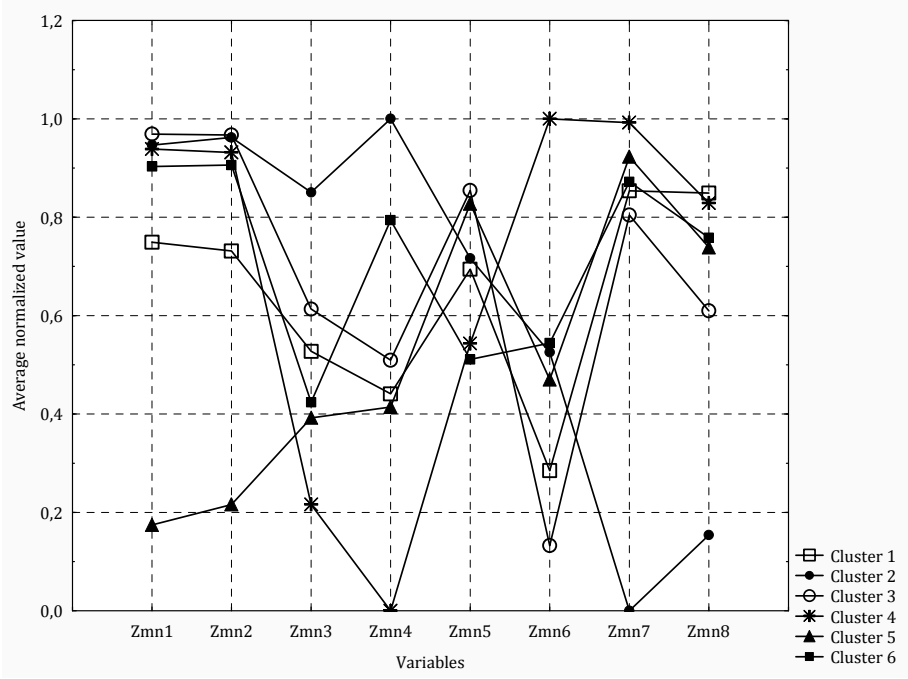
2010		2016	
Cluster elements	Distance from the center of cluster	Cluster elements	Distance from the center of cluster
Cluster 6		Denmark	0.173219
Czechia	0.155702	Austria	0.116986
Estonia	0.154563	Finland	0.125825
Croatia	0.031004	Sweden	0.117216
Latvia	0.074931	Cluster 5	
Hungary	0.141034	Germany	0.205567
Poland	0.213809	Spain	0.171354
Romania	0.169403	France	0.091844
Slovenia	0.037186	Italy	0.128973
Finland	0.256169	United Kingdom	0.107218
Sweden	0.406447		

Source: author's own work.

When analyzing figure 2, the following conclusions can be drawn:

- Cluster 1 had the highest value of the 8th variable compared to other clusters, which means that countries belonging to this cluster were characterized by a low intensity of greenhouse gas emissions in energy consumption (when interpreting the results, remember to replace destimulants with stimulants). The values of variables 1, 2, and 6 took the penultimate place compared to other clusters, i.e. the countries from this cluster had relatively high values respectively in terms of primary energy consumption, final energy consumption, and were highly dependent on energy imports, not a favorable perspective for providing sustainable energy. The values of the other variables 3, 4, 5, and 7 were average.
- Clusters 2 and 3 are among the best clusters. Bulgaria belonging to cluster 2 is a country with a high value of variable 2, 3, and 4, i.e. low final energy consumption and final energy consumption in household per capita, and high energy productivity, respectively. The value of variable 1 was also quite high, which means low primary energy consumption in the country forming the group. However, in this group/country there was the lowest value of variable 7 amongst all clusters, meaning that its country had the worst indicator of adequate heat for the population because of poverty. The values of the other variables were average. However, it should be taken into account that Bulgaria, which forms Cluster 2 was one of the poorest EU members, hence the low values of certain indica-

tors, favorable from the point of view of ensuring sustainable energy was not always the result of deliberate actions in this respect, but rather of existing conditions.



Key: Zmn=x – variable

Figure 2. Average values of quantitative variables measuring the provision of sustainable energy by clusters determined by the k-means method (2010)

Source: author's own work.

- Cluster 3 is the cluster in which the values of variables 1, 2, and 5 were the highest compared to other clusters. Thus, the countries in this group were characterized by low primary and final energy consumption and a high share of energy from renewable sources in gross final energy consumption by sector. The value of variable 3 was quite high, which indicates a high consumption of final energy in households per capita. The value of variable 4 (energy productivity) was average. On the other hand, variables 6, 7, and 8 took last or penultimate place, i.e. countries in this cluster were characterized, respectively, by high dependence on energy imports, poor situation in terms of adequate heating of houses by the population due to poverty, and high intensity of greenhouse gas emissions in energy consumption.

- Cluster 4 included the country with the highest values of the last three variables (6, 7, 8) compared to other clusters (it was the best in this area). Thus, it was characterized respectively as having low dependence on energy imports, a small percentage of the population unable to properly heat the house due to poverty, and low intensity of greenhouse gas emissions in energy consumption. Other variables had an average value, except for variable 4 (energy productivity), which had the lowest value among all clusters. It is interesting to note that in the case of the country examined (Denmark), it was not associated with low energy productivity but rather with a minor increase. Denmark had the highest energy productivity in the EU during the period examined. Generally, Cluster 4, together with Cluster 6, was average in terms of the implementation of sustainable energy variables.
- Cluster 5 is one of the weakest clusters. The values of variables 1 and 2 were the lowest. In this cluster, only variables 5 and 7 were at a fairly high, but not the highest level, that is, countries from this group were characterized by a relatively large share of the renewable energy sector in gross final energy consumption by sector and a relatively low indicator of the population unable to heat the house properly due to poverty. The values of the other variables were poor or average.
- In Cluster 6, variables 4 and 6 achieved quite positive values so, the countries in this group were characterized by relatively good energy productivity and are not overly dependent on energy imports. The values of other variables were average (1, 2, 3, 7, 8) or poor (variable 5 – a low share of energy from renewable sources in gross final energy consumption by sector) compared to other clusters.

This implies that, in 2010, the countries of Clusters 2 and 3, namely Bulgaria, Ireland, Greece, Cyprus, Lithuania, Luxembourg, Malta, and Slovakia had the most favorable situation in terms of ensuring sustainable energy. In these countries, most variables had the highest values in the examined range. In the countries from cluster 5, i.e. Germany, France, Great Britain, most of the variables were poor or average, and only two variables were quite high. Countries from other clusters (1, 4, 6) were average in terms of the implementation of sustainable energy variables. The results obtained will be compared with the results of the analysis in 2016 so as to assess the degree of providing sustainable energy in EU countries.

The dendrogram prepared using the Ward method (figure 3) presents the clusters of EU Member States in the field of ensuring sustainable energy obtained in the next steps in 2016.

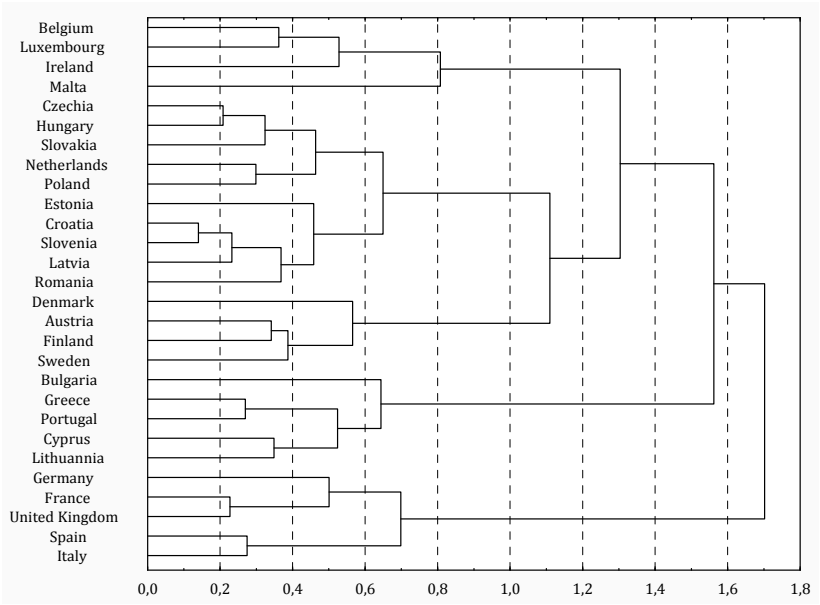


Figure 3. Dendrogram of clusters of EU countries in the field of ensuring sustainable energy determined by the Ward method (2016)

Source: author's own work.

Analysis of figure 3 shows that when there is a cut-off at a height of 1.5-2, a clear and logical division into 5 groups takes place, where:

- 1st group: Italy, Spain, United Kingdom, France, Germany,
- 2nd group: Lithuania, Cyprus, Portugal, Greece, Bulgaria,
- 3rd group: Sweden, Finland, Austria, Denmark,
- 4th group: Romania, Latvia, Slovenia, Croatia, Estonia, Poland, Netherlands, Slovakia, Hungary, Czech Republic,
- 5th group: Malta, Ireland, Luxembourg, Belgium.

The remaining divisions are less characteristic, therefore, division into five groups was adopted in the grouping using the k-means method as the initial value of the number of clusters. The results of grouping EU countries by this method are shown in table 2 and figure 4.

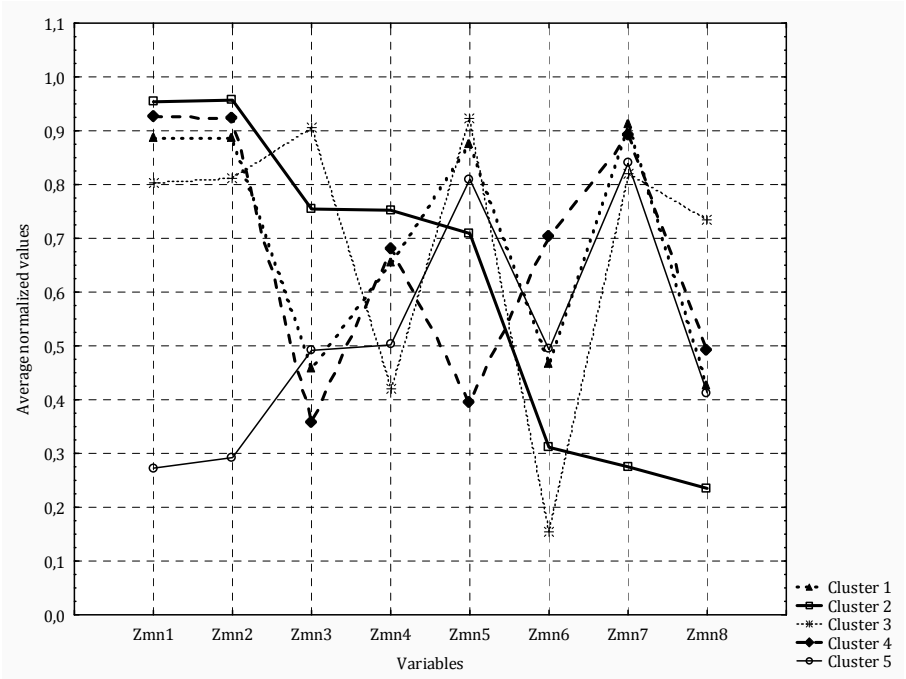


Figure 4. Average values of quantitative variables measuring the provision of sustainable energy by clusters determined by the k-means method (2016)

Source: author's own work.

When analyzing figure 4, the following conclusions can be drawn:

- Cluster 1 was ranked second after Cluster 3, among the best grouping in this research in terms of providing sustainable energy. Variables 4 and 6 had the highest values in this cluster. This means that the countries grouped in it were characterized by high energy production and not very high dependence on energy imports. The values of the other variables were quite high (variable 1, 2, 7) or average (variable 3, 5, 8), which placed the cluster mostly in third place among other clusters.
- Cluster 2 had the highest value for variable 3, compared to other clusters. Thus, the countries in this group were characterized by low final energy consumption in households per capita. The values of variables 1, 2, 4 were quite high, which placed this cluster second in relation to other clusters in this respect. For variables 1 and 2, this meant low primary energy consumption and final energy consumption, respectively, and for variable 4, high energy production. The values of variables 5 and 6 were average. In contrast, the values of variables 7 and 8 were the lowest compared to other clusters, i.e. countries from this group were characterized

by a high rate of the population unable to properly heat their house due to poverty and high intensity of greenhouse gas emissions in energy consumption.

- Cluster 3, as already mentioned, was the best in this study in the context of providing sustainable energy. The values of its three variables 1, 2, and 5 were the highest compared to other clusters, i.e. the countries in this cluster were characterized by low primary energy consumption, low final energy consumption, and a low share of renewable energy in gross final energy consumption by sector. The values of variables 3, 7, 8 were quite high, placing this cluster second among the others. These values meant, respectively, relatively high final energy consumption in households per capita, small changes in the index of the population unable to properly heat the house due to poverty, and high intensity of greenhouse gas emissions in energy consumption. Only the average values of variables 4 and 6 reached the lowest level in the study, which meant a high dependence on energy imports and low energy efficiency. It should be noted, however, that three countries from this cluster (Ireland, Luxembourg, Malta) were characterized by high energy efficiency both in 2010 and 2016, and the remaining countries in the group featured low energy efficiency, hence the average value of a given variable was low.
- In cluster 4, the values of variables 6, 7, and 8 were the highest in the research, i.e. the countries belonging to it were characterized by low dependence on energy imports, low rate of population unable to properly heat the house due to poverty, and lower intensity of greenhouse gas emissions in energy consumption compared to countries outside this cluster, which is very good in terms of providing sustainable energy. Further, the values of variables 3 and 5 were the lowest compared to other clusters, i.e. the countries in this cluster were characterized by high final energy consumption in households per capita and a large share of energy from renewable sources in gross final energy consumption by sector. The values of the other variables were average.
- Cluster 5 showed the worst result in the research. In this cluster, two variables (1, 2) out of eight featured the lowest values, therefore, the countries in this group were characterized by high primary energy consumption and final energy use. Other variables featured average values.

The analysis shows that in 2016, countries from clusters 1 and 3, i.e. Ireland, Luxembourg, Malta, Denmark, Austria, Finland, and Sweden had the most favorable situation in terms of providing sustainable energy. In these countries, most variables had either the highest values or quite high in the examined range. The countries from cluster 5, i.e. Germany, Spain, France,

Italy, and the United Kingdom featured the poorest result, where most of the variables had average or poor values, and only one variable (5) was at a fairly high level. Countries from other clusters (2, 4) were average in terms of the implementation of sustainable energy variables.

Conclusions

Comparing the situation in 2010 with the achievements of EU Member States in providing sustainable energy in 2016, it may be said that:

- In 2016, the first cluster was made up of 11 countries, including 9 from the so-called former Eastern Bloc (Czech Republic, Estonia, Croatia, Latvia, Hungary, Poland, Romania, Slovenia, Slovakia), which were in a group along with two countries with a more developed economy and better indicators regarding the provision of sustainable energy (Belgium and the Netherlands). This fact alone is indicative of the positive changes that have taken place in these post-socialist countries in the researched field. In 2016, these countries were characterized by much better levels of the examined variables than in 2010. They maintained a high level of variables 4 and 6 and achieved higher values of other variables. Variables 1, 2, and 7 (respectively: primary energy consumption, final energy consumption, people unable to heat the house properly due to poverty) increased from average to quite high, and variables 3, 5, and 8 (final energy consumption in households per capita, share of renewable energy sector in gross final energy consumption by sector, intensity of greenhouse gas emissions in energy consumption) from poor to average. As a result, there has evidently been progress in providing sustainable energy that has put these countries in a group with Belgium and the Netherlands. These last two countries had good levels of all variables in 2010 and improved them further, which had a positive effect on the average values of individual variables in the cluster, hence, the results of cluster 1 in providing sustainable energy can be assessed as quite satisfactory because five out of eight variables reached quite high values (1, 2, 4, 6, 7) and the other three variables (3, 5, 8) were average. On a four-point rating scale (unsatisfactory, medium satisfactory, fairly satisfactory, and satisfactory), this is a good result.
- In 2016, cluster 2 covered 5 countries being Bulgaria, Greece, Cyprus, Lithuania, and Portugal. It is interesting that while Greece, Cyprus, and Lithuania were already in one cluster in 2010, the other two countries then joined them. Bulgaria was previously included in a one-element cluster, and its entry was associated with an improvement in the values of

the variables researched (five out of eight, i.e. variables 4, 5, 6, 7, 8), which reduced the distance from the center of the cluster (from 0 to 0,2). In contrast, Portugal, despite the improvement in the values of the researched variables (seven out of eight indicators improved, only the intensity of greenhouse gas emissions in energy consumption deteriorated) (Kryk, 2019a; Eurostat, 2018), moved away from the center of the cluster due to the increase in the number of countries with similar achievements in the field of ensuring sustainable energy (Greece, Cyprus, and Bulgaria).

Compared to 2010, virtually all countries from cluster 2 showed relatively good achievements with respect to four of the variables (primary and final energy consumption, final energy consumption per household per capita, and energy productivity), average results were seen in the share of energy from renewable sources in gross final energy consumption by sector and dependence on energy imports. The group had lower achievements in two cases; the population unable to heat the house properly due to poverty and the intensity of greenhouse gas emissions in energy consumption.

Taking into account that four out of the eight average variable values were quite high and high, two were average, and two were low, the achievements of a given cluster can be assessed as moderately satisfactory.

- Cluster 3 consists of countries with a similar economic situation (Ireland, Luxembourg, and Malta), which were in the same group in both researched years; however, within six years, these countries moved away from the center of the cluster, as indicated by the reduced values of distance from the center (table 2). This was related to both a larger number of member countries in which the values of certain variables improved as well as to the poor performance of given countries in relation to variable 6 (still high dependence on energy imports) and variable 3 (final energy consumption in households per capita is still high despite its lowering). Quite good results were achieved in the case of variable 4 (energy productivity in these countries became one of the highest in the EU), variable 2 (final energy consumption is also relatively lower compared to countries from other clusters) and good results in the case of variable 5 (significantly increasing the share of energy from renewable sources in gross final energy consumption by sector). Variable 1 (primary energy consumption) decreased slightly. Despite this, its level was relatively lower compared to other countries, which is still a positive achievement. The changes that took place in the values of variable 7 (the indicator on population unable to heat the house properly due to poverty) and variable 8 (the intensity of greenhouse gas emissions in energy consumption – still high) were not large, but they improved the standing of these countries in rela-

tion to the other clusters. The change of variable 7 was moderately satisfactory, and for variable 8 it was unsatisfactory.

Taking into account that four out of eight average variable values were quite high and high, two were average but vital, and two were low, the achievements of a given cluster can be assessed as quite satisfactory overall.

- In 2016, four countries with a similar economic situation were included in cluster 4 (Denmark, Austria, Finland, and Sweden), which in 2010 belonged to different groups. Over the six years to 2016, the distance from the center of the cluster of these countries increased, which was associated with a greater number of member countries in which the values of certain variables have improved as well as with moderately satisfactory changes in variables 1 (primary energy consumption), 2 (final energy consumption), 3 (final energy consumption in households per capita), 4 (energy productivity), and 6 (dependence on energy imports). It should be noted, however, that the level of these variables in cluster 4 countries was better than in other Member States, therefore, it will be increasingly difficult for them to achieve spectacular results in this respect. The researched countries obtained the best achievements in the case of variable 5, as they were characterized by the largest share of energy from renewable sources in gross final energy consumption by sectors (in each country of the cluster, this indicator increased) and variable 8 (in all cluster countries the intensity of greenhouse gas emissions in energy consumption decreased to a greater extent than in other EU countries). In the case of variable 7, there is the issue of the success of the group, which is characterized by the lowest values of the population unable to properly heat the house due to poverty (resulting in first place among other groups in Fig. 4) compared to other groups. However, within the group, this indicator only decreased in Austria, while in the other three countries it increased, which is why achievements in this area can be described as moderately satisfactory.

In light of the above achievement, cluster 4 (taking into account the relatively favorable level of five variables out of eight and the level of changes compared to other clusters) can be described as moderately satisfactory in terms of providing sustainable energy.

- In 2016, cluster 5 was made up of five countries which, in 2010, were placed in different clusters. During the period researched, the distance from the center of the cluster of four of them slightly decreased (Germany, Spain, France, and the United Kingdom), which indicates positive, albeit slight, changes in the provision of sustainable energy. However, the distance from the center of the cluster for one country – Italy, increased, which was associated with more minor achievements relative to the

achievements of other countries. It should be noted, however, that positive changes occurred in Italy in seven of the eight variables researched, the negative change being only in the case of variable 7 (the population is not able to warm the house properly due to poverty). Generally, during the six years in the countries belonging to this cluster, fifth in achievement relative to variables 1, 2, 3, 6, 7, and 8 was unsatisfactory, in relation to variable 4 (energy productivity) – moderately satisfactory, while variable 5 (share of energy from renewable sources in gross final energy consumption by sector) – quite satisfactory. In the context of the above, the assessment of the overall achievements of this cluster is unsatisfactory.

To sum up, the research shows that:

- Achievements in providing sustainable energy were quite satisfactory in two clusters (1, 3) covering 14 countries, moderately satisfactory in clusters 2 and 4, covering 9 countries, and unsatisfactory in cluster 5, covering 5 countries. The evaluation of achievements confirms a diverse approach and the possibilities for EU countries not only in relation to a given issue but also for environmental responsibility and social justice.
- The EU's six-year achievements in providing sustainable energy are not overly spectacular, as suggested by the time series analysis (Kryk, 2019b). This proves the need to modify/take actions that will intensify the effects in this respect.

In general, EU Member States are characterized by an average degree of sustainable energy provision and thus the results are insufficient in terms of achieving the 7th goal of Agenda 2030, and thereby environmental responsibility and social justice. Despite some progress being made in the area examined, existing initiatives have not been able to ensure full implementation of the UN 2030 action program. Therefore, there was a need for more efficient implementation and further targeted action in all areas. In the context of the above, the EU has taken new initiatives to facilitate the achievement of the 7th goal of Agenda (COM 22 final, 2019), which are implemented and should bring better results than before. One of the most important initiatives is the already mentioned package "Clean Energy for All Europeans". In May 2019, the EU completed the final legislative acts of this package, thus reaching an important stage towards the completion of the Energy Union. The package includes documents on energy efficiency, renewable energy sources, new energy and climate laws, consumer rights, energy security, electricity market efficiency, and cooperation between the EU and Member States to achieve the ambitious energy and climate goals (Clean Energy Package, 2019). The suggested regulations are aimed at creating a secure, sustainable, and affordable energy system that will materialize and bring results when EU Member

States cooperate in a spirit of solidarity. Achieving satisfactory results requires Member States to quickly implement new regulations and intensify efforts, especially in areas requiring it. The involvement of countries will also be a sign of their environmental responsibility and social justice.

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