energies

Article

Assessment of the Feasibility of Energy Transformation Processes in European Union Member States

Michał Bernard Pietrzak [1,*], Magdalena Olczyk [2] and Marta Ewa Kuc-Czarnecka [1]

[1] Department of Statistics and Econometrics, Faculty of Management and Economics, Gdańsk University of Technology, Gabriela Narutowicza 11/12, 80-233 Gdańsk, Poland; mkuc@zie.pg.gda.pl
[2] Department of Economics, Faculty of Management and Economics, Gdańsk University of Technology, Gabriela Narutowicza 11/12, 80-233 Gdańsk, Poland; mw@zie.pg.gda.pl
* Correspondence: michal.pietrzak@zie.pg.gda.pl

Abstract: The energy transition is now treated in most countries as a necessary condition for their long-term development. The process of energy transformation assumes the simultaneous implementation of the Sustainable Development Goals, which are a major challenge for modern economies and introduce significant restrictions in their functioning. Our study aims to group EU member states according to their ability to achieve energy transition over time. The novelty of our approach is the assessment of energy transformation in the European Union through two aspects. The first one, "smart and efficient energy systems", assess the current, widely understood energy consumption in economy, and the second one, "macroeconomic heterogeneity", refers to the economic potential of a country. In our analysis, we included indicators from the 7th, 8th, 10th, 11th, and 12th Sustainable Development Goals. Using taxonomic methods, we created clusters of countries according to the emissivity of their economies and the socio-economic potential for the energy transition. The analysis results revealed that countries vary more due to their emissivity than economic potential.

Keywords: energy transition; sustainable development; Sustainable Development Goals; economic growth; renewable energy

check for updates

Citation: Pietrzak, M.B.; Olczyk, M.; Kuc-Czarnecka, M.E. Assessment of the Feasibility of Energy Transformation Processes in European Union Member States. *Energies* **2022**, *15*, 661. https://doi.org/10.3390/en15020661

Academic Editor: Behnam Zakeri

Received: 8 December 2021
Accepted: 13 January 2022
Published: 17 January 2022

1. Introduction

The paper focuses on the process of energy transition in the European Union and the new approach to its assessment. By energy transition, we mean the shift from a fossil–nuclear energy system to one based on renewable energy sources, including the associated technological, political, and economic structures [1–4]. In the literature, energy transition is described as one of the most urgent challenges for the global economy and one of the most desirable processes in almost any country, i.e., a panacea to solve certain pressing socio-economic problems [5–7]. Undoubtedly, all world economies are currently undergoing energy transformation. This process is the result of intensive globalization processes already in the early 1990s, which translated into a significant increase in interdependence between economies [8,9]. In subsequent stages of the development of economies, there has been a significant increase in investment, innovation, economic development of countries, an increase in the level of wealth of the society, and changes in consumption patterns in the world and on the labor market [10–20]. All this contributed to the fact that the goals of sustainable development found ground for implementation. In addition, a significant reduction in the costs of technologies for producing energy from renewable sources and the commercialization of green energy for individuals and business entities made the step towards energy transformation consistent with the goals of sustainable growth possible. Energy transition is crucial for three main reasons. Firstly, energy transition can help slow down global warming, which has devastating effects on both nature and people, especially in terms of food security and potential migration [21,22]. Secondly, a successful energy transition may facilitate closing the gap between energy supply and demand [23,24]. As the average annual growth rate of the global economy was around 3.5% in the last decade (not taking into account the pandemic period), increasing demand for energy has been observed, regardless of the energy source [25]. Furthermore, the world population is expected to grow by about two billion people over the next two decades, while living standards are significantly rising, especially in India and China [26]. All of the above indicates that energy production will increase by 49% by 2040 under conditions of shrinking natural resources; therefore, energy transition provides the global economy with the possibility of closing the gap between supply and demand [27]. The third reason is that the effective energy transformation process has become an essential element, referred to as "green competitiveness" [28]. Changes in the consumption patterns related to new groups of customers on the markets, namely Gen Z, Millennials, and Gen X, and alterations in innovations cause energy transition to be necessary in implementing new "green" business models and smart green innovations in the economy. That is why the fundamental question is how to effectively carry out this desirable energy transformation process and how to measure it.

In our paper, we focus on the institutional framework of the energy transition process and its measurement in the European Union (EU) using the approach based on the Sustainable Development Goals. This topic was first undertaken in 2010, when the United Nations (UN) stated that the year 2012 was to be the International Year of Sustainable Energy for All "(...) to ensure access to affordable, reliable, sustainable and modern energy for all". In 2015, the United Nations General Assembly adopted a new post-2015 agenda of universal Sustainable Development Goals (SDGs) containing 17 goals and 169 targets concerning sustainable development [29]. As discussed earlier, the development of globalization processes, the economic growth of most of the economy combined with an increase in investment and the level of innovation, as well as a significant change in consumption patterns contributed to the fact that the goals of sustainable development found ground for implementation. It should be noted that energy transition constitutes the center of sustainable development. It is particularly visible in the seventh (to ensure access to affordable, reliable, sustainable, and modern energy) and twelfth (responsible consumption and production) Sustainable Development Goals, which include signposts related to "greening" the economy for all countries. As a political and economic association of 27 members, the European Union adopted the SDG declaration known as "the 2030 Agenda for Sustainable Development" to achieve 17 universal sustainable goals [30]. To reach SDGs in the field of energy transformation, the EU, as an institution, has also ratified and implemented several legal acts. The most important initiatives include the Paris Agreement, in which the EU has agreed to put the European Union on track to become the first climate-neutral economy and society by 2050. Additionally, the EU introduced a set of policies referred to as the European Green Deal, i.e., an ambitious package of measures ranging from ambitious cuts in greenhouse gas emissions to investment in cutting-edge research and innovation to preserve Europe's natural environment [31].

What distinguishes European Union countries from others implementing the universal sustainable development agenda is solid institutional cooperation and the need to introduce uniform legal acts by all EU members [32]. This also applies to the fulfilment of SDGs in the context of energy transition. This is why our idea was to assess this shift through the lens of SGDs. Previous analyses evaluating the energy transition referred to composite indices that combine a wide range of energy indicators. They often refer to a specific aspect of this phenomenon, e.g., the Energy Security Index [33] and the Multidimensional Energy Poverty Index [34] to accessibility, the World Energy Council Energy Trilemma Index [35] to energy security, and the Energy Transition Index (ETI) to four aspects: accessibility, security, sustainability, and readiness [36]. However, one should be aware that composite indexes, despite their intuitiveness and simplicity, are often constructed with methodological errors. These errors can take the form of omitted or subjective weighting stage; questionable selection of diagnostic variables not supported by the literature; or a non-transparent construction process [37–41]. The authors of this study also showed methodological flaws in the construction of the Energy Transition Index: ETI turns out to be unbalanced and includes many variables of marginal importance for the shape of the final ranking (most of which are "soft variables" such as transparency, credit rating, or the rule of law) [36].

The aim of our article is to propose a new method of assessing the feasibility of energy transition in European Union countries by applying selected indicators of the Agenda for Sustainable Development Goals. Our original approach consisted of selecting individual SDGs and some diagnostic variables that describe two main aspects related to the energy transition. The first one, named "smart and efficient energy systems", refers to the assessment of the current state of the economy in terms of energy consumption, energy production, and circular economy. The second aspect, called "macroeconomic heterogeneity", refers to factors associated with or regulated by macroeconomic policy, such as investments, GDP, research and development (R&D) expenditures, education level and income of citizens, and air pollution.

The remaining part of the paper is structured as follows: Section 2 describes the selection of SDGs and indicators related to the energy transition. Section 3 contains the analytical framework, while Section 4 includes the empirical results of our analysis. Section 5 provides conclusions and policy recommendations.

2. Implementation of Sustainable Development Goals Relating to the Energy Transition in the EU Countries

There are some studies in the literature that relate the concept of sustainable development to the energy transition in European countries. Mostly, they refer to the concept of sustainable energy transition [42] or effective energy transition [43]. These studies strongly focus on a selected aspect of sustainable development such as energy security [44], financing [45], citizen activity [46], COVID pandemics [47,48], income distribution [49], or negative externalities [50]. They often focus on a selected SDG, e.g., [51] for SDG 7 or analyses refer to only one economy [52] for Germany; [53] for Greece. In our research, we assume that a multi-criteria perspective is required to evaluate energy transition through the prism of implementing the Sustainable Development Goals. This is due to the nature of SGDs, which affect almost all areas of human activity. In the literature, we find several attempts to construct an index that combines the concepts of sustainability and development, named a sustainable energy development indicator (SEDI) [54–57]. Based on the review of the SEDI methodology by [58] and some improvements suggested by [59,60], we use it to assess the sustainable energy development of the EU-28 countries. The analysis shows that Denmark, the Netherlands, and Austria are leading in sustainable energy development in Europe.

In turn, there are very few proposals in the literature for an index linking sustainability to energy transition. Neofytou et al. (2020) propose assessing the EU's readiness for a sustainable energy transition and introduce an index based on a multi-criteria scoring system inspired by the AHP and PROMETHEE II methodologies. They rank countries based on societal, political, economic, and technological indicators that are considered drivers of the energy transition. Taking all factors into account, Sweden, Spain, and Austria seem to be leading the EU in terms of conditions for the transition to a more sustainable energy system. Our approach is new in the context of the above research. It has a clear focus on energy transition and uses a number of different but coherent criteria to emphasize the potential, rather than progress, and readiness for energy transition. Our approach foregrounds the energy transition in the context of selected Sustainable Development Goals, which is not as broad as the diversity of all the SDGs.

2.1. "Smart and Efficient Energy Systems" in the SDG Agenda in the Context of the Energy Transformation in EU Countries

According to Eurostat [61], energy efficiency is vital on the path towards an affordable, reliable, sustainable, and modern energy system, as indicated in the SDGs. Efficient energy systems are connected to reduce consumption and costs, limit energy dependency, and mitigate the environmental and climate impacts associated with the use and supply of energy [62]. Acceleration of the transition into a sustainable energy system in the EU involves taking into account developments in energy consumption, energy supply, and access to affordable energy [63].

In previous decades, economies were developed in line with an increase in energy consumption, as higher resource and energy use contribute to economic growth. Energy consumption must decrease to address the climate crisis, which implicates a “decoupling” of economic growth from energy consumption [64]. Many empirical analyses indicate a strong decoupling of economic growth and energy consumption in EU countries, which can be perceived as a positive trend [65,66]. This is the reason why we used three indicators related to energy consumption in our analysis; its changes may determine the country’s potential for a successful energy transition. The first indicator, energy losses, shows the energy sector’s energy consumption and losses occurring during the transformation and distribution of energy. The second one, energy productivity, measures the amount of economic output produced per unit of gross available energy. The last one is greenhouse gas emissions’ intensity of energy consumption, evaluated as the ratio between energy-related GHG emissions and gross inland consumption of energy (see Table 1).

An efficient energy system cannot exist without a functional supply system. Almost every industry, home, and transport system, as well as the Internet, depends on energy. Additionally, the global energy supply chain is stretched almost to its breaking point, and each new disruption creates problems, partially due to the already conducted decarbonization [67]. A successful shift towards climate neutrality requires a massively increased use of renewable energies to allow for industrial transformation [68]. Technological advancements and cost reductions in wind and solar power and their storage mean that the use of renewable sources now constitutes the most competitive form of electricity generation [69]. According to Krepl et al. [70], the increasing share of renewable energy in gross final energy consumption not only ensure the stability of the energy system but also help promote sustainable development in the post-pandemic era (by reducing greenhouse gas emissions, protecting the environment, increasing energy efficiency, creating jobs, etc.). Considering that the European Commission [71] set a target of −55% greenhouse emissions by 2030, a long-term goal of net zero GHG emissions by 2050, as well as an increase in the minimum share of renewable energy in final energy consumption to 40% by 2030 [71], we decided to include the indicator “share of renewable energy in gross final energy consumption” in our analysis (see Table 1). We also incorporated the second indicator related to energy supply, i.e., the energy import dependency. Between 2004 and 2019, in the European Union, the fuel import from non-EU countries did not change significantly and remains very high—56.9% of gross energy available in the EU was imported in 2004, while in 2019, it was 60.7% [16]. According to Eurostat [16], in 2019, all member states were net importers of energy, with 17 countries importing more than half of their total energy consumption from others (EU countries and non-EU countries). It shows that EU countries need to enhance domestic energy production, and energy import dependency can be regarded as a good measure of the energy transition process.

Apart from three energy consumption measures and two energy supply indicators, we took into account one indicator, which presents access to affordable energy. According to IEA [27], in 2019, 759 million people still had no access to electricity, and at the same time, 2.6 billion people remained without the ability to use clean cooking facilities. Although the lack of access to affordable energy is closely related to low-income levels combined with high energy expenditure and poor building efficiency standards [72], Eurostat [61] confirmed that, in 2019, 6.9% of the EU population were still unable to keep their homes adequately warm, since expanding access to electricity and other forms of energy is fundamental not only to improve the lives of people and their communities but also to increase the level of social acceptance. Flachsbarth [73] used a German example to present how social acceptance is becoming a factor limiting the implementation of the energy transition. Segreto et al. [74] analyzed 25 case studies of the most significant social drivers and barriers that include all European countries and confirmed that a low level of local acceptance has hindered the development of renewable energy projects (while general acceptance of renewable energy systems is high). That is why our study includes "the share of the population who are unable to keep home adequately warm" as a proxy indicator of public acceptance of the energy transition.

Table 1. Indicators related to the "smart and efficient energy systems" aspect of energy transition.

Variable	Description	Type *	Symbol
	Energy Consumption		
Energy losses	Energy consumption of the energy sector itself and losses occurring during transformation and distribution of energy (tonnes of oil equivalent (TOE) per capita).	D	X_1
Energy productivity	The indicator measures the amount of economic output that is produced per unit of gross available energy. The gross available energy represents the quantity of energy products necessary to satisfy all demand of entities in the geographical area under consideration (PPS per kilogram of oil equivalent (KGOE)).	S	X_2
Greenhouse gas emissions intensity of energy consumption	The indicator is calculated as the ratio between energy-related GHG emissions and gross inland consumption of energy. It expresses how many tonnes CO_2 equivalents of energy-related GHGs are being emitted in a particular economy per unit of energy that is being consumed.	D	X_3
	Energy Supply		
Share of renewable energy in gross final energy consumption	The indicator measures the share of renewable energy consumption in gross final energy consumption according to the Renewable Energy Directive. The gross final energy consumption is the energy used by end-consumers plus grid losses and self-consumption of power plants.	S	X_4
Energy import dependency	The indicator shows the share of total energy needs of a country met by imports from other countries. Energy dependence = (imports − exports) / gross available energy.	D	X_5
	Access to Affordable Energy		
Population unable to keep home adequately warm	The indicator measures the share of the population who are unable to keep home adequately warm.	D	X_6
	The Circular Economy		
Circular material use rate	The circular material use rate (CMR) measures the share of material recovered and fed back into the economy in overall material use.	S	X_7
Generation of waste excluding major mineral wastes	The indicator measures all waste generated in a country (kg per 1000 inhabitants). Due to the strong fluctuations in waste generation in the mining and construction sectors and their limited data quality and comparability, major mineral wastes, dredging spoils and soils are excluded.	D	X_8
Gross value added in environmental goods and services	The gross value added in EGSS represents the contribution of the environmental goods and services sector to GDP and is defined as the difference between the value of the sector's output and intermediate consumption (% of GDP).	S	X_9

Source: Authors' study based on [75]; * S—stimulant, D—destimulant.

Furthermore, our analysis includes certain indicators of circular economy (CE). CE aims to "design out" waste through reducing, reusing, recycling, and recovering of materials, all to achieve resource sustainability [76]. According to Chen and Kim [77], energy transition needs to be broadened to cover the conversion of non-energy use and the achievement of a closed-loop non-energy use that constitutes part of the circular economy. The coordinated approach of the CE and energy transition may lead to synergy effects, i.e., promoting circular economy activities in the industry, reducing energy demand, and acquiring the additional potential to reduce greenhouse gas emission [78]. That is why the analysis cover three indicators of circular economy: the circularity rate (the share of material recovered and fed back into the economy in the overall material use), the generation of waste excluding major mineral wastes (which measures all waste generated in a country), and gross value added in environmental goods and services, (which shows the contribution of the environmental goods and services sector to gross domestic product).

2.2. "Macroeconomic Heterogeneity" of the SDG Agenda in the Context of Energy Transformations in EU Countries

Many countries are making numerous efforts to switch from fossil fuels to cleaner fuels and increase energy efficiency to become carbon-free economies. Still, the transition process is not easy, mainly due to its complexity [79]. It affects different regions of the world to different degrees, depending on their local energy consumption basket, geographic location, and economic ties to fossil fuels [80]. An essential question in the economic literature is how macroeconomic variables can accelerate the energy transition in different regions, leading to similarities in energy transition patterns between these regions. Sovacool [81] discussed the speed of this process in various countries and found that the potential for energy transition is not identical in all countries and depends on various factors, policies, geographical location, and energy flows. For this reason, we have chosen certain macroeconomic indicators described in the SDG agenda to assess a country's potential for the energy transition.

Many previous analyses suggested the occurrence of a positive relationship between economic growth (measured by means of GDP) and energy transition (see [82] for CEE countries; [80] for Asian economies). A unique role is played by investment as a part of GDP. Apergis and Payne [83] found a positive relationship between renewable energy consumption and gross fixed capital formation in a panel of 16 emerging economies between 1990 and 2011. Similarly, Sineviciene [84] indicated that fixed capital constitutes an essential driver of energy efficiency in analyzed countries. Therefore, our analysis includes the investment share of GDP, defined as gross fixed capital formation expressed as a percentage of GDP for the government, business, and household sectors (see Table 2).

Table 2. Indicators related to the "macroeconomic heterogeneity" aspect of energy transition.

Variable	Description	Type *	Symbol
	Investment		
Investment share of GDP (total investment)	Defined as gross fixed capital formation (GFCF) expressed as a percentage of GDP for the government, business, and household sectors.	S	X_{10}
	Innovation		
Gross domestic expenditure on R&D	The indicator measures gross domestic expenditure on R&D (GERD) as a percentage of the gross domestic product (GDP).	S	X_{11}
R&D personnel	The indicator measures the share of R&D personnel. Data are presented in full-time equivalents as a share of the economically active population.	S	X_{12}
	Education and Income Household		
Tertiary educational attainment	The indicator measures the share of the population aged 25–34 who have successfully completed tertiary studies.	S	X_{13}
Adjusted gross disposable income of households per capita	The indicator reflects households' purchasing power and ability to invest in goods and services or save for the future by accounting for taxes and social contributions and monetary in-kind social benefits.	S	X_{14}
	Dirtiness of Economy		
Air emission intensity from industry	This indicator measures the emissions intensity of fine particulate matter (PM2.5).	D	X_{15}
Average CO_2 emissions per km from new passenger cars	The indicator is defined as the average carbon dioxide (CO_2) emissions per km by new passenger cars in a given year.	D	X_{16}

Source: Authors' study based on [75]; * S—stimulant, D—destimulant.

We also took into account the R&D expenditures as a potential driver of the energy transition. The International Renewable Energy Agency (IRENA) [85] indicates technological breakthroughs are necessary to reduce carbon emissions in the energy sector. Even if economically viable and scalable renewable energy-based solutions are available for about two-thirds of the world's energy supply, population growth and rising energy demand could outpace energy decarbonization without urgent investment in research and development (R&D). In our research, we focused on R&D expenditures, which helps increase energy efficiency through innovation in technology [86], promotes a reduction in CO_2 emissions [87], and positively contributes to the carbon neutrality targets [88]. Therefore, our macroeconomic variables covered gross domestic expenditure on R&D (% of GDP) and R&D personnel (% of the labor force).

In addition, in our study, we applied variables characterizing two features of household members, namely their education and income. The literature shows that households' energy literacy is crucial in shaping a successful energy transition and building its resilience [89]. Energy literacy does not mean only the device energy literacy but also the awareness of, attitude, and behavior towards the energy process [90]. A positive attitude to the energy transformation with its costs and benefits strongly depends on the education of citizens [91]; that is why we adopted tertiary educational attainment as a determinant of this process. It is worth emphasizing that universities are the most important institutions for the dissemination of knowledge through teaching and for the creation of new knowledge through research. These aspects make universities important players in achieving the Sustainable Development Goals [92].

Moreover, we assumed that a household's income could determine the energy transition. As indicated by Nguyen et al. [93], the occurrence of such a shift varies between wealthy and poor groups of citizens. Poor households still heavily rely on traditional energy sources, including coal and biomass to meet their energy needs. In their analysis of the German energy transition, Schlesewsky and Winter [94] also pointed to a larger share of consumers from high-income households than poor households in this process.

At last, we added two variables that constrain the energy transition process. They include the pollution of the economy, i.e., the intensity of air emissions from the industry and the average CO_2 emissions (per km from new passenger cars). In this study, we assumed that social aspects are essential for the success of this transformation. The energy transition is costly to almost every household as a result of higher electricity prices, partly due to the renewable energy levy, but also entails many positive environmental impacts (the mitigation of pollution) and public health benefits [95]. The costs and benefits should be shared equitably and transparently across society, particularly in the context of rising inequality in the majority of countries [96]. The health benefits are particularly important and expected by each household, as air pollution emissions are recognized as a major contributor to the global burden of disease, especially cardiovascular and respiratory mortality [97]. That is why we included air pollution indicators in our study as the most crucial aspect of the economy's pollution.

To sum up, we selected (out of 17 Sustainable Development Goals) 16 individual SDG diagnostic variables describing two main aspects related to the energy transition, i.e., smart and efficient energy systems and macroeconomic factors of the energy transition.

3. Research Methods and Data

In this paper, the Ward's method, which constitutes one of the hierarchical cluster analysis approaches, was used to identify groups of countries similar to each other in terms of energy consumption and potential for the energy transition. We decided to use clustering methods rather than a composite indicator, as the former seems to have fewer design pitfalls. It has been tentatively mentioned that composite indicators often suffer from an inadequate weighting system [98]. Therefore, we have opted for a more robust method that focuses on the taxonomic similarity of objects and does not require artificial and subjective weights [99]. Ward's method represents agglomeration clustering methods, i.e., it is based on the assumption that, initially, every object creates a separate class, and pairs of clusters are merged as one moves up in the hierarchy—the so-called "bottom-up" approach [100].

The Ward's approach can be described in the following steps:

Every object $Q_i = (i = 1, 2, \ldots, m)$ creates a separate class; thus, the initial number of single-element classes equals m.

1. Based on the lowest value in the distance matrix, a pair of the most similar objects p and q is established,
2. Objects p and q are formed into one cluster, reducing the number of groups to $m - 1$,
3. The distance between the newly formed cluster and other items is calculated,
4. Steps 2–4 are repeated until sample units are combined into a single large cluster of size m.

The distance between the objects is a positive, definite, and symmetric [101] vector onto the positive reals, fulfilling the triangular inequality. Therefore, for the object p, q, v, the following relation occurs:

$$d(p, q) > 0; d(p, q) = 0 \Leftrightarrow p = q;\ d(p, q) = d(g, p); d(p, q) \leq d(p, v) + d(v, q) \quad (1)$$

where: d—distance; p, q, v—observations.

The distance is calculated as the error sum of squares:

$$ESS = \sum_{i=1}^{k} x_i^2 - \frac{1}{k}\left(\sum_{i=1}^{k} x_i\right)^2 \quad (2)$$

where: x_i—criterion of segmentation for ith unit; k—number of objects in a given cluster. At each stage of cluster analysis, the total ESS is minimized.

The number of clusters was determined based on the dendrogram analysis and supported by the value of the silhouette index [102] calculated for the analogous analysis carried out using the k-means method. Since, in this case, the results obtained with Ward's approach and the k-means method were similar, we decided to present only the former. In a subsequent analysis step, we also verified the mean values of diagnostic variables in the selected group of countries. Using the Kruskal–Wallis test [103], we studied whether differences between these groups were statistically significant. Finally, the chi-square test of independence [104] indicated whether the obtained clustering based on different variables was independent.

Table 3 presents the basic descriptive statistics for the variables used in the analysis. An analysis of the data in Table 3 shows that most of the variables are characterized by significant differentiation (the coefficient of variation above 0.3), thus indicating their high ability to differentiate the discussed European Union member states. These countries are particularly enormously diversified in terms of generation of waste (X_8), air emission intensity (X_{15}), and proportion of population unable to keep home adequately warm (X_6). In most cases, the analyzed variables were characterized by positive asymmetry, which means that, in most countries, the values of the discussed variables were below the average. The opposite situation was observed only in the case of four diagnostic variables, i.e., values above the average were observed in the majority of countries. This concerned the following variables: energy import dependency (X_5), average CO_2 emission per km from new passenger cars (X_{16}), tertiary education attainment (X_{13}), and R&D personnel (X_{12}).

Table 3. Descriptive statistics of the variables used in the study.

Variable	Min	Max	Mean	Median	S.D.	C.V.	As
X_1	0.25	1.39	0.78	0.74	0.38	0.49	0.37
X_2	5.53	19.63	9.20	8.45	2.93	0.32	2.09
X_3	63.10	102.60	81.82	80.95	8.87	0.11	0.19
X_4	8.77	56.39	23.96	20.62	11.86	0.50	1.06
X_5	4.83	77.48	55.68	60.47	19.27	0.35	−0.81
X_6	1.80	30.10	7.91	5.15	7.82	0.99	1.81
X_7	1.30	30.00	9.66	7.20	7.46	0.77	1.28
X_8	0.02	7.36	0.53	0.21	1.47	2.79	4.78
X_9	0.88	5.68	2.42	2.21	1.16	0.48	1.42
X_{10}	10.14	45.60	22.64	21.59	6.09	0.27	2.10
X_{11}	0.48	3.40	1.76	1.47	0.90	0.51	0.49
X_{12}	0.36	2.12	1.32	1.32	0.48	0.36	−0.18
X_{13}	25.50	55.40	41.33	42.60	8.04	0.19	−0.24
X_{14}	10,875.00	30,142.00	20,872.79	19,952.00	5094.83	0.24	0.09
X_{15}	0.02	0.88	0.18	0.08	0.24	1.31	2.24
X_{16}	98.40	137.60	122.41	122.60	9.26	0.08	−0.61

S.D.—standard deviation; C.V—coefficient of variation, As—skewness. Source: Authors' study based on [75].

4. Results

4.1. "Smart and Efficient Energy Systems" Analysis

The subject of the analysis consisted of 24 European Union countries in 2019 (Cyprus, Malta, and Luxembourg were excluded due to the missing data). The empirical research began with the energy-intensity aspect, which includes energy consumption, energy supply, access to affordable energy, and circular economy aspects. It is created by the variables X_1–X_9 (a detailed description of these variables is provided in Table 1 in the second section of the article). In this case, four groups of countries were distinguished (Figures 1 and 2).

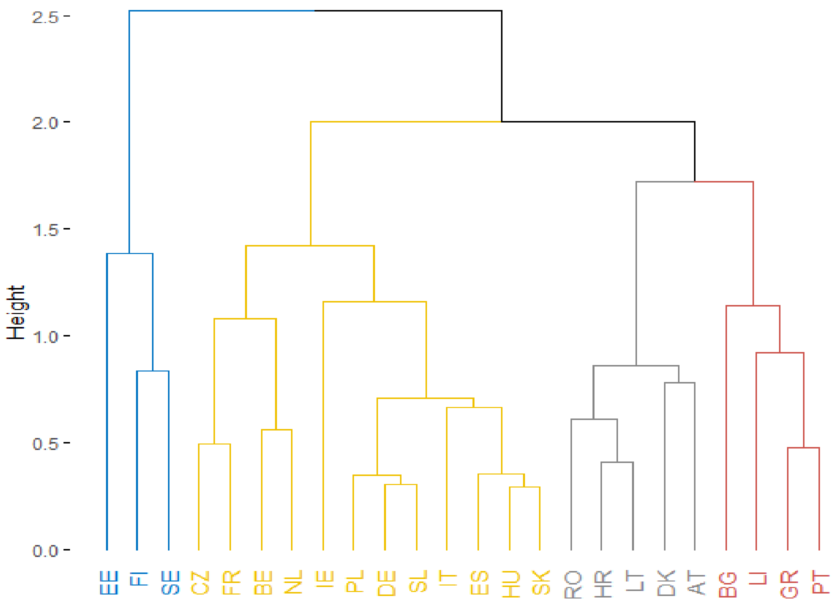

Figure 1. Cluster dendrogram for "smart and efficient energy systems". Source: Authors' study based on [75].

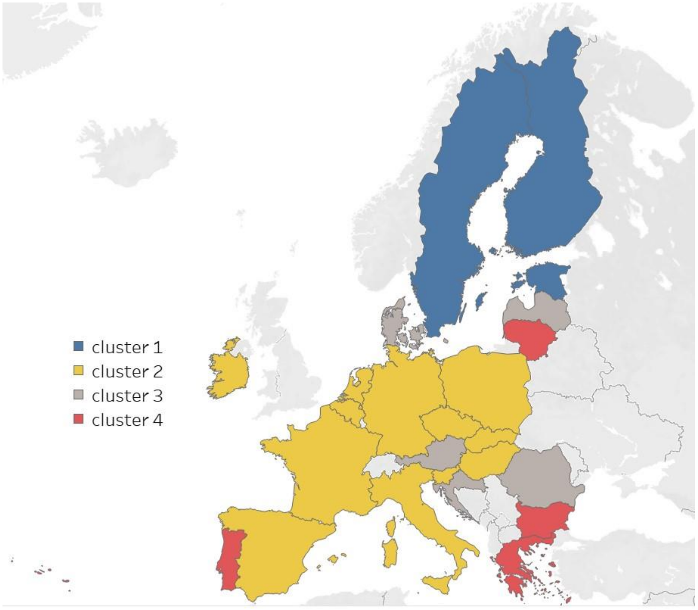

Figure 2. Choropleth map for "smart and efficient energy systems". Source: Authors' study based on [75].

An analysis of Figures 1 and 2 allows establishing cluster 1 (blue), which consists of the most prominent users of renewable energy sources that are simultaneously the least dependent on external energy sources. This cluster is made up of the following countries: Estonia, Finland, and Sweden. Compared to other groups, countries assigned to cluster 1 also stand out in terms of the lowest values of the variables X_5 and X_6 (population unable to keep home adequately warm, and greenhouse gas emissions intensity of energy consumption) and the highest values of variables X_1, X_8, and X_9 (energy losses, generation of waste excluding major mineral wastes, and gross value added in environmental goods and services) (Table 4). The actual values of the diagnostic variables for the "smart and efficient energy systems" aspect for the first cluster are included in Table 4. The analysis of the data in this table shows that these three countries are indeed similar in terms of the levels of diagnostic variables. Estonia slightly differs from the others (variables X_5, X_7, and X_8). Despite these differences, the inclusion of Estonia in cluster 1 is still justified, as in the case of other groups, the differences would be even more visible.

Table 4. "Smart and efficient energy systems"—values of diagnostic variables for countries constituting cluster 1.

ISO	X_1	X_2	X_3	X_4	X_5
SE	1.38	7.39	68.30	56.39	30.24
EE	1.36	6.91	79.70	31.89	4.83
FI	1.22	5.53	69.60	43.08	42.09
MEAN	1.32	6.61	72.53	43.78	25.72
ISO	X_6	X_7	X_8	X_9	**-**
SE	1.90	6.50	0.21	2.08	-
EE	2.50	15.60	7.36	4.45	-
FI	1.80	6.30	0.47	5.68	-
MEAN	2.00	9.46	2.68	4.07	-

Source: Authors' study based on [75].

An opposite to cluster 1 is cluster 2, which is the largest and contains 12 elements(yellow). Cluster 2 is formed by countries of Central and Eastern Europe, which includes: Belgium, Czechia, France, Germany, Hungary, Ireland, Italy, Netherlands, Poland, Slovakia, Slovenia, and Spain. They are characterized by the highest circular material use rate (X_7) and a relatively high energy import dependency (X4). At the same time, they have the lowest share of renewable energy in gross final energy consumption (X_4), the lowest level of waste generation excluding major mineral waste (X_8), and the lowest gross value added in environmental goods and services (X_9) (Table 5). Therefore, these economies are largely dependent on energy imports and are based on non-ecological energy sources (mostly coal or gas). The actual values of the diagnostic variables for the "smart and efficient energy systems" aspect for the second cluster are included in Table 5. In this case, there are no significant differences between the values of the variables observed in individual countries and the average level of a given variable in the cluster. The exceptions are Ireland for the variable X_2, Italy for X_6, and Belgium for X_7).

Table 5. "Smart and efficient energy systems"—values of diagnostic variables for countries constituting cluster 2.

ISO	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
IE	0.47	19.63	79.6	11.98	68.4	4.90	1.60	0.33	0.88
BE	1.16	6.50	84.6	9.92	76.68	3.90	24.20	0.31	0.94
HU	0.61	8.34	77.3	12.61	69.70	5.40	6.80	0.11	1.11
SK	0.88	7.01	77.7	16.89	69.76	7.80	6.40	0.29	1.47
SL	0.80	8.36	89.8	21.97	52.14	2.30	11.40	0.72	1.6
FR	1.34	8.81	79.5	17.22	47.60	6.20	20.00	0.02	1.62
IT	0.51	11.38	82.2	18.18	77.48	11.10	19.50	0.03	1.87
DE	0.82	10.16	87.2	17.35	67.61	2.50	12.30	0.02	1.96
PL	0.71	8.37	85.9	12.16	46.82	4.20	10.30	0.06	2.21
ES	0.73	9.95	79.7	18.36	74.96	7.50	10.00	0.03	2.22
NL	0.78	7.88	92.6	8.77	64.72	3.00	30.00	0.15	2.25
CZ	1.39	7.17	73.6	16.24	40.89	2.80	8.30	0.15	2.30
MEAN	0.85	9.46	82.48	15.13	63.06	5.13	13.4	0.19	1.70

Source: Authors' study based on [75].

The third group (cluster 3) consists of countries such as Austria, Croatia, Denmark, Latvia, and Romania (grey in Figure 2). They are characterized by the lowest energy losses and relatively low generation of waste (Table 6 includes actual values of the diagnostic variables for countries included in third cluster). The last group, including Bulgaria, Greece, Lithuania, and Portugal, form cluster 4 (red in Figure 2) and consists of countries with the highest energy dependence (X_5), and greenhouse gas emissions intensity of energy consumption (X_3) as well as the highest proportion of the population struggling to maintain an appropriate temperature in their apartments (X_6) (Table 7). As in the previous cases, the actual values of the diagnostic variables for the countries included in the fourth cluster are included in Table 7. The analysis of Table 7 shows that it is the most homogeneous cluster.

Table 6. "Smart and efficient energy systems"—values of diagnostic variables for countries constituting cluster 3.

ISO	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
HR	0.32	9.37	86.60	28.47	56.22	6.60	5.20	0.22	1.45
LV	0.25	8.32	83.80	40.98	43.96	8.00	4.30	0.36	2.53
RO	0.42	12.68	85.70	24.29	30.37	9.30	1.30	0.06	3.00
DK	0.43	13.05	63.10	37.20	38.78	2.80	7.60	0.31	3.19
AT	0.45	10.08	83.90	33.63	71.73	1.80	11.50	0.21	4.30
MEAN	0.37	10.7	80.62	32.91	48.21	5.70	5.98	0.23	2.89

Source: Authors' study based on [75].

Table 7. "Smart and efficient energy systems"—values of diagnostic variables for countries constituting cluster 4.

ISO	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
GR	0.75	8.53	74.90	19.68	74.11	17.90	4.20	0.14	0.84
BG	1.20	6.09	97.10	21.56	38.10	30.10	2.30	0.44	1.90
LI	0.26	9.10	102.60	25.46	75.22	26.70	3.90	0.50	2.20
PT	0.48	10.24	78.60	30.62	73.85	18.90	2.30	0.13	2.28
MEAN	0.67	8.49	88.30	24.33	65.32	23.40	3.17	0.30	1.81

Source: Authors' study based on [75].

The results of the Kruskal–Wallis test (Table 8) indicate that the variables selected as forming the aspect of "smart and efficient energy systems" are discriminatory with regard to the analyzed countries. The null hypothesis should be rejected in the case of seven out of nine variables, which indicates a statistically significant difference in the median values of variables under study. The null hypothesis should not be rejected in the case of variable X_3 (greenhouse gas emission intensity) and variable X_8 (waste generation). However, it is worth emphasizing that the variables mentioned above distinguish cluster 1 from the others. It takes place because in cluster 1, variable X_3 takes much lower values than in the other three groups, while variable X_8 takes much higher values. Taking into account this observation, it is justified to leave variables X_3 and X_8 in the set of diagnostic variables.

Table 8. "Smart and efficient energy systems" aspect—Kruskal–Wallis test results.

Test Chi-Squared	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Statistics	13.891	6936	3584	18.212	8657	13.270	9502	5112	8169
p-Value	0.003	0.074	0.310	0.0004	0.034	0.004	0.023	0.163	0.042

Source: Authors' study based on [75].

4.2. "Macroeconomic Heterogeneity" Analysis

In the previous part, countries were grouped according to the emissivity of economies and the degree of dependence on energy imports. These variables, associated with the 7th and 12th SDG, determined the actual demand of economies and indicated the primary energy sources. This section focuses on the potential for the energy transition, understood as the strength of the economy entering the transition process. Variables used in this section of the analysis focus on aspects such as investments, innovation, education, and dirtiness of the economy. They are therefore connected with 8th, 9th, and 10th SDG.

Figure 3 presents a dendrogram created for variables X_{10}–X_{16}. When analyzing Figures 3 and 4, it is possible to notice a clear distinction of two groups, nearly identical to the "old" and "new" Europe. Countries marked as blue (Figure 4), i.e., Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, and Sweden form cluster 1. They are economically stronger, and therefore, the energy transformation in these countries is likely to run more efficiently, for example, due to increased investments and the functioning of the R&D sector (X_{10} and X_{11}). In addition, these countries are characterized by a larger percentage of people with higher education and wealthier households (Table 9). As already mentioned in the theoretical part of this work, the education and wealth of the inhabitants translate into environmental awareness as well as absorption of novelties and trends in the field of less or zero waste movements. The real values of the diagnostic variables for the first cluster of countries created based on the "macroeconomic heterogeneity" aspect are included in Table 9. The analysis of data from this table shows that the values observed in individual countries do not differ significantly from the average value, which proves the high homogeneity of the cluster.

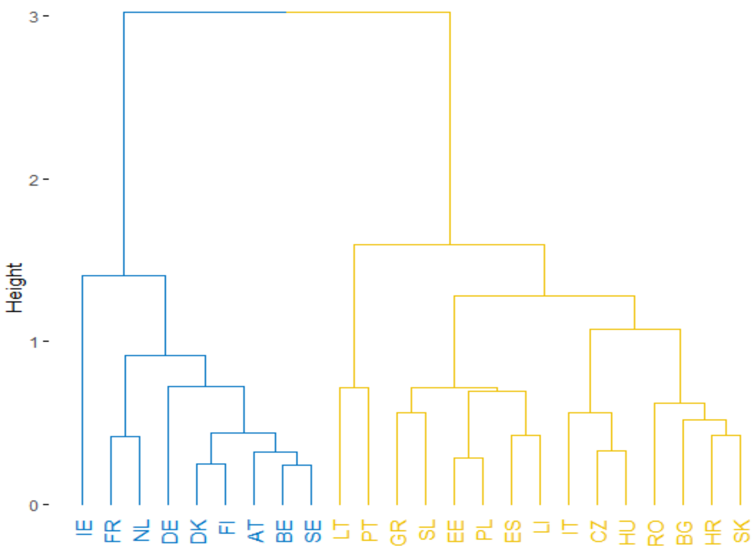

Figure 3. Cluster dendrogram for the "macroeconomic heterogeneity" aspect. Source: Authors' study based on [75].

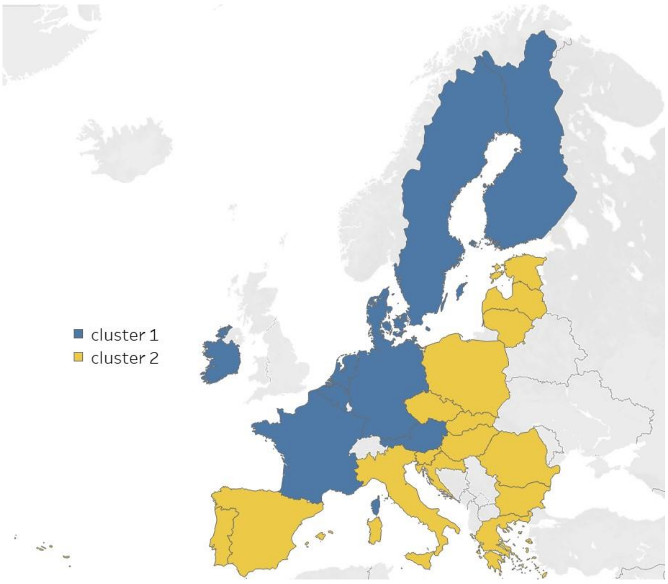

Figure 4. Choropleth map for the "macroeconomic heterogeneity". Source: Authors' study based on [75].

Table 9. "Macroeconomic heterogeneity"—values of diagnostic variables for the countries constituting cluster 1.

ISO	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
BE	24.16	2.89	1.91	47.30	27,082	0.07	121.5
DK	21.30	2.91	2.12	47.10	25,754	0.02	111.9
DE	21.69	3.18	1.73	33.30	30,142	0.02	131.2
IE	45.60	0.78	1.58	55.40	22,541	0.02	114.00
FR	23.63	2.19	1.59	48.20	26,158	0.06	113.7
NL	21.25	2.16	1.78	49.10	26,842	0.05	98.40
AT	24.68	3.19	1.87	41.60	28,177	0.02	125.5
FI	23.74	2.79	1.93	42.00	25,912	0.09	115.30
SE	24.41	3.40	1.72	48.40	25,004	0.06	119.70
MEAN	25.61	2.61	1.80	45.82	26,401.30	0.04	116.8

Source: Authors' study based on [75].

The countries of Central and Eastern Europe including Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia as well as Greece, Italy, Portugal and Spain, constitute cluster 2 (yellow in Figure 4). They are characterized by high air emission intensity from the industry and high average CO_2 emissions per km from new passenger cars (X_{15} and X_{16}). This indicates that their economies are based mainly on coal and that old passenger cars, imported from Western Europe, dominate on the roads. The lower material status of inhabitants translates into smaller absorption of pro-ecological solutions, which are often more expensive, at least in the short term (Table 10). Table 10 contains the values of diagnostic variables observed among the members of the second cluster. Additionally, in this case, there were no significant deviations from the average value in the cluster, and therefore, the group was well separated.

Table 10. "Macroeconomic heterogeneity"—values of diagnostic variables for countries constituting cluster 2.

ISO	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
BG	18.52	0.84	0.81	32.70	10,875	0.27	137.60
CZ	27.07	1.94	1.51	32.60	20,106	0.04	128.70
EE	26.21	1.61	0.97	42.80	17,786	0.44	130.10
GR	10.14	1.27	1.18	42.40	15,904	0.25	115.60
ES	19.87	1.25	1.01	46.50	20,346	0.10	121.30
HR	21.02	1.11	0.82	35.50	14,969	0.19	119.40
IT	17.96	1.45	1.41	27.70	23,003	0.06	119.40
LV	22.19	0.64	0.64	43.80	15,519	0.88	127.90
LI	21.37	1.00	0.92	55.20	19,798	0.04	132.00
HU	27.12	1.48	1.24	30.60	15,896	0.09	131.80
PL	18.52	1.32	0.99	43.50	17,306	0.32	132.00
PT	18.15	1.40	1.23	37.40	19,628	0.87	109.40
RO	23.63	0.48	0.36	25.50	16,608	0.22	124.30
SL	19.64	2.04	1.67	44.10	19,548	0.14	123.70
SK	21.49	0.83	0.78	39.20	16,043	0.06	133.40
MEAN	20.86	1.244	1.04	38.63	17,555.70	0.26	125.77

Source: Authors' study based on [75].

Furthermore, in this case, the hypothesis concerning the equality of medians was verified using the Kruskal–Wallis test. The results of the procedure are presented in Table 11. For each of the analyzed variables X_{10}–X_{16}, the null hypothesis should be rejected since statistically significant differences occur in the median levels between the two groups, and thus, the indicated set of diagnostic variables has discriminatory properties.

Table 11. "Macroeconomic heterogeneity"—Kruskal–Wallis test results.

Test Chi-Squared	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
Statistics	3875	10.561	15.254	5270	15.724	9337	5004
p-Value	0.049	0.001	0.0001	0.021	0.001	0.002	0.025

Source: Authors' study based on [75].

4.3. Analysis of Potential to Follow up Energy Transition Processes

In the third part of the empirical analysis, we juxtaposed variables of the two aspects discussed above. We believe that the emissivity of the economy and its economic strength determines the potential to conduct the energy transition; thus, constituting an indicator that allows establishing the economies in which this process will be the most difficult, and those that should relatively quickly achieve the set of energy, environmental, or broadly understood Sustainable Development Goals.

In this case, we also divided the countries according to their taxonomic similarity. The analysis of the dendrogram (Figure 5) and the indication of the silhouette index divided the European Union Member States into four clusters (Figures 5 and 6). The first one, which includes Bulgaria, Croatia, Greece, Latvia, Lithuania, Portugal, and Romania (blue on Figure 6) appears to comprise of countries that are likely to find it very challenging to achieve the EU's energy targets within the set time frame. This interpretation is supported by the fact that countries within this cluster are characterized by the highest values of variables concerning greenhouse gas emissions (X_3), air emissions intensity from the industry (X_{15}), and the percentage of people who struggle to maintain an adequate temperature in their houses (X_6) (Table 12). Moreover, these countries have the lowest circular material use (X_7) and values of five out of eight economic and development variables (X_{10}–X_{14}), describing investments, innovations, and the wealth and education of the inhabitants. Taking into account the high emissivity of economies, an unremarkable renewable energy fraction, as well as the poor economic condition, it can be assumed that achievement of the EU's energy targets, both at the national level and the level of individual households, may be challenging in these countries. It appears that, without adequate financial support, the desired greening of the economy will not be possible, even after taking into account the overall downturn caused by the global COVID pandemic. Nevertheless, as a positive phenomenon, it can be indicated that they are the countries with the lowest energy losses.

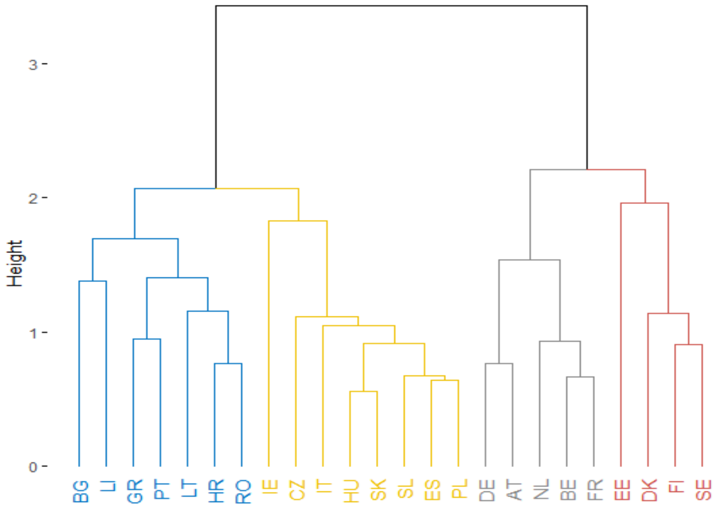

Figure 5. Cluster dendrogram for a holistic approach. Source: Authors' study based on [75].

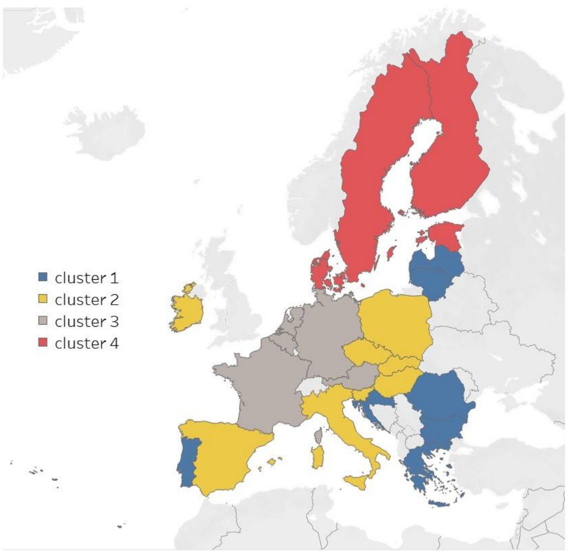

Figure 6. Choropleth map for a holistic approach. Source: Authors' study based on [75].

Table 12. Mean values of diagnostic variables in each cluster.

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
X_1	0.53	0.76	0.91	1.10	X_9	2.03	1.71	2.21	3.85
X_2	9.19	10.03	8.69	8.22	X_{10}	19.29	24.66	23.08	23.92
X_3	87.04	80.73	85.56	70.18	X_{11}	0.96	1.39	2.72	2.68
X_4	27.29	16.05	17.38	42.14	X_{12}	0.85	1.27	1.78	1.69
X_5	55.98	62.52	65.67	28.99	X_{13}	38.93	39.95	43.90	45.08
X_6	16.79	5.75	3.48	2.25	X_{14}	16,185.86	19,348.63	27,680.20	23,614.00
X_7	3.36	9.29	19.60	9.00	X_{15}	0.39	0.10	0.04	0.15
X_8	0.26	0.22	0.14	2.09	X_{16}	123.74	125.54	118.06	119.25

Source: Authors' study based on [75].

The second cluster (yellow in Figures 5 and 6), including eight countries: Czechia, Hungary, Ireland, Italy, Slovakia, Slovenia, Spain, and Poland, is the cluster with the highest values of energy productivity (X_2), investment rate (X_{10}), and, unfortunately, CO_2 emissions per km from new passenger cars (X_{16}). At the same time, they have the lowest level of renewable energy sources (X_4) and the gross value added in environmental goods and services (X_9) (Table 12). Relatively low ecological burdens and a high degree of investment should contribute to achieving the set energy goals. Still, it will require significant changes in infrastructure and the mentality of inhabitants.

The third cluster consists of five countries: Austria, Belgium, France, Germany, and Netherlands (grey on Figures 5 and 6). They are characterized by the highest degree of innovation (variable X_{11} and X_{12}), use of circular material (X_7), and levels of wealth (X_{14}). The largest degree of energy dependence (X_5) may constitute a problem in these countries. The third cluster consists of countries with the lowest waste generation (X_8) as well as CO_2 emissions from the industry and passenger cars. All the above factors prove that the five countries mentioned will certainly achieve their energy targets. The only aspect that innovation and investment should focus on is increasing energy independence (mainly from Russia), which, in fact, already takes place by investing in hydrogen-based energy.

The fourth cluster is formed by the Nordic countries: Denmark, Finland, Sweden, and Estonia (Figures 5 and 6). They are characterized by tremendous potential for a smooth transition in the energy transformation process. These countries have the highest share of renewable energy (variable X_4), investment in GDP (X_{10}), and inhabitants with higher education (X_{13}). They are also countries with the lowest greenhouse gas emissions (X_4), energy dependence (X_5), and the proportion of inhabitants who have problems with maintaining a proper temperature in their homes (X_6). The lowest energy productivity in this group (X_2) results from a high share of renewable energy sources. However, taking into account the small population of these countries, renewable energy sources completely fulfil their role and effectively supply the inhabitants and industry with the necessary energy; all this makes them the countries with the highest potential for a smooth energy transition and fully achieving energy goals.

Table 12 summarizes the mean values for individual diagnostic variables. In the vast majority of cases, significant differences can be noticed between the average levels of diagnostic variables in the selected clusters, which proves the high separability of clusters and the high quality of the presented groups. The Kruskal–Wallis test additionally confirmed this. Table 13 shows the results of the Kruskal–Wallis test for the holistic approach in our analysis. The juxtaposition of variables revealed slightly worse discriminatory properties than in the case of two aspects separately, i.e., smart and efficient energy systems and macroeconomic heterogeneity. This time, statistically significantly different medians occurred only in the case of eight individual variables. However, similarly to the first analyzed aspect, also at this point, maintenance of all individual variables is logically justified. Variables X_3, X_5, X_8, X_9, and X_{13} clearly distinguish the fourth cluster from other groups. Variable X_{10} separates cluster 2 from the rest, while variables X_{10} and X_{16} distinguish the appropriate clusters 1 and 3, respectively.

Table 13. Kruskal–Wallis test results—holistic approach.

Test Chi-Squared	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Statistics	8894	2202	2585	9424	4452	16.140	14.337	1284
p-value	0.031	0.532	0.460	0.024	0.217	0.001	0.003	0.733
Test Chi-Squared	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
Statistics	3805	5063	16.614	14.929	3894	15.362	7958	4062
p-Value	0.283	0.167	0.001	0.002	0.273	0.015	0.047	0.2548

Source: Authors' study based on [75].

The grouping consistency obtained based on taxonomic analyses of various aspects was also investigated using the chi-square test of independence. In the case of smart and efficient energy systems and macroeconomic heterogeneity, the test statistic was 3.5911 ($p = 0.31$), which indicates that the results obtained in the first and second grouping are not consistent. Therefore, there is no association between the analyzed aspects. However, when studying the potential for the energy transition and the aspects above, the null hypothesis should be rejected in each case, meaning that there is an association between the potential for the energy transition and the emission intensity ($\chi^2 = 37.82; p = 0.00$), as well as the potential for the energy transition and the strength of the economy ($\chi^2 = 17.07, p = 0.001$).

5. Discussion and Conclusions

The article presents a discussion focusing on the implementation of the energy transition in the European Union. Such a transformation is currently taking place in all economies and results from many processes that have overlapped since the beginning of the 1990s. Globalisation, which increased the interdependence between countries in social, economic, and institutional terms, contributed to the shape of the energy transformation to the greatest extent [8,9,105]. Systematically developing globalization facilitated significant socio-economic development and the related increase in the wealth of societies [14,106,107]. Positive socio-economic changes were also influenced by the parallel dynamic growth of innovation, foreign direct investment, and significant institutional progress [10–13,15,108].

Additionally, significant changes in consumers' attitudes and the labor market have also taken place [16–19,109]. All these processes allowed for the commercialization of technologies related to the production of electricity and heat, which are currently available to households in retail sales [110]. Commonly available technologies generating energy from renewable sources for households and enterprises solve problems associated with the systematic increase in energy demand and a limited amount of traditional energy sources, which are becoming increasingly expensive and cause significant environmental degradation [3,4]. All the above indicates that the problem of energy transformation is a key issue related to the possibility of further development of world economies.

The analysis of the EU's member states presented in this scientific paper constitutes an interesting research problem due to this process's institutional and legal determinants. In the EU, legal acts were adopted that to oblige all member states to introduce assumptions regarding the energy transformation within strictly defined deadlines. The discussion entails a question about the success of this process in the case of all countries, as all countries are obliged to carry out the energy transition. Failure to meet the adopted transformation conditions by one country or a group of countries may hinder the assumed energy transition process and lead to a change in the assumed conditions or even withdrawal of the entire European Union from the undertaken path. In the light of such information, the research questions posed by the authors, i.e., how to effectively carry out the desired process of energy transformation and how to measure it appears to be important from the perspective of further development of the EU in the upcoming years. To obtain an answer to such questions, the article proposes an innovative method of assessing European Union countries in terms of energy transformation. The analysis of member states was conducted based on the selection of individual Sustainable Development Goals and related diagnostic variables. It allowed the authors to focus on studying two distinct aspects related to energy transformation processes. The first "smart and efficient energy systems" concerns the nature of energy and heat consumption by economies of the member states. The second aspect, "macroeconomic heterogeneity", allows for assessing countries in terms of their economic potential necessary to carry out the energy transformation effectively.

The assessment of member states in the light of these two aspects allowed for the grouping of European economies according to of their ability to achieve goals related to the energy transformation. In the study, the countries were first evaluated in terms of "smart and efficient energy systems", which enabled the identification of four clusters. The second step considered the "macroeconomic heterogeneity" aspect, and countries were assigned to only two clusters. Finally, a country analysis was performed by taking into account both elements, resulting in the division of countries into four groups.

The analysis revealed that Estonia, Denmark, Finland, and Sweden were countries in which the energy transformation should proceed smoothly and, at the same time, translate into further economic growth. Countries involving a risk of non-compliance with conditions provided for in the applicable EU legal acts were also identified. These are: Bulgaria, Croatia, Greece, Latvia, Lithuania, Romania, and Portugal. This indicates that the EU policy should take into account possible difficulties with the implementation of required environmental criteria by some countries or certain regions. Specific guidelines related to instruments supporting the achievement of energy transformation goals should also be included in subsequent legal acts issued by the EU.

In the article, an evaluation of the generally understood readiness of countries to go through the energy transformation in the long term has been made. The proposed approach to assessing the energy transition is to combine the concept of the energy transition with sustainable development and growth. Authors do not want to benchmark countries on their fulfillment of energy transition and climate goals but attempt to assess the readiness of countries to effectively implement the energy transition. The presented perspective is new because countries may be leaders in energy transformation, but their economies may not be prepared for the related changes, which, in the long term, may translate into a deterioration of the socio-economic situation of selected countries. The direction of further research of the authors will be an attempt to confront the obtained results regarding the readiness of countries to go through the energy transformation with the actual state of implementation of selected tasks of sustainable development or selected aspects of these tasks by these countries. The conclusions will provide a basis for determining the likely long-term development paths of the EU member states, both in the context of the energy transformation processes and the level of sustainable development. This will allow us to answer the question, to what extent the selected EU member states will be able to implement simultaneously processes related to energy transition and challenges of sustaining sustainable economic development.

Finally, the authors want to emphasize the fact that there is a significant problem related to the implementation energy transformation of the EU member states. The situation in the community is specific because the entire transformation is strongly surrounded by institutions and legislation that obliges countries to meet the next conditions related to the energy transformation and the implementation of the Sustainable Development Goals. The issue of achieving the goals of the European Union's energy transformation is a process subordinated to the goals set out in legal documents. The goals pursued in this way may differ significantly from the capabilities of economies, enterprises, households, and social acceptance. Undoubtedly, the functioning of all economies is based on energy, and the functioning of households and the costs of living and possible inflation are related to it. Meanwhile, there are regions in the EU (regions within countries) where the energy transition is too expensive from an economic point of view, where a significant percentage of households are doomed to energy poverty, and where social opposition to green transformation is slowly emerging. In such regions, the processes of energy transformation may be slowed down or even stopped from below. The authors want to emphasize the need to include energy justice in transformation processes and that the transformation should result from or be combined with grassroots initiatives at the local level, and that such an approach has the greatest sense in the long-term implementation of the EU energy strategy [111–114]. It should be emphasized that it is not possible to determine what effect energy transformation will bring for the economy and societies in the future. It may turn out that the suspension of the energy transformation processes will move from the one region to the entire member state, or that the economy of one of the countries or a group of countries will undergo a serious economic crisis. In such a situation, some countries will go back to the starting point, and the entire EU project will end in failure.

Author Contributions: Conceptualization, all authors; methodology, M.B.P., M.O. and M.E.K.-C.; software, M.B.P. and M.E.K.-C.; formal analysis, M.B.P. and M.E.K.-C.; investigation, M.B.P., M.O. and M.E.K.-C., resources, M.E.K.-C.; writing—original draft preparation, M.B.P., M.O. and M.E.K.-C.; writing—review and editing, M.B.P., M.O. and M.E.K.-C.; visualization M.E.K.-C.; supervision, M.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available on request due to restrictions. The data presented in this study are available on request from the corresponding author.

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

References

1. Strunz, S. The German energy transition as a regime shift. *Ecol. Econ.* **2014**, *100*, 150–158. [CrossRef]
2. Tian, J.; Yu, L.; Xue, R.; Zhuang, S.; Shan, Y. Global low-carbon energy transition in the post-COVID-19 era. *Appl. Energy* **2021**, *307*, 118205. [CrossRef]
3. Pietrzak, M.; Igliński, B.; Kujawski, W.; Iwański, P. Energy Transition in Poland—Assessment of the Renewable Energy Sector. *Energies* **2021**, *14*, 2046. [CrossRef]
4. Chovancová, J.; Tej, J. Decoupling economic growth from greenhouse gas emissions: The case of the energy sector in V4 countries. *Equilib. Q. J. Econ. Econ. Policy* **2020**, *15*, 235–251. [CrossRef]
5. Henderson, J.; Anupama, S. The Energy Transition: Key Challenges for Incumbent and New Players in the Global Energy System, OIES Paper. Oxford Institute for Energy Studies. 2021. Available online: https://www.oxfordenergy.org/publications/the-energy-transition-key-challenges-for-incumbent-and-new-players-in-the-global-energy-system/ (accessed on 19 September 2021).
6. Grosse, T.G. Low Carbon Economy Policy in Poland: An Example of the Impact of Europeanisation. *Equilib. Quart. J. Econ. Econ. Policy* **2011**, *6*, 9–39. [CrossRef]
7. Szopik-Depczynska, K.; Cheba, K.; Bąk, I.; Stajniak, M.; Simboli, A.; Ioppolo, G. The study of relationship in a hierarchical structure of EU sustainable development indicators. *Ecol. Indic.* **2018**, *90*, 120–131. [CrossRef]
8. Rees, W.E. Globalization, trade and migration: Undermining sustainability. *Ecol. Econ.* **2006**, *59*, 220–225. [CrossRef]
9. Overland, I. Energy: The missing link in globalization. *Energy Res. Soc. Sci.* **2016**, *14*, 122–130. [CrossRef]
10. Cheba, K.; Szopik-Depczyńska, K. Multidimensional comparative analysis of the competitive capacity of the European Union countries and geographical regions. *Oeconomia Copernic.* **2017**, *8*, 487–504. [CrossRef]
11. Szopik-Depczynska, K.; Kędzierska-Szczepaniak, A.; Szczepaniak, K.; Cheba, K.; Gajda, W.; Ioppolo, G. Innovation in sustainable development: An investigation of the EU context using 2030 agenda indicators. *Land Use Policy* **2018**, *79*, 251–262. [CrossRef]
12. Kijek, T.; Matras-Bolibok, A. The relationship between TFP and innovation performance: Evidence from EU regions. *Equilib. Q. J. Econ. Econ. Policy* **2019**, *14*, 695–709. [CrossRef]
13. Kijek, A.; Matras-Bolibok, A. Technological convergence across European regions. *Equilib. Q. J. Econ. Econ. Policy* **2020**, *15*, 295–313. [CrossRef]
14. Ginevičius, R. Multi-criteria assessment of socioeconomic systems' conditions based on hierarchically structured indicator systems. *Econ. Sociol.* **2020**, *13*, 256–266. [CrossRef]
15. Androniceanu, A.-M.; Kinnunen, J.; Georgescu, I.; Androniceanu, A. A Multidimensional Approach to Competitiveness, Innovation and Well-Being in the EU Using Canonical Correlation Analysis. *J. Compet.* **2020**, *12*, 5–21. [CrossRef]
16. Piekut, M. The Consumption of Renewable Energy Sources (RES) by the European Union Households between 2004 and 2019. *Energies* **2021**, *14*, 5560. [CrossRef]

17. Gajdos, A.; Arendt, L.; Balcerzak, A.P.; Pietrzak, M.B. Future trends of labour market polarisation in Poland. *Perspect. Trans. Bus. Econ.* **2020**, *19*, 114–135.
18. Rollnik-Sadowska, E.; Dąbrowska, E. Cluster analysis of effectiveness of labour market policy in the European Union. *Oeconomia Copernic.* **2018**, *9*, 143–158. [CrossRef]
19. Fragkos, P.; Paroussos, L. Employment creation in EU related to renewables expansion. *Appl. Energy* **2018**, *230*, 935–945. [CrossRef]
20. Chocholatá, M.; Furková, A. The analysis of employment rates in the context of spatial connectivity of the EU regions. *Equilib. Quart. J. Econ. Econ. Policy* **2018**, *13*, 181–213. [CrossRef]
21. United Nations. Theme Report on Energy Transition. Toward the Achievement of SDG7 and Net-Zero Emission. 2021. Available online: https://www.un.org/sites/un2.un.org/files/2021-twg_2-062321.pdf (accessed on 1 September 2021).
22. Lin, M.-X.; Liou, H.M.; Chou, K.T. National Energy Transition Framework toward SDG7 with Legal Reforms and Policy Bundles: The Case of Taiwan and Its Comparison with Japan. *Energies* **2020**, *13*, 1387. [CrossRef]
23. Markandya, A.; Arto, I.; González-Eguino, M.; Román, M.V. Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union. *Appl. Energy* **2016**, *179*, 1342–1350. [CrossRef]
24. Gielen, D.; Boshell, F.; Saygin, D.; Bazilian, M.D.; Wagner, N.; Gorini, R. The role of renewable energy in the global energy transformation. *Energy Strat. Rev.* **2019**, *24*, 38–50. [CrossRef]
25. International Monetary Fund (IMF). *World Economic Outlook*; International Monetary Fund (IMF): Washington, DC, USA, 2021; ISBN 1557757402.
26. United Nations. World Population Prospects. 2019. Available online: https://population.un.org/wpp/ (accessed on 23 February 2020).
27. IEA. Tracking SDG. The Energy Progress Report. 2019. Available online: https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2019 (accessed on 10 October 2021).
28. Chygryn, O.; Rosokhata, A.; Rybina, O.; Stoyanets, N. Green competitiveness: The evolution of concept formation. *E3S Web Conf.* **2021**, *234*, 00004. [CrossRef]
29. United Nations. Resolution Adopted by the General Assembly on 25 September Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Available online: https://www.eea.europa.eu/policy-documents/resolution-adopted-by-the-general (accessed on 19 October 2021).
30. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. Available online: https://sdgs.un.org/2030agenda (accessed on 7 December 2021).
31. European Commission. The European Green Deal. 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN (accessed on 7 December 2021).
32. Zielenkiewicz, M. Institutional Environment in the Context of Development of Sustainable Society in the European Union Countries. *Equilib. Quart. J. Econ. Econ. Policy* **2014**, *9*, 21–38. [CrossRef]
33. Iddrisu, I.; Bhattacharyya, S. Sustainable Energy Development Index: A multi-dimensional indicator for measuring sustainable energy development. *Renew. Sustain. Energy Rev.* **2015**, *50*, 513–530. [CrossRef]
34. Global Energy Institute (GEI). Assessing Risk in a Global Energy Market 2020. 2020. Available online: https://www.globalenergyinstitute.org/assessing-risk-global-energy-market (accessed on 7 December 2021).
35. Nussbaumer, P.; Bazilian, M.; Modi, V. Measuring energy poverty: Focusing on what matters. *Renew. Sustain. Energy Rev.* **2012**, *16*, 231–243. [CrossRef]
36. Kuc-Czarnecka, M.; Olczyk, M.; Zinecker, M. Improvements and Spatial Dependencies in Energy Transition Measures. *Energies* **2021**, *14*, 3802. [CrossRef]
37. OECD-JRC. *Handbook on Constructing Composite Indicators: Methodology and User Guide, OECD Statistics Working Paper JT00188147, STD/DOC(2005)3*; OECD-JRC: Ispra, Italy, 2008.
38. Saltelli, A. Composite Indicators between Analysis and Advocacy. *Soc. Indic. Res.* **2007**, *81*, 65–77. [CrossRef]
39. Gnaldi, M.; Del Sarto, S. Variable Weighting via Multidimensional IRT Models in Composite Indicators Construction. *Soc. Indic. Res.* **2016**, *136*, 1139–1156. [CrossRef]
40. Greco, S.; Ishizaka, A.; Tasiou, M.; Torrisi, G. On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness. *Soc. Indic. Res.* **2018**, *141*, 61–94. [CrossRef]
41. Cinelli, M.; Spada, M.; Kim, W.; Zhang, Y.; Burgherr, P. MCDA Index Tool: An interactive software to develop indices and rankings. *Environ. Syst. Decis.* **2021**, *41*, 82–109. [CrossRef]
42. Sgouridis, S.; Csala, D. A Framework for Defining Sustainable Energy Transitions: Principles, Dynamics, and Implications. *Sustainability* **2014**, *6*, 2601–2622. [CrossRef]
43. World Economic Forum (WEF). *Fostering Effective Energy Transition 2019*; World Economic Forum (WEF): Cologny, Switzerland, 2019.
44. Sachs, J.; Woo, W.; Yoshino, N.; Taghizadeh-Hesary, F. (Eds.) *Handbook of Green Finance: Energy Security and Sustainable Development*; Springer: Berlin/Heidelberg, Germany, 2019.
45. Van de Putte, A.; Campbell-Holt, A.; Littlejohn, G. *Financing the Sustainable Energy Transition*; Springer International Publishing: Berlin/Heidelberg, Germany, 2020; Volume 73, ISBN 9783030390662.
46. Vainio, A.; Varho, V.; Tapio, P.; Pulkka, A.; Paloniemi, R. Citizens' images of a sustainable energy transition. *Energy* **2019**, *183*, 606–616. [CrossRef]

47. Zinecker, M.; Doubravský, K.; Balcerzak, A.P.; Pietrzak, M.B.; Dohnal, M. The Covid-19 disease and policy response to mitigate the economic impact in the EU: An exploratory study based on qualitative trend analysis. *Technol. Econ. Dev. Econ.* **2021**, *27*, 742–762. [CrossRef]
48. Kuzemko, C.; Bradshaw, M.; Bridge, G.; Goldthau, A.; Jewell, J.; Overland, I.; Scholten, D.; Van de Graaf, T.; Westphal, K. Covid-19 and the politics of sustainable energy transitions. *Energy Res. Soc. Sci.* **2020**, *68*, 101685. [CrossRef] [PubMed]
49. Luciani, G. *The Impacts of the Energy Transition on Growth and Income Distribution*; Springer International Publishing: Berlin/Heidelberg, Germany, 2020; Volume 73, ISBN 9783030390662.
50. Pysmenna, U.Y.; Trypolska, G.S. Sustainable Energy Transitions: Overcoming Negative Externalities. *Energ. Proc. CIS High. Educ. Inst. Power Eng. Assoc.* **2020**, *63*, 312–327. [CrossRef]
51. Schwanitz, V.J. The Sustainable Energy Transition—A Critical View on the Monitoring of SDG. In *Paradigms, Models, Scenarios and Practices for Strong Sustainability*; Editions Oeconomia: Paris, France, 2020; pp. 51–60.
52. Rösch, C.; Bräutigam, K.-R.; Kopfmüller, J.; Stelzer, V.; Fricke, A. Sustainability assessment of the German energy transition. *Energy Sustain. Soc.* **2018**, *8*, 12. [CrossRef]
53. Nikas, A.; Neofytou, H.; Karamaneas, A.; Koasidis, K.; Psarras, J. Sustainable and socially just transition to a post-lignite era in Greece: A multi-level perspective. *Energy Sources Part B Econ. Plan. Policy* **2020**, *15*, 513–544. [CrossRef]
54. Azzuni, A.; Breyer, C. Global Energy Security Index and Its Application on National Level. *Energies* **2020**, *13*, 2502. [CrossRef]
55. Muniz, R.N.; Stefenon, S.F.; Buratto, W.G.; Nied, A.; Meyer, L.H.; Finardi, E.C.; Kühl, R.M.; De Sá, J.A.S.; Da Rocha, B.R.P. Tools for Measuring Energy Sustainability: A Comparative Review. *Energies* **2020**, *13*, 2366. [CrossRef]
56. Phillis, A.; Grigoroudis, E.; Kouikoglou, V.S. Assessing national energy sustainability using multiple criteria decision analysis. *Int. J. Sustain. Dev. World Ecol.* **2020**, *28*, 18–35. [CrossRef]
57. Kouikoglou, V.S.; Grigoroudis, E.; Phillis, Y.A. National Energy Sustainability and Ranking of Countries. *Energy Syst. Eval.* **2021**, *2*, 63–101. [CrossRef]
58. Gunnarsdottir, I.; Davidsdottir, B.; Worrell, E.; Sigurgeirsdottir, S. Review of indicators for sustainable energy development. *Renew. Sustain. Energy Rev.* **2020**, *133*, 110294. [CrossRef]
59. Razmjoo, A.A.; Sumper, A.; Davarpanah, A. Development of sustainable energy indexes by the utilization of new indicators: A comparative study. *Energy Rep.* **2019**, *5*, 375–383. [CrossRef]
60. Ligus, M.; Peternek, P. The Sustainable Energy Development Index—An Application for European Union Member States. *Energies* **2021**, *14*, 1117. [CrossRef]
61. Eurostat, Sustainable Development in the European Union. Monitoring Report on Progress Towards the SDGs in an EU Context 2020 Edition. 2021. Available online: https://ec.europa.eu/eurostat/web/products-statistical-books/-/ks-02-20-202 (accessed on 7 December 2021).
62. International Renewable Energy Agency (IRENA) Accelerating the Energy Transition through Innovation. 2017. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Energy_Transition_Innovation_2017.pdf (accessed on 5 October 2021).
63. Musiał, W.; Zioło, M.; Luty, L.; Musiał, K. Energy Policy of European Union Member States in the Context of Renewable Energy Sources Development. *Energies* **2021**, *14*, 2864. [CrossRef]
64. Moreau, V.; Vuille, F. Decoupling energy use and economic growth: Counter evidence from structural effects and embodied energy in trade. *Appl. Energy* **2018**, *215*, 54–62. [CrossRef]
65. Chovancová, J.; Vavrek, R. Decoupling analysis of energy consumption and economic growth of v4 countries. *Probl. Ekorozw.* **2019**, *14*, 159–165.
66. Papież, M.; Śmiech, S.; Frodyma, K. The role of energy policy on the decoupling processes in the European Union countries. *J. Clean. Prod.* **2021**, *318*, 128484. [CrossRef]
67. World Economic Forum (WEF). Agenda of WEF. 2021. Available online: https://www.weforum.org/agenda/ (accessed on 1 September 2021).
68. Lund, P.D.; Skytte, K.; Bolwig, S.; Bolkesjö, T.F.; Bergaentzlé, C.; Gunkel, P.A.; Kirkerud, J.G.; Klitkou, A.; Koduvere, H.; Gravelsins, A.; et al. Pathway Analysis of a Zero-Emission Transition in the Nordic-Baltic Region. *Energies* **2019**, *12*, 3337. [CrossRef]
69. Ram, M.; Child, M.; Aghahosseini, A.; Bogdanov, D.; Lohrmann, A.; Breyer, C. A comparative analysis of electricity generation costs from renewable, fossil fuel and nuclear sources in G20 countries for the period 2015–2030. *J. Clean. Prod.* **2018**, *199*, 687–704. [CrossRef]
70. Krepl, V.; Shaheen, H.I.; Fandi, G.; Smutka, L.; Muller, Z.; Tlustý, J.; Husein, T.; Ghanem, S. The Role of Renewable Energies in the Sustainable Development of Post-Crisis Electrical Power Sectors Reconstruction. *Energies* **2020**, *13*, 6326. [CrossRef]
71. European Commission. Green New Deal. 2019. Available online: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed on 7 December 2021).
72. Ugarte, S.; Van Der Ree, B.; Voogt, M.; Eichhammer, W.; Ordoñez, J.A.; Matthias, R.; Schlomann, B.; Lloret, P.; Villafáfila, R. Energy Efficiency for Low-Income Households. 2016. Available online: https://upcommons.upc.edu/handle/2117/100956 (accessed on 18 October 2021).
73. Flachsbarth, F.; Wingenbach, M.; Koch, M. Addressing the Effect of Social Acceptance on the Distribution of Wind Energy Plants and the Transmission Grid in Germany. *Energies* **2021**, *14*, 4824. [CrossRef]

74. Segreto, M.; Principe, L.; Desormeaux, A.; Torre, M.; Tomassetti, L.; Tratzi, P.; Paolini, V.; Petracchini, F. Trends in Social Acceptance of Renewable Energy Across Europe—A Literature Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9161. [CrossRef] [PubMed]
75. Eurostat, Sustainable Development Indicators. 2021. Available online: https://ec.europa.eu/eurostat/web/sdi/main-tables (accessed on 7 December 2021).
76. Reike, D.; Vermeulen, W.J.V.; Witjes, S. The circular economy: New or Refurbished as CE 3.0?—Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resour. Conserv. Recycl.* **2018**, *135*, 246–264. [CrossRef]
77. Chen, W.-M.; Kim, H. Circular economy and energy transition: A nexus focusing on the non-energy use of fuels. *Energy Environ.* **2019**, *30*, 586–600. [CrossRef]
78. Su, C.; Urban, F. Circular economy for clean energy transitions: A new opportunity under the COVID-19 pandemic. *Appl. Energy* **2021**, *289*, 116666. [CrossRef]
79. Wiseman, J. The great energy transition of the 21st century: The 2050 Zero-Carbon World Oration. *Energy Res. Soc. Sci.* **2017**, *35*, 227–232. [CrossRef]
80. Taghizadeh-Hesary, F.; Rasoulinezhad, E. Analyzing Energy Transition Patterns in Asia: Evidence from Countries with Different Income Levels. *Front. Energy Res.* **2020**, *8*. [CrossRef]
81. Sovacool, B.K. How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy Res. Soc. Sci.* **2016**, *13*, 202–215. [CrossRef]
82. Marinaș, M.-C.; Dinu, M.; Socol, A.-G.; Socol, C. Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. *PLoS ONE* **2018**, *13*, e0202951. [CrossRef]
83. Apergis, N.; Payne, J.E. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy* **2010**, *38*, 656–660. [CrossRef]
84. Sineviciene, L.; Sotnyk, I.; Kubatko, O. Determinants of energy efficiency and energy consumption of Eastern Europe post-communist economies. *Energy Environ.* **2017**, *28*, 870–884. [CrossRef]
85. International Renewable Energy Agency (IRENA) Global Energy Transformation: A roadmap to 2050. 2019. Available online: https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition (accessed on 5 October 2021).
86. Ganda, F. The impact of innovation and technology investments on carbon emissions in selected organisation for economic Co-operation and development countries. *J. Clean. Prod.* **2019**, *217*, 469–483. [CrossRef]
87. Jin, L.; Duan, K.; Shi, C.; Ju, X. The Impact of Technological Progress in the Energy Sector on Carbon Emissions: An Empirical Analysis from China. *Int. J. Environ. Res. Public Health* **2017**, *14*, 1505. [CrossRef]
88. Shao, X.; Zhong, Y.; Li, Y.; Altuntaş, M. Does environmental and renewable energy R&D help to achieve carbon neutrality target? A case of the US economy. *J. Environ. Manag.* **2021**, *296*, 113229. [CrossRef]
89. Chodkowska-Miszczuk, J.; Kola-Bezka, M.; Lewandowska, A.; Martinát, S. Local Communities' Energy Literacy as a Way to Rural Resilience—An Insight from Inner Peripheries. *Energies* **2021**, *14*, 2575. [CrossRef]
90. Van den Broek, K.L. Household energy literacy: A critical review and a conceptual typology. *Energy Res. Soc. Sci.* **2019**, *57*, 101256. [CrossRef]
91. Motz, A. Consumer acceptance of the energy transition in Switzerland: The role of attitudes explained through a hybrid discrete choice model. *Energy Policy* **2021**, *151*, 112152. [CrossRef]
92. Kic, P. Role of Universities in Relation and Strategy of Sustainable Development Goals. *Agric. Mech. Asia Afr. Lat. Am.* **2020**, *51*, 77–82.
93. Nguyen, T.T.; Nguyen, T.-T.; Hoang, V.-N.; Wilson, C.; Managi, S. Energy transition, poverty and inequality in Vietnam. *Energy Policy* **2019**, *132*, 536–548. [CrossRef]
94. Schlesewsky, L.; Winter, S. Inequalities in energy transition: The case of network charges in Germany. *Int. J. Energy Econ. Policy* **2018**, *8*, 102. [CrossRef]
95. Mujtaba, G.; Shahzad, S.J.H. Air pollutants, economic growth and public health: Implications for sustainable development in OECD countries. *Environ. Sci. Pollut. Res.* **2020**, *28*, 12686–12698. [CrossRef]
96. OECD. Enhancing Equal Access to Opportunities for all in G20 Countries, 2020. Available online: https://www.oecd.org/economy/enhancing-equal-access-to-opportunities-g20/ (accessed on 7 October 2021).
97. Hamanaka, R.B.; Mutlu, G.M. Particulate Matter Air Pollution: Effects on the Cardiovascular System. *Front. Endocrinol.* **2018**, *9*, 680. [CrossRef] [PubMed]
98. Kuc-Czarnecka, M.; Piano, S.L.; Saltelli, A. Quantitative Storytelling in the Making of a Composite Indicator. *Soc. Indic. Res.* **2020**, *149*, 775–802. [CrossRef]
99. Murtagh, F.; Legendre, P. Ward's Hierarchical Agglomerative Clustering Method: Which Algorithms Implement Ward's Criterion? *J. Classif.* **2014**, *31*, 274–295. [CrossRef]
100. Ward, J.H. Hierarchical grouping to optimize an objective function. *J. Am. Stat. Assoc.* **1963**, *58*, 236–244. [CrossRef]
101. Murtagh, F. Ward's Hierarchical Clustering Method: Clustering Criterion and Agglomerative Algorithm. *arXiv* **2011**, arXiv:1111.6285.
102. Kaufman, L.; Rousseeuw, P.J. *Finding Groups in Data: An Introduction to Cluster Analysis*; Wiley Series in Probability and Statistics; Wiley & Sons: Hoboken, NJ, USA, 1990; ISBN 9780471878766. [CrossRef]

103. Kruskal, W.H.; Wallis, W.A. Use of ranks in one-criterion variance analysis. *J. Am. Stat. Assoc.* **1952**, *47*, 583–621. [CrossRef]
104. McHugh, M.L. The Chi-square test of independence. *Biochem. Med.* **2013**, *23*, 143–149. [CrossRef]
105. Dreher, A. Does globalization affect growth? Evidence from a new index of globalization. *Appl. Econ.* **2006**, *38*, 1091–1110. [CrossRef]
106. Simionescu, M.; Lazányi, K.; Sopková, G.; Dobeš, K.; Balcerzak, A.P. University of Economics in Bratislava Determinants of Economic Growth in V4 Countries and Romania. *J. Compet.* **2017**, *9*, 103–116. [CrossRef]
107. Skare, M.; Porada-Rochoń, M. Financial and economic development link in transitional economies: A spectral Granger causality analysis 1991–2017. *Oeconomia Copernic.* **2019**, *10*, 7–35. [CrossRef]
108. Balcerzak, A.P. Quality of Institutions in the European Union countries. Application of TOPSIS Based on Entropy Measure for Objective Weighting. *Acta Polytech. Hung.* **2020**, *17*, 101–122. [CrossRef]
109. Jankiewicz, M.; Pietrzak, M.B. Assesment of Trends in the Share of Expenditure on Services and Food in the Visegrad Group Member States. *Int. J. Bus. Soc.* **2020**, *21*, 977–996. [CrossRef]
110. Ellabban, O.; Abu-Rub, H.; Blaabjerg, F. Renewable energy resources: Current status, future prospects and their enabling technology. *Renew. Sustain. Energy Rev.* **2014**, *39*, 748–764. [CrossRef]
111. Carley, S.; Konisky, D.M. The justice and equity implications of the clean energy transition. *Nat. Energy* **2020**, *5*, 569–577. [CrossRef]
112. Oehlmann, M.; Meyerhoff, J. Stated preferences towards renewable energy alternatives in Germany—Do the consequentiality of the survey and trust in institutions matter? *J. Environ. Econ. Policy* **2016**, *6*, 1–16. [CrossRef]
113. Rogers, J.; Simmons, E.; Convery, I.; Weatherall, A. Public perceptions of opportunities for community-based renewable energy projects. *Energy Policy* **2008**, *36*, 4217–4226. [CrossRef]
114. Zoellner, J.; Schweizer-Ries, P.; Wemheuer, C. Public acceptance of renewable energies: Results from case studies in Germany. *Energy Policy* **2008**, *36*, 4136–4141. [CrossRef]