

Article

Energy Performance of the European Union Countries in Terms of Reaching the European Energy Union Objectives

Roman Vavrek ^{1,*}  and Jana Chovancová ² 

¹ Department of Informatics, Faculty of Economics, Technical University of Liberec, 460 01 Liberec 1, Czech Republic

² Department of Environmental Management, Faculty of Management, University of Prešov, 080 01 Prešov, Slovakia; jana.chovancova@unipo.sk

* Correspondence: vavrek.roman@gmail.com; Tel.: +420-48-535

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Abstract: European energy policy, especially the project of the Energy Union, is one of the most rapidly developing areas of the EU, and one through which European institutions are obtaining gradually more extensive power over the performance of the national energy sectors. The paper focuses on an analysis of the energy performance of EU member states (MS) with regard to the priorities of the European Energy Union. For an assessment of the energy performance of EU countries, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was chosen, using the Coefficient of Variation method (CV) as an objective method for determining the weights of eight input indicators, including CO₂ intensity, electricity and gas price, energy productivity, energy dependence, consumption of renewables and research and development. The analysis for the period from 2008 to 2016 showed significant changes in the input indicators, which directly influenced the results of both methods mentioned above. Long-term differences between the best- and worst-rated countries are seen mainly in CO₂ emissions, energy imports and total consumption of renewable energy sources. It is these aspects of comprehensive energy performance and their convergence at the level of EU countries that we believe should be addressed in the near future.

Keywords: energy union; EU countries; long-term evaluation; TOPSIS technique; coefficient of variance

1. Introduction

Energy has played an important role in the European Union since its beginnings and has become a frequently discussed topic in the EU's political agenda, which has led to a comprehensive body of legislative documents that address the security, economic, environmental and climate aspects of energy policy. The evidence of this was shown by Benson et al. [1], who stated that, by 2010, the EU had adopted a cumulative total of over 350 legal instruments and measures addressing this topic. More recently, Isoaho et al. [2] provided a big data view where they analyse more than 5000 policy documents related to energy and climate issues. One of the European Union's current initiatives to tackle energy issues is the Energy Commission [3], which has set out priorities and principles in order to address the challenges related to enhancing energy efficiency, support for renewable energy, climate change action, clean energy innovation and fair conditions for energy consumers. The formation of the Energy Union can be seen as the most significant policy effort creating the platform for important transition of European energy system, allowing for the shift to decarbonization of the economy and promoting long-term sustainability and climate protection.

In April 2019, vice-president of the Commission for Energy Union, Maroš Šefčovič, presented the current state of the Energy Union, where he announced that the Energy Union has become a reality. From our perspective, the project of the European Energy Union stands on the starting line, and the success of this project and its bold ambitions will depend on the political will and support of individual MS. Moreover, each of the MSs occupies a different position on the starting line.

The paper is based on an analysis of the current state of the energy performance of EU MSs in regard to the priorities of the European Energy Union. The aim of the paper is to assess the energy performance of EU countries, using relevant energy-related indicators. Performed research is focused on the long-term results in the energy performance of individual EU countries; as for an objective evaluation, we consider it important to identify whether the overall results for the country are due to one highly negatively or positively evaluated indicator, or a combination of several above- or below-average indicators.

The paper begins with a definition of the term “European energy policy” (EEP) and a brief description of its historical development. We continue with a description of a methodological approach to assessing the energy performance of EU countries. We describe the set of selected indicators as well as their relevance to recent trends in European energy policy. Then, we determine the acceptable level of the variability of the indicators. For a multi-criteria evaluation of countries, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Coefficient of Variation method (CV) were chosen. The results of the research were divided into identifying the differences in the weights of eight indicators and their development over a 9-year period, and identifying the causes of a good (or bad) long-term position for selected EU countries, with an emphasis on the differences between them.

2. Literature and Policy Background

In this chapter, we focus on the process of creating a European energy policy (EEP), a brief history of this development and an analysis of some major historical milestones. Our effort will be to point out the ongoing trends as well as changing priorities of the EEP at individual stages of development.

Before we begin with the interpretation, it is necessary here to clarify what we actually mean by European energy policy. In a broad sense, the term “European policies” refers to all issues that are discussed at the level of the European Union. The nature of the Union’s competences (i.e., whether shared, exclusive or merely subsidiary) is not entirely relevant in this respect. Importantly, the issue is discussed at the EU level. EU institutions as well as member countries are joining this discussion. European energy policy therefore refers to an effort to comprehensively grasp energy issues within the European Union’s agenda. It not only relates to the concept of energy security, but also includes issues related to reducing the environmental impact of the energy sector, building a common market, etc.

The concept of the historical development of European energy policy can be found in the work of several authors [4–11]. From our perspective, it is possible to distinguish three periods of European energy policy development.

The first is the period between World War II and the end of the 1960s, when we can observe the first coordinated and transnational efforts to obtain a grasp on energy issues on the European continent. The European Coal and Steel Community (ECSC) and, later, EURATOM were set up, and the first reports and documents calling for a communitarized energy policy appeared [12,13].

The second period can be dated to the so-called “first energy crisis” of 1973/1974, which ended in the mid-1990s with the 1987 Single European Act (SEA) and the subsequent Single Market Program. This period was characterized by an attempt to cope with the previously unknown phenomenon of Western countries’ dependence on imported energy sources (specifically oil), including all the associated turbulence and difficulties [14–17].

With the publication of the SEA, the European Community (and later the EU) took the initiative in addressing domestic energy issues, in particular, the functioning of energy markets, as well as environmental issues related to energy production and consumption. This is where the third phase of energy policy development begins, when the cycling efforts to build a Community union energy

policy were revived in the first decade of the new millennium. This period actually continues to this day, especially in the context of new phenomena on the world scene, such as problems associated with fuel supplies from the Russian Federation, the US shale gas revolution, the emergence of new Asian consumers, and the adverse impacts of climate change.

At the beginning, the priorities of European energy policy were focused primarily on energy security and reducing energy dependency (first period) and liberalization of the energy market (second period). Recently, EU energy policy has comprised rules concerning energy sources, technology and innovation, renewables, energy efficiency, a single market for gas and electricity, energy dependence, energy infrastructure and the environmental issues of energy production, consumption and transit [18]. There is a broad consensus in literature that the environmental and climate protection were the main drivers for initiating the transfer of competencies for advancing energy policy from the hands of EU MSs to the Commission's agenda [19–22].

A significant step towards European energy integration was the approval of the Energy Union by the MSs on the European Council in March 2015. One of the main incentives for the creation of the Energy Union was the awareness of European countries' strong dependence on Russian supplies of energy raw materials. This was highlighted by the Polish Prime Minister, Donald Tusk, in an article for the Financial Times in April 2014, arguing that this dependence makes the EU weak, which is a major problem in the current tense situation. However, energy security, on which the original intention of the Energy Union was aimed, is only one of the building blocks of the approved proposal, covering the whole spectrum of energy topics such as the internal energy market, energy efficiency, decarbonization of the economy and research, innovation and competitiveness [23,24]. The document identifies major current energy challenges within the European Community and proposes concrete solutions in the form of 15 points, including legislative proposals. The European Commission has proposed building a common EU energy policy with an internal (market and environmental) and external (energy dependence) dimension over the next few years [25].

Although the topic of the European Energy Union is relatively new, it is frequently discussed both at political level and in academia. Researchers address various issues of European energy policy and European Energy Union. On their study, Ellenbeck et al. [26] discuss the issue of security of supply in European electricity markets and they identify further determinants of the investment decisions of electricity market participants. Pellerin-Carlin [27] addresses the fragmentation of a European energy system characterised by uncoordinated national policies and states that Energy Union strategy has the ambition to overcome this long-standing challenge of EU energy policy. Szulecky et al. [28] propose energy policy triangle: security, affordability and sustainability and apply this approach to four EU MSs. However, the literature focuses mostly on procedural aspects of EU energy governance, introduction of the Energy union and its concept [29]. There is a consensus among the professional community that achieving the objectives of Energy and Climate Policy will require a fundamental transformation of energy system at both EU and national level. When striving for such a bold ambition, it is necessary to monitor the performance of EU countries in all relevant European energy union priorities.

3. Methodology

The aim of the submitted research is to identify the long-term results in the energy performance of individual EU countries. As for an objective evaluation, we consider it important to identify whether the overall results for a country are due to one highly negatively or positively evaluated indicator, or a combination of several above-average or below-average indicators. The countries were divided into four groups in each year according to their ranking position based on eight selected indicators (Q1—countries ranked 1 to 7; Q2—countries ranked 8 to 14; etc.). This created a group of 6 countries (in Q1) whose status has been stable in the long term, and it can therefore be assumed that the cause of their assessment is long-term and this assessment is not the result of “coincidence.” For its evaluation, the following research hypotheses are tested:

Research hypothesis no. 1 (RH1): There are statistically significant differences in the importance of the selected eight indicators using the CV method.

Research hypothesis no. 2 (RH2): There are statistically significant differences in the energy performance of individual EU countries using the CV-TOPSIS technique.

Research hypothesis no. 3 (RH3): There is/are a statistically significant indicator(s) which could be considered as a typical one for any of group of countries (Q1–Q4).

The research focuses on the assessment of EU countries with a set of eight monitored indicators (Table 1). The indicators in this research were selected based on the availability and reliability of the data and reflect European Energy Union priorities, which include: (1) energy security, solidarity and trust (SoS); (2) single and fully integrated energy market (IEM); (3) energy efficiency contributing to moderation of energy demand (EE); (4) decarbonizing the economy (GHG); and (5) research, innovation and competitiveness (R&I). These five dimensions are closely interrelated and mutually reinforcing, and their implementation is expected to increase the EU's energy security, sustainable development and competitiveness [3]. The interconnection of key priorities and energy-related indicators is shown in the form of a matrix in Table 1.

Table 1. Selection of indicators for multi-criteria evaluation and their relevance for EEU priorities.

	Indicator	Unit	Dimensions of EEU					Related Documents
			SoS	IEM	EE	GHG	R&I	
I1	CO ₂ intensity of energy sector	Tons per capita				x		COM(2015)337 COM(2016) 482 (EU) 2018/1999
I2	CO ₂ intensity of all sectors	Tons per capita				x		COM(2015)337 COM(2016) 482 (EU) 2018/1999
I3	Electricity price and gas price	EUR per kWh		x				COM(2015)339 COM(2016) 769 SWD(2016) 420 COM/2019/1
I4	Import of energy products	Tons of oil equivalent per capita	x					COM(2016)53 COM(2014) 330 SWD(2014)330 COM(2016) 761 SWD(2016) 404
I5	Energy productivity	Euro per kilogram of oil equivalent			x			COM(2015) 341 COM(2016) 860 (EU)2018/2002
I6	Total energy consumption	Tons of oil equivalent per capita			x			COM(2016) 761 (EU)2018/2002
I7	Total consumption of renewable energy sources (RES)	Tons of oil equivalent per capita	x	x	x	x		COM(2016) 860 COM(2016) 763 (EU) 2018/2001
I8	Research and development	EUR per capita					x	COM(2016) 763 COM(2016) 860 COM(2017) 688

Short description of indicators is as follows:

- **CO₂ intensity of energy sector (I1)**—focuses on the mass of energy-related CO₂ of energy sector. To date, the energy sector is the largest emitter of greenhouse gases in Europe, with CO₂ being the most commonly emitted greenhouse gas across the sector [30].
- **CO₂ intensity of all sectors (I2)**—the ration between energy-related CO₂ emissions and energy consumption of all economic sectors. It expresses how many tons of CO₂ emissions are being emitted in a certain economy per unit of energy being consumed.
- **Electricity price and Gas price (I3)**—the development of electricity prices and natural gas prices for industrial end-users and for household consumers.
- **Import of energy products (I4)**—calculated as the net imports of energy products by EU MSs. Imports of primary energy and energy products increased over the past decades. For example,

import of natural gas doubled over the period 1990–2016. Increasing dependency on import of energy products forms the backdrop for policy concerns relating to the EU's energy security.

- **Energy productivity (I5)**—defined as the ratio of the economic output in terms of gross domestic product (GDP) divided by the gross available energy for a given time period. It measures the productivity of energy consumption and provides a picture of energy efficiency of an economy and the degree of decoupling of energy use from economic growth [31].
- **Total energy consumption (I6)**—the quantity of all energy necessary to satisfy energy needs of a country or region, including industry, transport, agriculture, trade and services and households. It consists of consumption by the energy sector, distribution and transformation losses and final energy consumption by end-users. From the long term perspective (with 1990 as a reference year), we can observe the significant drop in solid fuels and oil products consumption while consumption of renewables increased considerably.
- **Total consumption of renewable energy sources (RES) (I7)**—measures the total consumption of renewable energy sources. Increase of renewables within EU MSs is considerable; comparing 2016 with 2005, the consumption of renewables within the EU increased by 78.6%, with the highest share of solar energy [32].
- **Research and development (I8)**—the investment in research and development (R&D) is one of the long-term priorities of the EU. In its 2020 strategy is presented an objective to devote 3% of GDP to support research and development activities. Significant part of these activities are devoted to energy. European Commission in its Framework strategy for a resilient energy union [33] suggests research priorities focused both on energy and climate change policy, including development of renewable energy technologies and bio-energy, smart grids and customer-oriented products such as smart home appliances and home automation systems. Another research area is focused on development of efficient energy systems increasing energy and CO₂ neutrality of building stock and sustainable, energy efficient and climate neutral transport systems. Among the EU MSs, the R&D intensity varies considerably. While Sweden and Austria invest more than 3% of GDP in R&D, in countries such as Cyprus, Romania and Latvia, investments in research and innovation represents less than 0.5% of GDP [33]. Descriptive statistics of individual indicators are available in the supplementary material section (Supplementary material A).

As we are looking for indicators that should be typical for a given group, the accepted level of variability is subjectively determined at the level of 20% (i.e., v_i max. 20%). Subsequently, the rank correlation is tested between the results of these countries (c_i) and the identified group of indicators. A typical indicator is one that meets the following three conditions:

- the variability in absolute values is less than 20% (coefficient of variance);
- the position of the indicator is stable, i.e., the variability of ranking position does not exceed 20%;
- there is no linear correlation with the results of the CV-TOPSIS technique.

As the last step, an analysis was performed in which the indicators were divided into above-average and below-average in each year, with the intention of showing whether a good/bad placement could be attributed to one or more indicators, and identifying any differences between such placements.

Construction and calculation of a multi-criteria model, i.e., the CV-TOPSIS technique, is based on and implemented in accordance with the procedure of Singla et al. [34] and Vavrek and Chovancová [35]. The calculation is as follows:

- Create the criterion matrix, which represents the ranking of possibilities in accordance with these characteristics:

$$D = \begin{pmatrix} & X_1 & X_2 \dots & X_j \dots & X_n \\ A_1 & x_{11} & x_{12} \dots & x_{1j} \dots & x_{1n} \\ A_2 & x_{21} & x_{22} \dots & x_{2j} \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_i & x_{i1} & x_{i2} \dots & x_{ij} \dots & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_m & x_{m1} & x_{m2} \dots & x_{mj} \dots & x_{mn} \end{pmatrix} \quad (1)$$

where A_i is the i_{th} alternative and X_{ij} is the value of the j_{th} parameter achieved by the i_{th} alternative.

- Create the normalized criterion matrix. To get this matrix, calculate the next formula:

$$r_{ij} = x_{ij} / \sqrt{\sum_{j=1}^j x_{ij}^2} \quad (2)$$

where r_{ij} is the normalized value of the j_{th} criterion and x_{ij} is the value of the j_{th} criterion reached by the i_{th} alternative.

- Assign weights to each parameter:

$$v_{ij} = w_{ij} \cdot r_{ij} \quad (3)$$

where v_{ij} is the weight of the normalized value and w_{ij} is the weight of the parameter.

- Find and label PIS and NIS alternatives. These fictitious limits comprise real values, in most cases, and hypothetical alternatives:

$$H_j = \max(w_{ij}), D_j = \min(w_{ij}) \quad (4)$$

where H_j is Positive Ideal Solution (PIS), and D_j is Negative Ideal Solution (NIS).

- Compute the distance from these alternatives:

$$d_i^+ = \left[\sum_{j=1}^k (w_{ij} - H_j)^2 \right]^{1/2}, d_i^- = \left[\sum_{j=1}^k (w_{ij} - D_j)^2 \right]^{1/2} \quad (5)$$

where d^+ is the distance from the PIS alternative and d^- is the distance from the NIS alternative.

- Calculate the relative distance from the PIS alternative (in terms of alternatives, minimizing the distance from the PIS (d^+) and maximizing the distance from the NIS (d^+) are desired):

$$c_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (6)$$

where c_i is the relative distance from the PIS alternative.

Further details of these methods, as well as possible applications, can also be found in the studies of Kokaraki et al. [36], Rozentale et al. [37], Singh and Dasgupta [38], Yuan and Luo [39] and Wang et al. [40]. Consequently, a graphical representation of the TOPSIS technique is shown in Figure 1. As Vavrek [41] notes, each white ball represents one available alternative while the grey ball represents the negative ideal solution (NIS) and the black ball represents the positive ideal solution (PIS). Further, the white ball that is relatively near the black ball and away from the grey ball would be the best alternative amongst all [42,43].

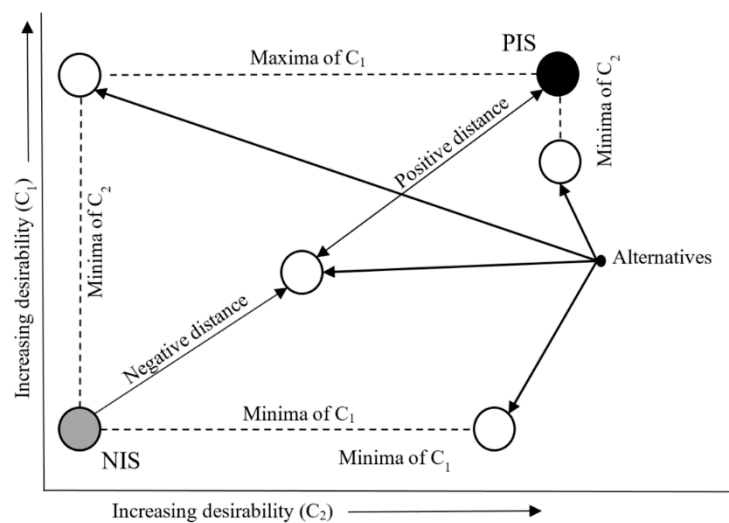


Figure 1. Graphical presentation of the TOPSIS technique.

Since it is impossible to assign weight to monitored indicators at one's convenience or according to opinion supported in professional literature (that is not unified regarding the importance of financial indicators), we decided to apply an objective method—Coefficient of Variance—which is already successfully applied for this purpose [35,41]. Results obtained were subjected to the statistical analysis including various tests—Shapiro-Wilkov test (SW), Kruskal-Wallis test (Q) and Levene test (LE). Data were obtained from the EUROSTAT database and processed in MS Office Excel, Statgraphics XVIII and Statistica 13.4.

4. Results

The presented research was carried out within the intentions defined in the methodology (i.e., Section 3), namely, using eight indicators whose weight was determined by the CV method and which were subsequently used in the calculation of the TOPSIS technique. In the first part, we focus on calculated weights, in terms of differences, as well as long-term development. The second part presents the overall results of the evaluation thus obtained, with primary attention being paid to the third part. It identifies the causes of the evaluation of selected EU countries whose ranking position has been identified as stable and balanced over the long term.

4.1. Evaluation of the Weight Balance of Individual Indicators

In this section, attention is paid to the weights of the input indicators, which were determined using the CV method. The intention was to identify differences in the variability of the importance so determined; in the context of long-term sustainability, the desired state is to achieve the highest possible balance. However, it should be noted that the differences in the variability of individual indicators are due to their interconnection and cumulative frequency in each year ($f = 1$). The graph in Figure 2 shows the structure of the calculated weights, showing variability across individual indicators (for information on individual years, see Supplementary material B).

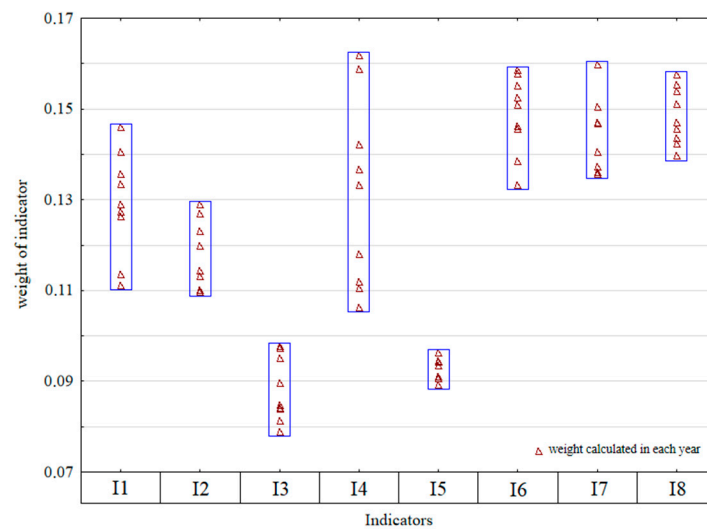


Figure 2. Structure of the weights determined by the CV method (w_{ij}) based on the results in 2008–2016.

The variability of individual weights shows considerable differences, and these differences can be considered statistically significant from the point of view of mean values ($Q = 55.411$; $p < 0.01$). Therefore, we can confirm the research hypothesis no. 1 (RH1). The reason for this is the significant difference in the pair of weights of the indicators I3—price of electricity and I5—energy productivity, which were evaluated as the lowest during the whole monitored period, or in other words, these indicators were the least important, with the weight of these indicators ranging from 0.0787 to 0.0975. Similar conclusions were reached when comparing the variance ($LE = 6.525$; $p < 0.01$), namely, heteroscedasticity, when the variance of 12 pairs of weights (out of 28 created) was different. When evaluating this structure across the particular years of the reporting period, it can be stated that there are no significant year-on-year changes ($Q = 0.115$; $p = 1$; $LE = 0.182$; $p = 0.992$); i.e., we consider the structure of the weights to be balanced and stable in the long term.

Despite the absence of statistically significant differences in mean value or variance, we can still observe changes in the variance (Figure 3). The most notable differences in the weights determined by the CV method were observed in 2014, when energy imports ($w_{I4} = 0.161$) was considered the most important indicator. The indicator with the least weight this year was energy price ($w_{I3} = 0.078$). After two years, however, we can observe a significant reduction in differences between weights, or their equalization, accompanied by a decrease in the variation range of 40.46% ($R_{2016} = 0.049$).

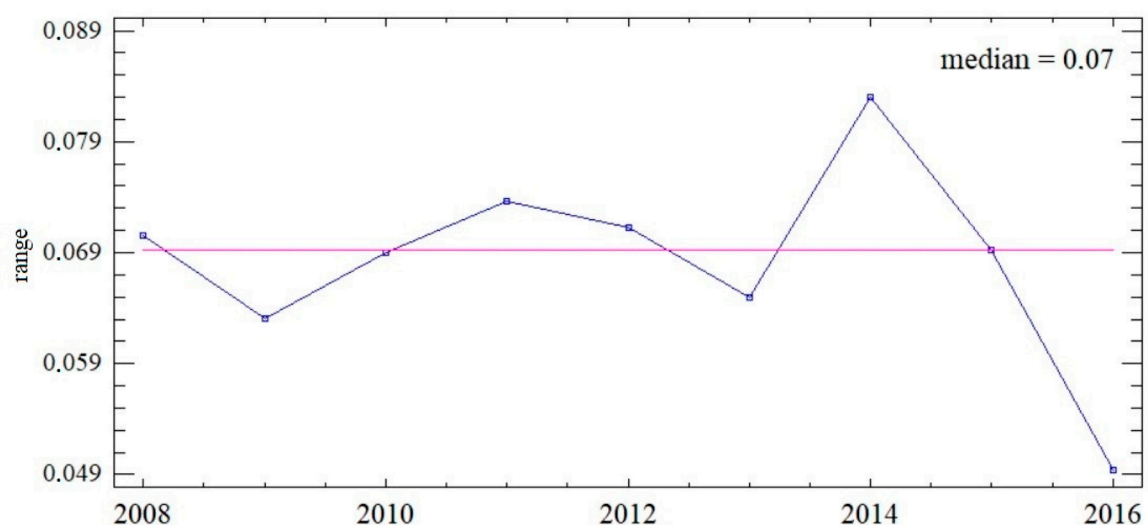


Figure 3. Development of a variation range across the observed period 2008–2016 (w_{ij}).

Then comparing the development of weights over the years (Figure 4), we observe an overall weight gain in the case of half of the monitored indicators, with the most significant being recorded by energy imports ($\Delta w_{I4} = 33.74\%$). The most significant decrease can be seen in the indicator I6 ($\Delta w_{I6} = -15.99\%$). This decrease is continuous, with the exception of 2011. Nevertheless, this indicator was considered the most important in 2011–2013.

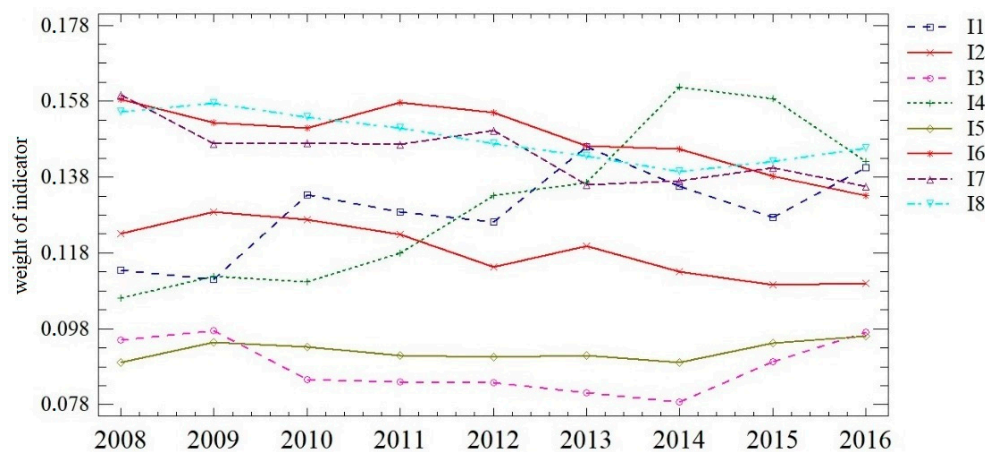


Figure 4. Development of weights of individual indicators in 2008–2016 (w_{ij}).

The high relative variability in the weights of the indicators under review (Table 2), especially in the case of CO₂ intensity in the energy sector (I1), electricity prices (I3) and energy imports (I4), does not allow their future development to be predicted. For the other indicators, a possible estimated value using linear regression (and the least squares method) would show a high error rate ($R^2 < 0.8$). Nevertheless, we expect the weight of energy productivity to be in the range of $w_{I5} \in (0.094; 0.102)$ and the R&D expenditure in the range of $w_{I8} \in (0.141; 0.149)$ in the near future.

Table 2. Relative changes of weights of individual indicators during the period under review (%).

	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	08/16	Min	Max	Range
I1	−2.18	20.05	−3.36	−1.99	15.56	−7.13	−6.06	10.36	23.76	−7.13	20.05	27.19
I2	4.68	−1.54	−3.05	−7.07	4.82	−5.57	−3.10	0.39	−10.60	−7.07	4.82	11.89
I3	2.62	−13.12	−0.72	−0.35	−3.06	−3.12	13.58	8.70	2.26	−13.12	13.58	26.70
I4	5.22	−1.23	6.82	12.83	2.63	18.40	−1.89	−10.45	33.74	−10.45	18.40	28.85
I5	6.02	−1.21	−2.48	−0.52	0.54	−2.12	5.83	2.01	7.95	−2.48	6.02	8.50
I6	−3.84	−0.97	4.56	−1.67	−5.74	−0.52	−4.88	−3.81	−16.00	−5.74	4.56	10.30
I7	−8.05	0.12	−0.20	2.46	−9.54	0.87	2.44	−3.44	−15.05	−9.54	2.46	12.00
I8	1.46	−2.32	−1.85	−2.69	−2.28	−2.80	1.89	2.38	−6.20	−2.80	2.38	5.18

4.2. Evaluation of EU Countries Based on the Results of the CV-TOPSIS Technique

While the content of the previous Section 4.1 assessed the importance of the selected indicators (by determining the weight using the CV method), the content of this part interprets the results obtained using these scales and the TOPSIS technique, with the aim of objectively assessing the energy performance of EU countries. However, the results obtained should be seen within the possible range, i.e., the interval $c_i \in (0; 1)$. Figure 5 shows the structure across the years of the reference period. (for information about individual countries, see Supplementary material C).

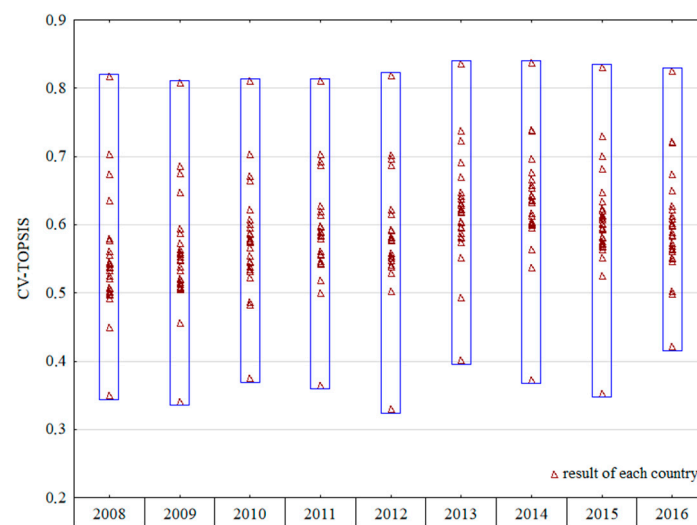


Figure 5. Structure of CV-TOPSIS results (c_i) across the observed period 2008–2016.

Within the results for the years 2008–2016, we observed minimal differences in terms of the variation range of the overall results, and the Levene test confirmed their homoscedasticity ($LE = 0.032$; $p = 1$). We observe a different variability (expressed in a variation coefficient decrease of 2.86 percentage points), especially when comparing the border years, which led to rejection of the null hypothesis of the Kruskal-Wallis test ($Q = 57.293$; $p < 0.01$), i.e., a confirmation of the differences between results for individual years. Therefore, we can confirm the research hypothesis no. 2. A slight increase or improvement in the energy efficiency of EU countries can primarily be observed until 2014 (in the form of an increasing median and average). In 2015, with the exception of Estonia, the results deteriorate, which also continue in 2016 in the majority of countries.

From the perspective of countries, we observe striking differences in the form of a minority of countries whose results were outperformed by the results of other countries in the long term ($Q = 175.265$; $p < 0.01$) and are not expected to decrease in the near future (see Figure 6).

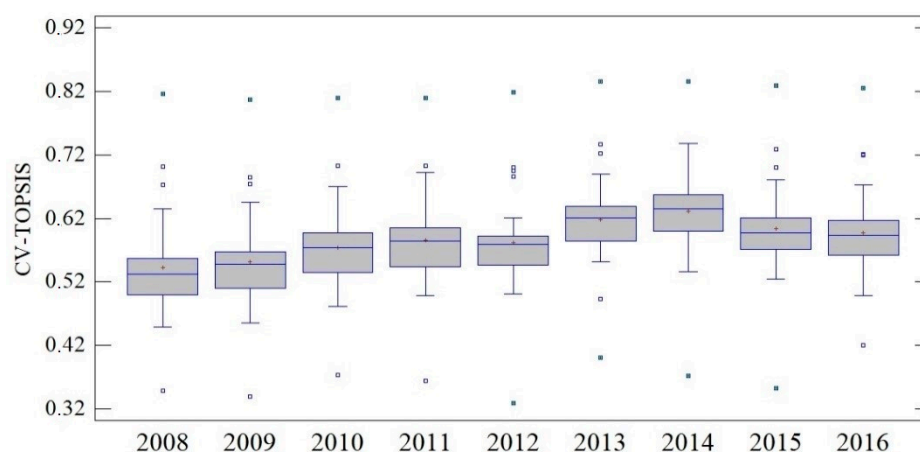


Figure 6. Results structure of the CV-TOPSIS technique (c_i) across the observed period 2008–2016.

As we can see in Figure 6, in each of the years 2008 to 2016, it is possible to identify the countries whose results can be described as having outlying or extreme values on either side of the evaluation spectrum. The best-rated country was Sweden, whose rating did not fall below a 0.80 relative distance to the PIS alternative. Luxembourg was placed at the other end of the ranking, with results not exceeding 0.42 ci. In the case of other countries, it is not possible to speak of an annual recurring situation in the form of a remote or extreme rating position.

The countries evaluated in this way were divided into four groups (Q1–Q4); the condition for their inclusion in the group was being in the same quartile during each year within the reference period, e.g., the aforementioned Sweden has always ranked first, in Q1 (see Table 3).

Table 3. Classification of selected countries based on long-term results of the CV-TOPSIS technique across the observed period 2008–2016.

Group	Countries
Q1	Austria, Denmark, Finland, France, Latvia, Sweden
Q2	Romania, Slovenia
Q3	Netherlands, Slovakia
Q4	Cyprus, Luxembourg

The purpose of such a division was to identify countries whose status has changed as little as possible over time. As indicated above, Table 1 therefore captures the countries that ranked in the same quartile (Q1–Q4) in each of the years under review, i.e., their position was stable. In the case of other countries, we observe the difference of at most one group, attributing this change of classification to partial results in individual years, not to a long-term trend.

4.2.1. Identifying Common Features of Countries in Group Q1

To identify the causes of the status, the results of the best-ranked group of countries, namely, group Q1, in each of the years under review, are analyzed. In order to classify one of the indicators, or the level of one of the indicators, as is typical for this group of countries, we proceed in the context of the above three steps, i.e., we focus on the variability of the absolute results of individual indicators, variability of the location of these indicators and their relationship with the overall results.

As Table 4 suggests, the variability in absolute values of the indicators under review in the individual years is high. The differences between the indicators are significant, which makes it impossible to consider any of them as typical for this group of EU countries. In the context of possible overall changes that could partially negate the significant absolute differences between EU countries, in the next step we focus on the location of countries on the basis of individual indicators (Table 5).

Table 4. Coefficient of variation of the indicators in group Q1 (%) across the observed period 2008–2016.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
I1	80.66	83.59	83.26	77.36	70.34	76.29	78.40	65.09	68.16
I2	52.65	53.19	49.17	49.85	47.10	46.97	45.22	43.04	45.16
I3	40.75	36.67	36.70	33.63	32.63	30.55	29.74	28.77	29.77
I4	87.23	83.65	81.12	80.26	70.39	66.20	54.22	60.68	54.72
I5	36.87	38.37	39.41	39.49	40.92	41.02	43.56	42.61	41.98
I6	32.35	30.95	33.21	32.85	32.51	31.55	32.42	31.50	32.59
I7	60.75	55.67	57.35	57.22	56.69	52.70	53.95	56.31	52.77
I8	54.13	54.05	53.42	53.25	52.55	52.81	51.21	52.69	54.45

Table 5. Coefficient of variation of the indicator ranking in group Q1 (%) across the observed period 2008–2016.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
I1	106.92	107.97	99.20	100.09	100.01	101.97	98.92	91.36	74.79
I2	87.53	83.39	67.32	79.33	81.70	74.04	73.62	74.81	75.84
I3	59.17	57.23	64.09	57.51	55.16	53.50	44.82	35.99	30.34
I4	58.67	57.35	54.49	62.87	61.85	62.40	53.96	60.96	59.93
I5	67.43	70.32	69.23	66.73	68.08	62.20	63.79	62.41	58.66
I6	33.62	31.61	28.88	30.09	27.60	26.76	24.36	25.94	25.94
I7	87.49	92.58	92.58	106.31	101.98	101.98	106.31	106.31	106.31
I8	118.86	124.15	125.29	122.82	126.42	126.42	123.98	122.82	119.60

However, similar conclusions can be stated on the basis of position variability or ranking of the monitored indicators, which, to a large extent, copies and multiplies the differences identified on the basis of absolute values. This suggests that a significant absolute change (worsening or improvement of the indicator) is rather rare and is associated with a more significant change in the ranking of the country.

The last aspect of our analysis, i.e., the linear correlation of individual indicators with the overall results of the CV-TOPSIS technique, would eliminate half of the indicators (I2, I3, I6, I8), which correlated linearly with the overall results in at least one of the nine years under review. With the exception of 2009 and 2010, there has always been a positive correlation between overall results and the volume of R&D expenditures; i.e., expenditure in this area strongly stimulates an overall positive assessment (see Table 6).

Table 6. Significant rank correlation of overall results with individual indicators ($\alpha < 0.05$) across the observed period 2008–2016.

2008	2009	2010	2011	2012	2013	2014	2015	2016
I6, I8	I6	I2, I6	I3	I8	I8	I8	I8	I8

Based on the above, it is not possible to identify any of the indicators used in the clearly defined range as typical for positively assessed countries. Their variability is too significant, which in the context of a long-term results analysis may indicate a link between the overall assessment and a larger group of indicators (since it is not possible to attribute a good assessment to only one indicator or small group of indicators that would compensate the loss in the other monitored areas).

4.2.2. Identifying the Causes of the Countries' Status Based on Individual Indicators

Since, in the previous section, we could not prove that any of the indicators are typical for positively evaluated countries, we turned our attention to the position of countries at the level of individual indicators. The intention was to identify whether one or more of the positively (or above average) evaluated indicators can be sought for the success of the country (CV-TOPSIS).

The results of the sequential linear correlation indicate a moderate correlation of the overall assessment with the individual indicators evaluated (Table 7), i.e., with a growing ci (relative distance to the PIS alternative), the share of above-average indicators also increases to some extent, and vice versa; however, this may not be parallel and automatic. To identify the common characteristics of positively evaluated countries (i.e., countries in group Q1), the proportion of above-average indicators in the individual years of the period under review is monitored. Results are captured in Table 8.

Table 7. Linear correlation between overall results and the ratio of above-average indicators across the observed period 2008–2016.

2008	2009	2010	2011	2012	2013	2014	2015	2016
0.436 *	0.522 *	0.489 *	0.470 *	0.485 *	0.436 *	0.576 *	0.509 *	0.455 *

* Significant at the significance level $\alpha < 0.05$.

Table 8. Share of above-average indicators of countries in the Q1 group across the observed period 2008–2016.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Denmark	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
France	0.875	0.875	0.75	0.75	0.75	0.75	0.625	0.75	0.625
Latvia	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.625
Austria	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.5
Finland	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Sweden	0.625	0.625	0.625	0.625	0.625	0.75	0.75	0.625	0.75
Average	0.625	0.625	0.604	0.604	0.604	0.625	0.604	0.604	0.563

Based on the above results, we can conclude that for long-term placement in the group of the best-rated EU countries, it is necessary to achieve above-average results in an average of five out of the eight monitored indicators. These results confirm, i.a. the complexity of the set of indicators used, and underlines the fact that focusing on one area can be considered insufficient. Therefore, we can reject the research hypothesis no. 3.

When comparing countries in groups Q1 and Q4 (Table 9), we can see significant differences in CO₂ emissions (I2), energy imports (I4) and total consumption of RES (I7). Therefore, we can see that the differences in these indicators constitute the primary reason for the better position (or ranking) of the countries. One interesting fact is the better energy productivity values of the countries in group Q4.

Table 9. Share of above-average indicators of countries in the Q1 and Q4 groups across the observed period 2008–2016.

	I1	I2	I3	I4	I5	I6	I7	I8
Countries Q1	0.67	0.65	0.46	0.52	0.67	0.17	0.89	0.83
Countries Q4	0.39	0.06	0.11	0.00	0.94	0.22	0.17	0.50

5. Discussion and Conclusions

This paper has examined the energy performance of EU MSs by performing a multi-criteria analysis of selected indicators focused on the priorities of the European Energy Union.

Multi-criteria assessment is a method that is currently widely used in practice [35,41,44,45]. The relevance of MCA approach and its suitability for sustainability assessment is declared by Seghezze [46]. The problem with decision-making on the basis of several criteria is the selection of suitable criteria as well the determination of their importance, which can be determined subjectively [47–49] and also by objective methods [50,51]. The presented research focused on an evaluation of EU countries in the years 2008–2016 using eight indicators, including expenditures on research and development, intensity of CO₂ emissions, energy productivity, etc., and whose weights or importance was determined using the CV method. Based on the analysis we can conclude the following:

Throughout the monitored period, we observed significant changes in the input indicators, which directly influenced the calculation of their importance, or of weights, for subsequent use in the TOPSIS technique. We observed their high relative variability, especially in the intensity of CO₂ emissions in the energy sector (I1), price of electricity (I3) and energy imports (I4). These differences make it difficult (or perhaps impossible) to reliably predict their development in the future and also confirm research hypotheses no. 1 and no. 2. Other researchers have similarly pointed out that these issues (especially I3 and I4) are dynamically changing and are influenced by global political developments, and thus there is a high degree of uncertainty [52,53].

At the same time, it is not possible to identify any of the indicators used within a clearly defined time period as typical for the positively evaluated countries (group Q1). Their variability is so notable that good overall results in our assessment cannot be attributed to a stable trend in some of the monitored aspects of energy performance. Attention must be paid to the evaluation as a whole, which reflects dynamically on changes within the EU countries. Therefore, we have to reject the third research hypothesis.

In particular, we see differences in assessing CO₂ emissions (I2), energy imports (I4) and total consumption of RES (I7), which, in the majority of Q1 countries, are above average in most cases and different from Cyprus and Luxembourg, which were placed in the lowest quartile of the countries (i.e., group Q4) over the whole period.

As stated by the European Commission, the aim of the EEU is to ensure the transformation of energy into an affordable, competitive, secure and sustainable energy system [3]. The achievement of this goal is influenced by the differences between individual EU countries, which have not declined in the last decade but, on the contrary, increased. Appropriate attention should be paid to eliminating this heterogeneity at the level of the indicators identified above.

Although the paper is focused primarily on energy, it is necessary to adopt “thinking out of the energy box.” We agree with the study of Fabiani et al. [54], Venghaus and Hake [55] and others that cross-sectoral effects (e.g., on water, agriculture but also other sectors) should be taken into consideration in policy design. We saw long-term disparities between EU countries in CO₂ emissions, energy imports and overall renewable energy sources (RES) consumption, in which countries with long-term positive results in the CV-TOPSIS evaluation also achieved better results.

The results of our research can primarily be used to create a strategy in the form of real targets that EU countries should achieve in the medium and long term. The presented research also points out that it is not realistic to expect a quick reduction in differences between EU MSs, for example in CO₂ emissions, energy imports or total RES consumption. Based on long-term monitoring of the development of individual indicators in the evaluated period, we did not record their convergence. On the contrary, the differences either persisted or increased slightly.

Supplementary Materials: The following are available online at <http://www.mdpi.com/1996-1073/13/20/5317/s1>, Supplementary material A: Descriptive statistics of selected indicators across the observed period 2008–2016; Supplementary material B: Weights of selected indicators calculated by Coefficient of Variance method (CV); Supplementary material C: Results of the multi-criteria evaluation calculated by CV-TOPSIS technique.

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