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Energy Security in Light of Sustainable Development Goals

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Abstract: Energy security affects the functioning of countries politically, economically, and socially. Energy is an important factor in sustainable development efforts. Hence, countries are assessing their energy systems for compatibility with sustainable development goals by creating new concepts for energy development. Combining the concepts of energy security and sustainable energy consumption, an analysis of the differentiation of EU countries in terms of selected indicators indicated in Goal 7 of Agenda 2030 was carried out in dynamic terms. Two groups of indicators were distinguished. One group of indicators was selected to represent the changes in energy demand reported by final consumers, taking into account the use of energy obtained from renewable sources. The second group of indicators represents those relating to the security of supply of raw materials, i.e., energy dependency indicators broken down by major energy commodities and an energy productivity indicator. The analysis uses the coefficient of relative proximity of the facility to the ideal facility proposed in the TOPSIS method. The analyses carried out do not indicate that there is a relationship between the level of sustainable energy consumption and energy productivity or energy import dependency. A statistically significant correlation was observed between energy import dependency by oil and petroleum products and primary energy consumption, and between the share of renewable energy in gross final energy consumption and total energy import dependency.

Keywords: sustainable development; dependence on energy resources; sustainable energy; energy policy

Citation: Luty, L.; Zioło, M.; Knapik, W.; Bąk, I.; Kukuła, K. Energy Security in Light of Sustainable Development Goals. *Energies* **2023**, *16*, 1390. https://doi.org/10.3390/en16031390

Academic Editors: Seung-Hoon Yoo and Alban Kuriqi

Received: 7 December 2022
Revised: 4 January 2023
Accepted: 22 January 2023
Published: 30 January 2023

1. Introduction

Energy generation and consumption using technologies that prevent adverse environmental impacts are important contributors to sustainable development. The 2030 Agenda for Sustainable Development includes 17 Goals. One of them, Goal 7, is dedicated to energy. Its main premise is to ensure access to reliable, sustainable, and modern energy at affordable prices for everyone. The following has been noted regarding this Goal: Access to energy is necessary to overcome challenges and take advantage of numerous opportunities today. It is needed for work, security, combating climate change, food production, or increasing national incomes. Sustainable energy is a chance for a better future because it has the potential to transform human life, entire economies, and even the planet [1]. Unobstructed access to energy resources is important for the realization of Sustainable Development Goals. Awareness of the supply of resources will help shape the groundwork for the energy policies of individual states. Many of them decide to diversify energy sources to secure energy supply to final consumers.

In order to ensure energy security, policymakers need to consider several factors that are political, legal, economic, engineering, technological, and environmental in nature. In this case, it is not only any deposits of energy resources in the territory of a state that are of import, but also the diversification policy for their sourcing. Renewable energy is becoming more important in the energy mix, and its growth dynamics are increasing, catalyzed by climate policy. Another important contributor to energy security is energy infrastructure with which it is possible to obtain, transfer, distribute, and store energy resources and final energy. How effectively it is used depends mostly on the political situation, particularly internal and international stability.

The objective of the paper is to assess the dynamics of energy security and sustainable energy consumption as components of energy policies of member states from 2010 to 2020 in light of Goal 7 (affordable and clean energy) of the 2030 Agenda. During the implementation of the main objective, the following specific objectives were set:

First, the notion of sustainable development and sustainable energy are introduced. Second, the theory of energy security is presented, indicating the main factors emphasized in the definitions. It is worth emphasizing that universal access to energy at an affordable price is most often indicated. This indicates the importance of the economic factor in assessing energy security.

The authors' contribution consists in dividing Goal 7 indicators into the demand and supply side and conducting an analysis of this arrangement.

The first stage of the empirical part that assesses supply security characterizes the degree of dependency of EU member states on energy imports. Next, we selected those that reflect the dependency on energy imports. We also included energy productivity in the security domain, assuming that effective energy consumption is intended to reduce the amount of energy needed to deliver products and render services, which will slow down the pace of depletion of national energy resources and help curb energy import.

This way, we were able to identify countries with the best energy supply security levels and those that need to take action to become independent of energy import.

The other stage of the empirical part investigated the effort toward sustainable energy consumption. We chose those indicators for Goal 7 that characterize energy consumption in aggregate and per capita. Considering the impact of renewable energy sources (RES) on energy security, the assessment of sustainable energy consumption covered also the share of renewable energy in the total energy consumption. We assumed that RES consumption involves mostly RES typical of the country and independent of imports.

1.1. Literature Review on Definitions of Sustainable Development

Sustainable development is defined as a type of socioeconomic development that rejects the egocentric approach to development and extreme anthropocentrism, particularly any short-sighted one. Today, the notion also covers a new approach that goes beyond environmental concerns and emphasizes intergenerational equity, stability of the environment, and quality of human life. Cheba and Bąk stressed that the literature offers about 500 different definitions of sustainable development [2]. The Brundtland Report [3], which significantly contributed to the sustainable development nomenclature, pointed out three important implications of the proposed definitions of this type of development:

- Environmental commitments towards future generations;
- Intra- and interspecies equity;
- Sustainability as a process rather than a state.

When considering intergenerational equity, Haughton [4] concentrated on natural, environmental capital. Therefore, his main focus was frugal consumption of natural resources, recirculation of resources, maintaining a balance between consumption and investments, and ensuring demographic sustainability, which has often been downplayed.

Since the problem of sustainable development comes in so many dimensions, a researcher can follow any of them to search for a global or local dynamic balance. The complexity of the balancing process emerges from often conflicting interests of various economic stakeholders and diversified distributions of the bundle of benefits for consumers and the environment, their interrelationships, conditions, and feedback loops. Therefore, it is a daunting task to achieve a reasonable understanding of the specific conditions of a specific region with its socioeconomic and demographic structure. This is because a change that makes development sustainable goes far beyond the classical three-factor understanding of sustainable development.

It can be achieved with an analysis and assessment of ecological, economic, societal, psychological, demographic, spatial, and intertemporal balance dimensions proposed by Roszkowska [5]. Environmental, or ecological, balance is mainly about maximizing the net benefit from economic development while sustaining the usability and quality of natural resources. Economic balance means shaping development factors to optimize the use of factors of production and ensure economic growth. It is linked to societal balance whereby well-being is distributed among various social groups that generate it [6,7]. When an increase in income per capita is combined with an improvement in non-economic areas of societal life, it is well received and understood, which paves the way for the intellectual development of the people involved. This creates a psychological balance. Moreover, a demographic balance is struck when demographic processes are adapted to ecological processes and environmental capacity. Then, there is no disharmony in the functioning of the economy, environment, and society. If the phenomena referred to above occur in a stable and sustainable environment, a spatial balance is achieved. The last dimension in the multiple-criteria assessment of development sustainability is the intertemporal balance, which means no significant disruption of the future generations' opportunities to satisfy needs regarding environment accessibility similar to the needs satisfied now in this regard.

Kates, Leiserowitz, and Parris [8] proposed four ways to define sustainable development through goals, indicators, values, and economic practice. However, their approach fails to consider changing social needs, spatial components, and cultural differences. It focuses on the economic aspects, which determine how human well-being is shaped and affects or even controls the quality of human life. Depending on the author, the number of goals may change. Sachs [9], like Griggs [10], point to 6 goals and the United Nations to 17 [11]. The number of proposed indicators for assessing sustainable development ranges from the 56 mentioned by Hassini [12], to the 130 indicated by Andrada [13] and even the 220 indicated in the Rio Declaration [14]. Some authors link sustainable development to specific topics, such as 30 energy indicators as in the case of work Very and Langloisa [15].

Sustainable development can be defined as economic development that is stimulated by popular demand and realized according to reasonable economic principles considering ecological dimensions [16]. Janka [17] enumerated the following primary goals of sustainable development:

- Equal access to natural resources (also for future generations);
- Sustainability of any environmental processes and ecosystems;
- Preservation of non-renewable resources and letting renewable resources renew;
- Increasing the share of green projects;
- RES in global economies and improvement of the environment and life quality. Konstańczak [18] emphasized that the idea behind sustainable development is to improve both the condition of our planet and the quality of human life through consistent effort in specific areas.

In 2015, the UN adopted a 2030 development strategy. All UN member states unanimously passed the resolution with 17 Sustainable Development Goals to be reached by 2030.

Regarding the sustainable development strategy, it is emphasized that a modern model of life has to be promoted that takes into account the appropriate environmental policy and philosophy that counter past practices of short-sighted exploitation of the Earth's resources [19,20]. This concept is of significance for resource-based energy generation, and Goal 7 of the 2030 Agenda provides for energy security on the resource supply side and also on the consumer side as they contribute to sustainable energy consumption through their actions (Figure 1).

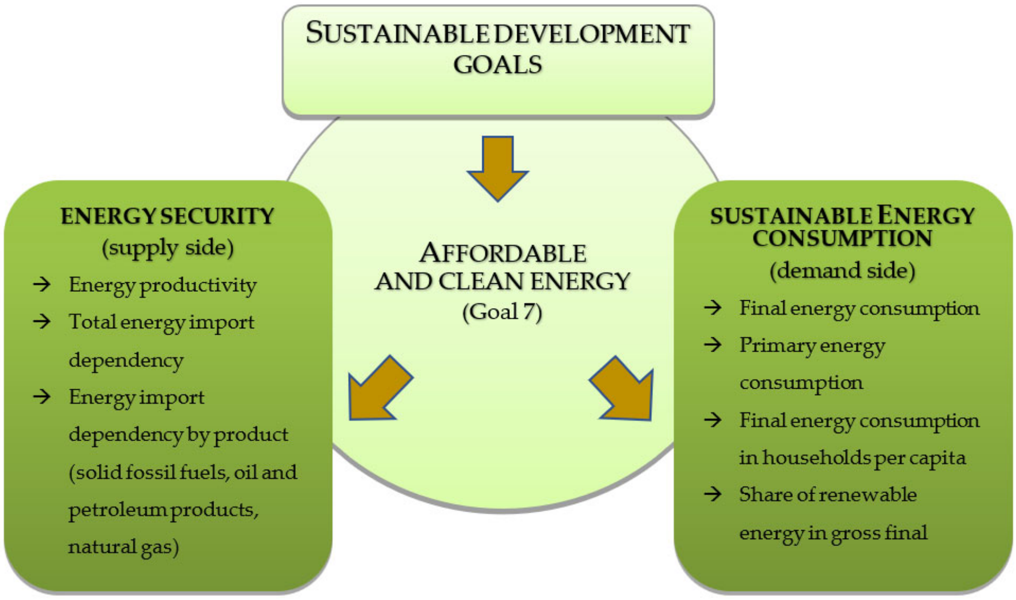

Figure 1. Indicators for Sustainable Development Goal 7.

1.2. Definitions of Energy Security

In the last century, energy resources and electric energy were the underpinnings of efficient global economies. This is why energy security has become such a relevant political, economic, and societal matter in every state. It guarantees a country's economic growth and preservation or even improvement of the living standards. For many EU states, energy security is becoming a major factor of foreign policy, and many experts believe it to be part of national security, and then even international security [21].

Keeping in mind the factors of energy security listed in Table 1, one can also take a step back to the more traditional definition that energy security means satisfying consumer demand for fuels and energy, taking into account:

– Technological security;
– ROI;
– Continuity and reliability of supply;
– Price acceptability [22,23].

Table 1. Factors most often indicated in the definitions of sustainable energy.

Factors	Economic		Environmental		Social
Sources	**Availability of Energy**	**Affordable Price**	**Using Renewable Sources**	**Environmental Sustainability**	**Improve the Quality of Peoples' Lives**
Dincer (2000), [24]	+		+	+	+
Vera, Langlois (2007), [25]	+			+	+
Peidong et al. (2009), [26]	+	+	+	+	+
Kruyt et al. (2009), [27]	+	+		+	
Sovacool and Brown (2009), [28]	+	+		+	
Hashim, Ho (2011), [29]	+		+	+	+
Nautiyal et al. (2011), [30]	+		+	+	+

Table 1. *Cont.*

Factors	Economic		Environmental		Social
Sources	**Availability of Energy**	**Affordable Price**	**Using Renewable Sources**	**Environmental Sustainability**	**Improve the Quality of Peoples' Lives**
Koyama, Kutani (2012), [31]	+	+			+
Martchamodol, Kumar (2012), [32]	+	+		+	+
International Energy Agency (2017), [33,34]	+	+	+		
World Bank (2017), [35]	+	+			+
Gunnarsdottir et al. (2022), [36]	+		+	+	+

It can also be perceived as the reliability of the supply of energy and energy carriers. In broader terms, energy security is first and foremost 'a condition where all citizens and businesses in a territory of a state have access to energy sources that satisfy their needs through the uninterrupted transfer and the energy prices are acceptable and can be estimated for the foreseeable future' [37]. Other important factors of energy security are the efficiency, condition, and capacity of infrastructure and the security of transfer, production, and extraction systems.

When discussing the rather wide topic of energy security, one has to note some additional aspects that organize the problem by indicating certain dimensions:

Economic—encompassing trade of all energy resources where importers look for cheap and reliable sources and exporters seek stable target markets and transit countries. Such trade requires initiatives to reach acceptable prices through negotiations and considering market changes;

Geopolitical and geostrategic—involving drafting and implementing primary premises for energy strategies to ensure the security of resource supply. Such strategies include the effort to diversify energy sources, steward national resources, and preserve stable levels of energy resources. They also define tools and institutions responsible for rapid crisis response;

Environmental—focusing on projects in the energy sector such as gas emissions, resource production, mining, and so on, and indicating actions that could minimize the adverse impact of such operations on the natural environment [38].

The effort to improve energy security can be directed internally and externally: The first group includes:

- Actions to maintain the reliability of supply;
- Compliance with environmental regulations; diversification, and keeping of state's fuel balance;
- Diversification of sources and supply routes of energy resources;
- Efficient production, mining, transfer, and distribution systems for fuels and energy;
- Continuity of supply to ensure the security of final consumers;
- Economic competitiveness of the energy industry [39].

The key external factors affecting energy security are the geopolitical environment (EU) and trade directions for primary energy resources. In the case of EU states, most resources used conventionally for energy production come from the Russian Federation. Other important determinants of energy system security are the energy and climate policy of the EU, the energy policy of Russia, and policies of and transformations in other countries with abundant energy resources [40].

Regulation (EU) No 994/2010 concerning measures to safeguard the security of gas supply and repealing Council Directive 2004/67/EC (hereinafter regulation 994/2010). The regulation defined diversification of routes and sources of gas supply as the foundation of energy security [41]. It stimulated the construction of bidirectional gas pipelines in Europe. In addition, regulation 994/2010 introduced three main crisis levels:

1. The first, warning level occurs in the case of a gas supply disruption threat.
2. The second, alert level occurs in the case of gas supply disruptions or in the case of an exceptionally high gas demand if gas shortages occurred. In such a case, companies with gas stocks should sell excess amounts.
3. The third, emergency level involves non-market gas supply mechanisms but only when the other two levels failed to improve gas supply.

The emergency level can be announced only by the European Commission following a request by a member state. If multiple member states put forward the motion, the European Commission announces an emergency for the entire territory of the EU or a region.

Russia is the leading supplier of natural gas, oil, and coal to the EU, which are the main energy resources in the EU's energy mix.

The primary imported energy resource in the EU is oil. The total oil imports to the EU in 2020 amounted to 440.3 Mt. Import dependency was record-high in 2020 when the EU's net import was 96.96% for oil and petroleum products. The largest share, 113 Mt, of the imported oil and petroleum products came from Russia; although, its contribution to the EU's oil imports has been dwindling since 2016, as the data shows. European fuel companies import oil also from Saudi Arabia, Iraq, and Kazakhstan.

Regarding solid fossil fuels, mainly hard coal, the member states were much less dependent on imports from Russia. It covered 19% of solid fossil fuels consumption in the EU. Some countries that relied on coal imports increased the share of RES in their energy mixes in recent decades. Ireland, Latvia, Portugal, and Austria cut down on solid fossil fuel energy the most. Ireland improved its self-sufficiency by investing in RES [42,43]. Latvia generates more than 70% of its energy in hydroelectric power plants [44]; Portugal increased its off-shore wind power generation [45,46]; Finland focuses on greater biomass use [47]; and Austria obtains its power from hydroelectric facilities [48].

1.3. Energy Security in Light of Sustainable Development Goals

An energy policy that ensures energy security permanently improves quality of life. An efficient and reliable power generation system fosters cohesion in societal, economic, and territorial (environmental) dimensions, which is typical of sustainable development. The societal element of energy security involves many aspects. Energy availability directly affects the labor market and poverty. In particular, relatively expensive energy is a burden on the household budget and deters investments and entrepreneurial effort. How energy is generated and consumed affects health, especially through environmental pollution. Furthermore, energy availability and quality indirectly affect educational opportunities, a sense of security, and social inclusion or exclusion. The societal aspect is also linked to occupational safety and failure risk control, which influence accidents related to the extraction, conversion, transfer, distribution, and consumption of energy.

Modern economies need reliable and affordable energy supply. Its availability to modern services that reduce costs is of great importance. Development of the local energy industry and services helps improve efficiency and competitiveness while affecting jobs, workforce productivity, and employee income.

Energy efficiency is important for economic growth, the economy's structure, and new technologies. It shapes consumer preferences and behavior. The indicator codetermines costs and competitiveness in the international market.

One of the primary goals of sustainable development is to ensure energy security. International net energy flows and fuel reserves are paramount to any assessment of energy security.

Not only do diversification of energy supply, growth in distributed energy systems, and supply reliability improve the economic security of energy industry growth, but they also significantly affect prices of energy and energy carriers in the national market.

They shape competition among suppliers in the market, which may reduce and diversify prices. On the other hand, subsidies, taxes, and covert support may distort energy carrier and energy pricing. It is of vital importance not only for effective energy supply and consumption but also for allocating capital to investments in specific energy technologies.

Energy production, distribution, and consumption exert environmental pressure. The environmental impact depends mostly on the production and consumption technologies and methods.

Atmospheric emissions deteriorate air quality. Human health is particularly affected by so-called low-stack emissions (emissions that occur below 40 m above the ground). These air pollutants such as ozone, sulfur and nitrogen oxides, carbon oxide, and dust close to the ground are detrimental to plants, animals, soil, and water.

Climate change, caused to a large extent by energy industry greenhouse gas emissions, is a global problem.

At the same time, energy sector growth transforms space and landscape. It is not only due to coal extraction and combustion, but also the construction of impounding structures and reservoirs on water courses, fuel wood harvesting, energy crops on agricultural land, construction of large photovoltaic and wind farms, and construction and operation of transmission networks and pipelines. Diversification of energy sources, including an increased share of RES, has a direct impact on national energy security.

Energy conversion processes, especially for non-renewable sources, lead to waste, including radioactive waste, which needs to be managed appropriately and can pose a threat to the public.

The environmental aspect of the power industry affects the other dimensions of sustainable development. It is linked primarily to two issues. The first one is the sustainment of development stability, which hinges on the effective use of non-renewable resources and growth in renewable resources. The other is security in a broad sense: not only regarding systemic reliability but also industry development costs. Goal 7 (clean and affordable energy) was established to assess changes in the energy area with seven indicators.

Four of them are related to energy consumption. The next two metrics, energy productivity and energy import dependency, assess national energy security.

The index of dependency on energy resources import (energy import dependency) shows how such an economy depends on the import of energy resources to meet its energy needs.

1.4. Research Gap

Due to the lack of research, there is a research gap in comparison with the places where the demand and supply side of the indicator are compared to objective 7 of the 2030 Agenda. In order to fill this gap and broaden the knowledge about the level of energy dependence of EU countries, as well as about the level of energy consumption in individual countries, research was carried out, the results of which are presented in this manuscript.

The concept of energy security can be considered from the point of view of the supply of energy resources, but when assessing this phenomenon, changes in the level of electricity consumption by end users should also be taken into account.

Awareness of the level of dependence on the supply of energy resources may be of key importance in gaining social acceptance for changes related to the energy transformation and diversification of supply sources or actions aimed at saving energy.

Moreover, the literature on the subject does not discuss the changes taking place in the researched areas over a longer period of time. The work takes into account the changes that last at least 10 years. The analyses carried out make it possible to indicate the leaders of these changes, or to identify groups of countries with a similar level of selected indicators.

Research on the energy security of EU countries in this respect gives the possibility of an objective assessment and can be used to create an effective and socially acceptable energy policy.

It can therefore be concluded that this work fills the research gap in the assessment of the level of energy security of EU countries and provides new knowledge in this field.

The diversity of EU countries and, despite a common energy policy, a certain independence in creating internal policy on this matter, makes it necessary to conduct an objective assessment of the energy security of countries.

In the context of the presented literature review, the proposed research approach is innovative, and the obtained results should enrich the knowledge about the state of energy security of EU countries.

To assess the level of energy dependence and energy consumption in the context of Goal 7 of the 2030 Agenda, the TOPSIS method was used, which, according to the authors, is appropriate for the analysis of this complex research problem.

2. Materials and Methods

The statistical input was obtained from Eurostat databases [49]. The investigation covered the years 2010–2020. Three countries were excluded from some analyses due to missing data: Cyprus, Malta, and Luxembourg. The dynamics of changes were determined with dynamics metrics.

Energy security was assessed (Table 2) with indicators assigned to Goal 7 of the 2030 Agenda. Next, we selected those that reflect the dependency on energy imports. It was observed that an increase in imports contributes to the dependency of the state on the supply, which puts the exporting state in a position to influence the energy security of energy consumers through the economy of the importing state. We also included energy productivity in the security domain. This parameter reflects how an economy uses energy, which may slow down the pace of depletion of national energy resources and help curb energy imports.

Table 2. Indicators for assessing energy security.

Variable	Full Name (Type)
W_1	Energy productivity (purchasing power standard (PPS) per kilogram of oil equivalent)
W_2	Total energy import dependency (%)
W_3	Energy import dependency by solid fossil fuels (%)
W_4	Energy import dependency by oil and petroleum products (excluding biofuel) (%)
W_5	Energy import dependency by natural gas (%)

We assessed the level of sustainable energy consumption using multivariate statistical analysis, a total ordering method. Total ordering is based on a synthetic variable the values of which are estimated from observations of diagnostic variables that describe the investigated objects. The synthetic variable is a latent variable because it is not observed directly. Total ordering was first proposed by Hellwig in 1968 in economics. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) employed here was first presented as a decision theory technique by C.L. Hwang and K. Yoon in 1981. TOPSIS is a standard-based method for aggregating variables where objects are referred to as two reference points in a multidimensional space: the positive ideal solution and the negative ideal solution. This method is widely used in socio-economic research; among others: Ishizaka and Nemery [50], Parida and Sahoo [51], Yoon and Kim [52], El Alaoui [53], and Roszkowska [54]. The algorithm for ordering states followed the procedure by Kukuła and Luty [55], which helps select the right total ordering method. Undoubtedly, the advantages of the TOPSIS method include its simplicity, comprehensibility, and the guarantee of easy interpretation of results. It uses reference points in the construction of the synthetic measure.

The construction of the synthetic metric followed a three-stage algorithm. First, we selected the features that characterized the investigated problem with the Sustainable Development Goal indicators (Table 3) and decided their type stimulant (S)—bigger the better, increases the value of the variable; destimulant (D)—smaller the better, decreases the value of the variable.

Table 3. Sustainable energy consumption assessment indicators.

Variable	Full Name [Type]
X_1	Primary energy consumption (tonnes of oil equivalent (TOE) per capita) (D *)
X_2	Final energy consumption (TOE per capita) (D)
X_3	Final energy consumption in households (TOE per capita) (D)
X_4	Share of renewable energy in gross final energy consumption (%) (S **)

* D—destimulant, ** S—stimulant.

We selected those indicators of affordable and clean energy that describe global and per capita energy consumption. Considering the impact of RES on energy system transformation towards resources of lesser environmental footprint, the assessment of sustainable energy consumption covered also the share of energy from RES in the total energy consumption. RES affect energy security as well because resources for these technologies are sourced locally, not from third-party suppliers. The selection followed from a statistical analysis. All the variables in the investigated group comply with the primary criterion for selecting variables to describe a complex phenomenon: they are not quasi-constant [56].

The next stage for formulating the synthetic variable is to normalize the diagnostic variables. The literature offers many methods and an extensive discussion on how to select them. The matter has been investigated by such authors as Perkal [57]; Hellwig [58]; Wesołowski [59]; Bartosiewicz [60]; Nowak [61]; Strahl [62]; Borys [63]; Grabiński [64]; Lira [65]; Pawełek [66]; Panek [67]; Walesiak [68]; Nermed [69]; Dębkowska, and Jarocka [70]; Czech [71]; Dudek [72]; Walesiak [73]; Izonin, Tkachenko, Shakhovska, Ilchyshyn, and Singh [74]; Ligus, and Peternek [75]; and Trojanowska, and Nęcka [76].

We followed the authors of the procedure [1] and chose the following normalization method:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \; i = 1, \ldots, n, \; j = 1, 2, \ldots, N \quad (1)$$

where x_{ij}, z_{ij}—the actual and normalized value of feature X_j for object i.

Next, we determined the coordinates of the positive ideal solution (z_j^+) and negative ideal solution (z_j^-) vector defined as follows:

$$z_j^+ := \begin{cases} \max_i \{z_{ij}\}, & X_j \in S \\ \min_i \{z_{ij}\}, & X_j \in D \end{cases} \text{ and } z_j^- := \begin{cases} \min_i \{z_{ij}\}, & X_j \in S \\ \max_i \{z_{ij}\}, & X_j \in D \end{cases} \quad (2)$$

In the absence of a substantive rationale, all variables were assigned weights equal to one.

The values of the synthetic variable as a proposal for an indicator of sustainable energy consumption in the country were estimated using aggregate functions:

$$Q_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (3)$$

where Q_i—values of the synthetic variable of object I (sustainable energy consumption indicator of object i); d_i^-, d_i^+—Euclidean distances between objects and the positive ideal solution and negative ideal solution of development defined as

$$d_i^- = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_j^-)^2} \text{ or } d_i^+ = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_j^+)^2} \quad (4)$$

The object with the highest value of Q_i is the best in terms of the investigated problem.

Correlations between the selected indicators were analyzed with the Pearson correlation coefficient or Spearman's rank correlation coefficient. They were then verified with Student's *t*-test.

3. Results

3.1. Energy Security in European Union Countries

European Union states are highly dependent on energy imports. However, they take action to diversify energy resources supply routes and improve energy efficiency. The improvement in energy productivity is a very promising trend, which grew to 22.42 from 9.8 (PPS) per kilogram of oil equivalent in the best member state (Table 4). The mean EU value improved as well. The median went up to 8.90 from 6.34 (PPS) per kilogram of oil equivalent. Basic indicators of energy security demonstrated an increase in the EU energy dependency rate in 2020 compared to 2010 due to increasing energy consumption. EU member states focused mainly on curbing solid fossil fuel use. The median energy import dependency by solid fossil fuels dropped from 89.6 to 87.02%, while it grew for the other two resources by 2.8 pp for oil and petroleum products and 1.1 pp for natural gas. At the same time, EU states grew less diversified in terms of energy dependency on these resources.

Table 4. Numerical characteristics of energy security indicators in specific years.

Variable	Specification											
	2010				2015				2020			
	min.	max.	M *	CV **	min.	max.	M	CV	min.	max.	M	CV
W_1	3.55	9.8	6.34	0.24	5.06	16.2	7.65	0.28	5.80	22.42	8.90	0.34
W_2	−16.0	87.5	49.1	0.48	11.2	88.8	50.2	0.42	10.5	81.4	55.0	0.32
W_3	−15.3	132.7	89.6	0.59	−11.4	103.0	85.1	0.66	0.33	122.1	87.02	0.55
W_4	−44.3	101.9	96.6	0.33	5.30	114.6	100.7	0.23	55.0	130.2	99.4	0.16
W_5	−68.3	100.4	92.7	0.65	−48.2	100.4	96.6	0.57	16.6	100.7	93.8	0.27

* M—median, ** CV—coefficient of variation.

Energy productivity increased in all EU states from 2010 to 2020 (Figure 2). The leaders for 2020 were Ireland (126% up vs. 2010), Romania (up 77%), and Denmark (up 67%). The lowest progress was made in Finland, Bulgaria, and Slovakia. Slovakia was the only EU state where productivity dropped by 3% from 2015 to 2020.

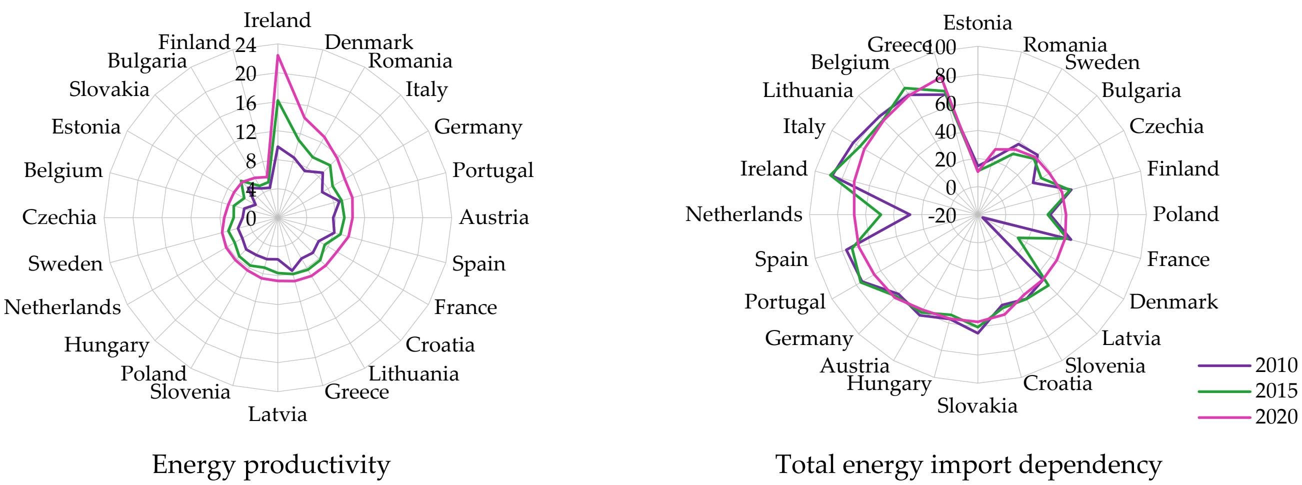

Figure 2. Values of energy productivity and energy import dependency in the years 2010–2020.

Estonia is the most energy-independent EU state. Due to growing electricity demand, Denmark transitioned from a state with an energy surplus in 2010 into an importer of

45% of its energy resources. The same was identified in the Netherlands, where the 2010 dependency was 30% and went up 40 pp by 2020. Sixteen countries exhibited positive changes. Ireland increased its self-sufficiency level by 16 pp; Portugal, Spain, and Italy also improved their energy dependency rates by 10%, 9%, and 9%, respectively. Slovakia also made an effort to transform its energy industry and curbed its energy dependency rate by 8 pp in 2020 compared to 2010.

Most states maintained the same level of imports of solid fossil fuels, oil and petroleum products, and natural gas over the decade (Figure 3). Three EU states (Poland, Bulgaria, and Greece) reduced their solid fossil fuel import dependency rates to 0.33, 9, and 10% of their total demands, respectively, in 2020, while the energy dependency of most (13) states increased. States that reduced their fossil fuel import dependency rates over the investigated period were Spain, Estonia, and Latvia (38, 25, and 17 pp, respectively). In Portugal, import dependency was the highest in 2020 after an increase of 24 pp compared to 2010. A similar trend was identified in Czechia, which exported solid fossil fuels in 2010, and had to import 12% of its demand in 2020. Slovakia also significantly increased its solid fossil fuel dependency by 10 pp. Finland, Denmark, and Poland also increased their import demands from 2010 to 2020 by approx. 5 pp.

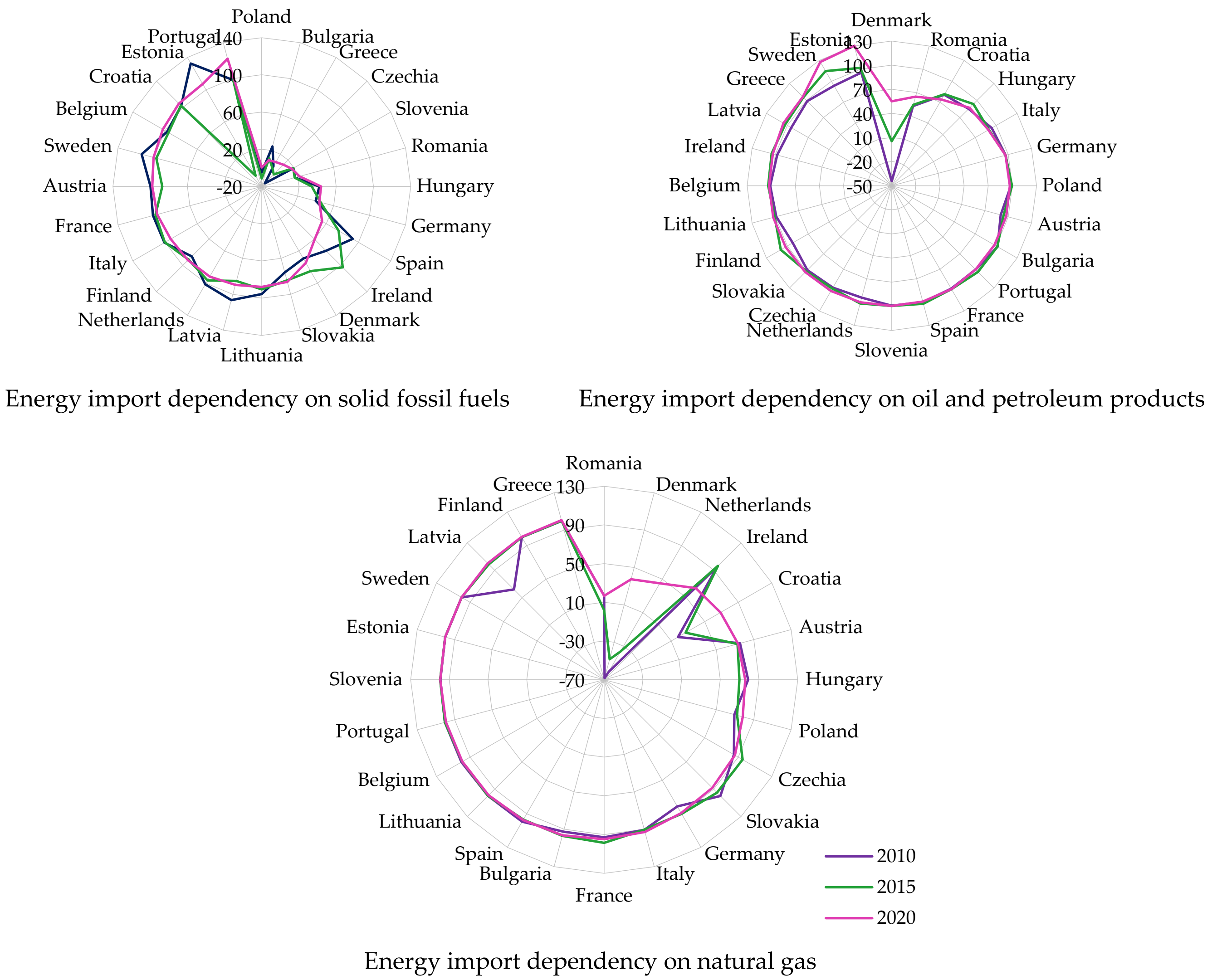

Figure 3. Values of energy import dependency for individual products in the years 2010, 2015, and 2020.

Regarding the imports of oil and petroleum products in 2020, Denmark, Romania, and Croatia were the most independent states. The situation in the oil market was rather unfavorable from 2010 to 2020 because import dependency grew in 18 countries, the most being in Denmark, which turned from being an exporter (−44%) into an importer (55%), which was also true for the Netherlands. In addition, Sweden and Estonia increased their demands by 30 pp. Most of the investigated countries (13) increased their natural gas import dependencies. The largest import dependency to total demand ratios were identified in Greece, Finland, Portugal, Belgium, Lithuania, Slovenia, Sweden, and Estonia, which import 100% of their consumption. The lowest rates in 2020 were found in Romania (17%), Denmark (37%), and the Netherlands (45%).

3.2. Sustainable Energy Consumption in EU Countries

The maximum and median values (X_1, X_2, and X_3) of energy consumption declined from 2010 to 2020 in the investigated group of EU states (Table 5). The dispersion across EU states is also shrinking as is evident from the coefficients of variation. The trend is beneficial because it reflects the introduction of more effective methods of energy use. Another optimistic insight is the significant increase in RES, which improves energy independence because energy from RES entails no energy resource import.

Table 5. Numerical characteristics of sustainable energy development indicators in specific years.

Variable	Specification											
	2010				2015				2020			
	min.	max.	M *	CV **	min.	max.	M	CV	min.	max.	M	CV
X_1	1.63	6.61	3.16	0.35	1.55	5.69	2.89	0.32	1.60	5.39	2.66	0.29
X_2	1.11	4.89	2.18	0.36	1.10	4.42	2.03	0.34	1.22	4.21	1.98	0.31
X_3	2.81	10.84	6.66	0.31	2.66	9.04	5.71	0.29	2.93	9.57	5.68	0.27
X_4	3.92	46.10	13.86	0.56	5.71	52.22	17.89	0.50	13.00	60.12	22.53	0.43

* M—median, ** CV—coefficient of variation.

It is worth investigating the dynamics of the indicators in individual states. All states aim to reduce energy consumption in line with the energy and climate policy of the EU. The primary energy consumption, which covers the energy consumption by end users such as industry, transport, households, services, and agriculture, plus energy consumption of the energy sector, went up in six countries from 2015 to 2020. Significant changes were identified in Lithuania, where energy consumption increased by 12%, and in Poland (up 8%), but also Latvia, Hungary, Romania (approx. 3.5%), and Croatia (1.6%) (Figure 4). The other states managed to limit energy consumption, which is advantageous for the economy and environment.

Only six countries increased their final energy consumption in 2020 compared to 2015. These were Lithuania and Poland (14%), Romania (11%), Latvia (6%), and Hungary and Bulgaria (4.5%).

It is important for entire economies and energy savings that individual households join the action and the public is educated about the adverse impact of energy overconsumption on the climate and environment. The final energy consumption per capita reflects how much citizens are committed to curbing energy consumption. The indicator grew in 13 states from 2015 to 2020. These were mostly Central and Easter European states: the consumption grew the most in Slovakia (37.4%), Romania and Bulgaria (12%), Poland (11%), and Portugal (10%).

As the energy demand grows and effort is made to increase the share of renewable energy, member states aim at replacing conventional energy resources with green technologies. Actions towards green resources are also included in national energy sector development plans. The share of renewable energy in gross final energy consumption grew for 22 states in 2020 compared to 2015. The Netherlands increased the share of renewable energy from 5.7 to 14%, which is by more than 146%. Other countries that focused on green solutions were Ireland (up 77%), Belgium (up 61.3%), Greece (up 38.6%), and Poland and Slovakia (up 35%).

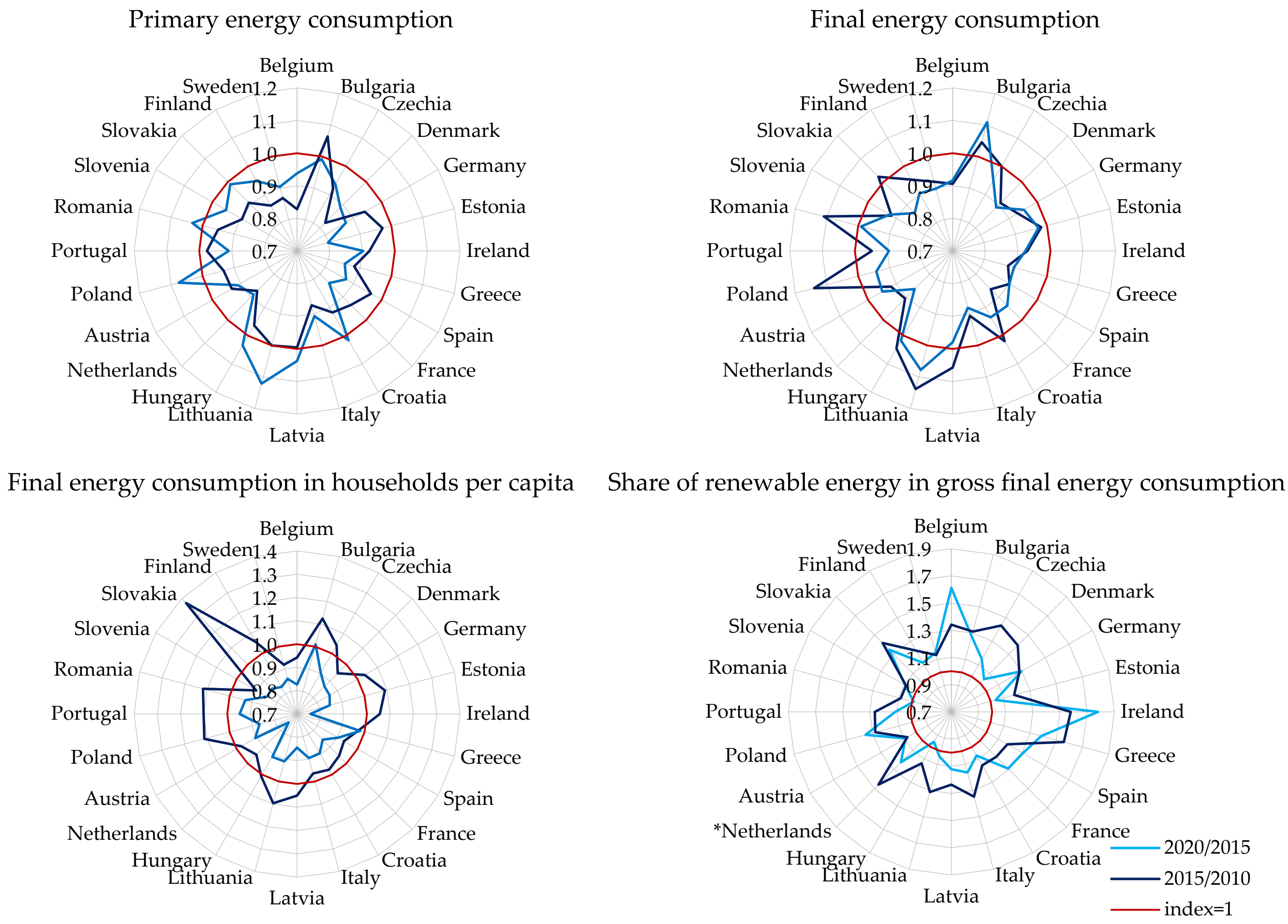

Figure 4. Indices of energy sustainability indicators. *: index value 2020/2015 doubled.

Considering the synthetic index of sustainable energy consumption in Equation (3), most countries changed their 2020 positions only slightly compared to 2015 or 2010 (Figure 5). Italy, Denmark, and Greece were classified at least three positions higher in 2020 compared to 2010. Austria, Hungary, and Lithuania were classified at least three positions lower. There are significant statistical correlations between state positions regarding sustainable energy consumption in the investigated period (p value < 0.01).

In 2020, the top-ranked state for sustainable energy consumption was Portugal, where both energy productivity (10.7 PPS per kilogram of oil equivalent) and total energy import dependency (65.3%) were among the highest in the EU. On the other hand, with one of the poorest energy productivities (7.1 PPS per kilogram of oil equivalent) and very high energy import dependency (78.1%), Belgium was classified last (Figure 6).

Our analyses did not identify any relationship between the degree of sustainable energy consumption and energy productivity or energy import dependency (Table 6). We identified a statistically significant correlation between energy import dependency by oil and petroleum products and primary energy consumption, which is only justified because oil is consumed mainly in the petrochemical industry, which is a consumer of primary energy. There was also a statistically significant relationship between the share of renewable energy in gross final energy consumption and total energy import dependency, which is an effect of EU states seeking to replace conventional resources with renewable energy. This makes them more independent of energy imports. Another statistically significant relationship was found between the share of renewable energy in gross final energy consumption and energy import dependency by solid fossil fuels.

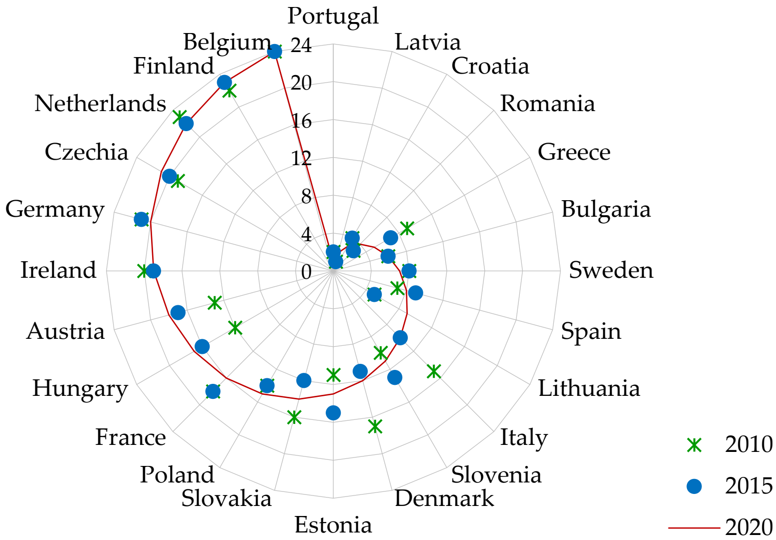

Figure 5. Ranks of EU states regarding sustainable energy consumption indicator (Q, determined by the Formula (3)) (Q, determined by the Formula (3)) in specific years.

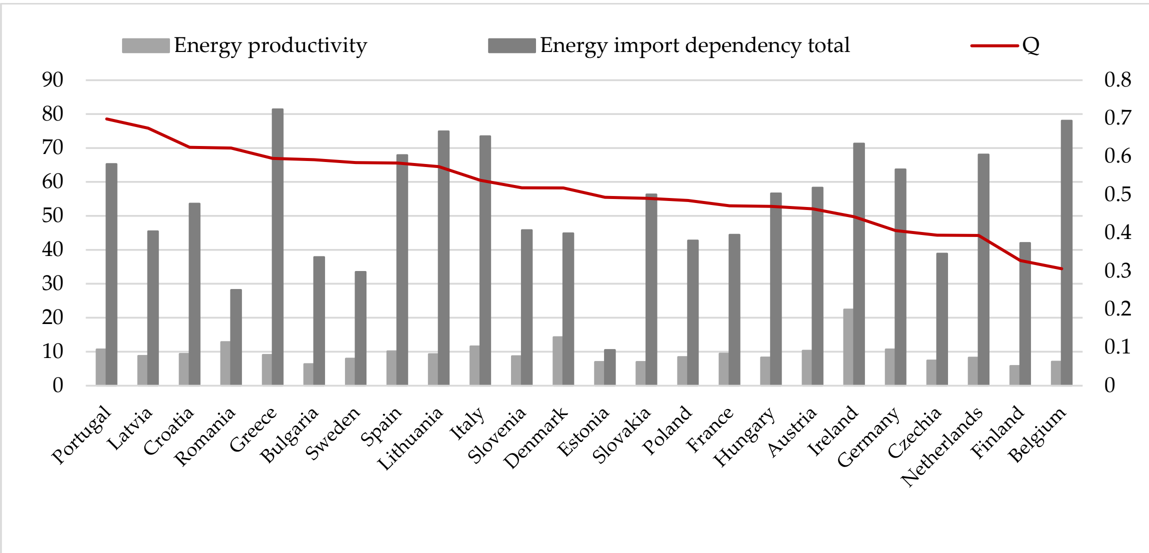

Figure 6. Sustainable energy consumption (Q, determined by Formula (3)), energy productivity, and total energy import dependency in 2020.

Table 6. Correlations between selected indicators in 2020.

Variable	X_1	X_2	X_3	X_4	Q
W_1	−0.343	−0.182	−0.060	−0.143	0.107
W_2	−0.225	−0.077	−0.264	−0.400 *	−0.090
W_3	0.245	0.352	0.278	0.409 *	0.005
W_4	0.427 *	0.298	0.118	0.234	−0.142
W_5	0.250	0.130	−0.022	0.197	0.021

X_j, W_j—designation according to Tables 4 and 5, respectively, Q—determined by the Formula (3). * Test significant at $p < 0.05$.

3.3. Practical Recommendation

Only a few of the analyzed countries are self-sufficient in access to energy resources, as shown by the conducted analyses. The supply of these raw materials may be an element of not only economic but also political struggle. Due to the dependence of a large number of countries on energy supplies, mainly from Russia, it is important to take action at the level of individual countries and the European Union in order to diversify suppliers.

The European Union has introduced many directives in the field of improving energy security. Under their influence, member states should continue to introduce laws, regulations, and ordinances giving priority to investments in the field of obtaining energy from various directions and sources, which improves energy security.

As the analyses show, almost all EU countries, apart from Slovakia, have increased their economic productivity, which should be assessed very positively and further actions should be taken in this direction, analyzing the possibilities of introducing solutions used in the most energy-efficient countries.

When selecting specific projects, individual Member States should be guided not only by economic calculations, but also choose those that allow for the diversification of suppliers.

From the point of view of energy security, it is beneficial to subsidize business entities and individual households, enabling them to use energy-saving technologies. At this stage, advertising campaigns informing individual recipients about available EU and national programs are of great importance.

As one of the possibilities of becoming independent from the supply of energy resources, EU countries see the use of renewable energy sources as being a vital component. When analyzing solutions in this area in the member states, individual countries can use the experience of other EU members.

4. Conclusions

We assessed energy security in the context of Goal 7 of the 2030 Agenda by considering indicators of energy import dependency in 2010, 2015, and 2020, on the one hand, and evaluating changes in energy consumption in EU states, on the other hand. Member states have taken numerous actions to curb the consumption of fossil resources in line with the climate and energy policy of the EU. Sixteen EU states reduced their energy dependency rates in 2020 compared to 2010, including twelve in solid fossil fuels, six in oil and petroleum products, and nine in natural gas, which reduced their import dependency. Estonia, Romania, Sweden, and Bulgaria exhibited the best energy security levels in terms of independence of energy imports in 2020.

As many as 20 countries managed to reduce their consumption of primary energy from conventional resources. Eighteen states reduced their final energy consumption, which is beneficial for the economy and the environment. Residents of numerous countries also took action to limit energy consumption, which led to a drop in the final energy consumption per capita in 20 states. The leaders in terms of reducing electricity consumption per capita are Slovenia, Sweden, Spain, Belgium, and the Netherlands.

Reliable energy supply is also ensured by tapping into renewable energy sources, which is reflected in the share of renewable energy in gross final energy consumption. Member states have set targets in the National Renewable Energy Action Plans requiring a shift from conventional resources toward low-carbon energy sources. This is the most successful area because 22 states increased their share of RES in their energy mixes in 2020 compared to 2015.

Author Contributions: Conceptualization, M.Z. and L.L.; methodology, L.L.; formal analysis, L.L. and M.Z.; investigation, M.Z. and L.L.; resources, M.Z. and L.L.; data curation, L.L., W.K. and M.Z.; writing—original draft preparation, M.Z. and L.L.; writing—review and editing, visualization L.L., I.B., W.K. and K.K.; supervision, funding acquisition, W.K., L.L. and M.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The research was financed by a subsidy from the Ministry of Education and Science for the Agricultural University of Hugo Kołłątaj in Krakow for the year 2022.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data were obtained from the Eurostat database (accessed on 12 October 2022).

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Acronyms	Explanation	Acronyms	Explanation
SDG	Sustainable Development Goals	S	Stimulant
RES	Renewable Energy Sources	D	Destimulant
PPS	Purchasing Power Standard	M	Median
TOE	Tonnes of Oil Equivalent	CV	Coefficient of Variation
Q	Sustainable Energy Consumption Indicator	TOPSIS	The Technique for Order of Preference by Similarity to Ideal Solution

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