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Article

Is Energy Use in the EU Countries Moving toward Sustainable Development?

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Abstract: The increase in energy demand requires urgent investments in sustainable energy. It is vital to the success of the 2030 Agenda, adopted by the United Nations General Assembly. The article aimed to assess the situation of the European Union countries with regard to energy use. Indicators related to the implementation of SDG7 and environmental and resource productivity of the economy were adopted for the study. The research presented in this article fits into contemporary debates on the effectiveness of implementing one of the SDG7: ensuring access to affordable, reliable, sustainable, and modern energy for all. The analysis included 26 countries that have been in the European Union since 2010. The study's originality lies in the use of primary data obtained from the Eurostat database for three research periods: 2010, 2015, and 2020, which will allow for assessing the situation of the surveyed EU countries in the area of energy use. In order to achieve the research objective, selected methods of descriptive statistics and vector measurement were used. The application of a vector measure made it possible to rank the studied countries in terms of efficient energy use. Based on the results obtained, there is a significant variation in space and time in the evolution of the energy system of the European Union's member states toward sustainable development. Rational energy use is primarily the domain of north-western European countries, with Sweden and Austria always leading the rankings. However, this does not mean that in these countries, in spite of their high position in the ranking, the levels of some indicators in 2015 and 2020 as compared with those in 2010 did not deteriorate. Due to this fact, attention should be paid to the energy use process and identification of signals responsible for deteriorating the outcomes. The research results can help diagnose the results obtained so far and correct the European Union's climate and energy policy in the future.

Keywords: energy use; energy efficiency; sustainable development; SDG7; vector measurement

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1. Introduction

The increase in energy demand, in parallel with the increase in population and climate change, requires urgent investments in sustainable energy [1]. It is vital to the success of the 2030 Agenda, adopted by the United Nations General Assembly in 2015. The global energy goal, SDG7, includes three key objectives: ensuring affordable, reliable, and universal access to modern energy services; significantly increasing the share of renewable energy in the global energy mix; and doubling the global rate of energy efficiency improvement.

The concept of a green economy is inextricably linked to the paradigm of sustainable development based on the technologies performing an ancillary function to the environment and on the social responsibility of business for the quality of life of future generations. It focuses on perceptions of the dangers posed by humans' expansive economic and social activities, which irretrievably destroy the environment and its limited resources [2]. UNEP has defined the green economy as "*one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low-carbon, resource-efficient and socially inclusive*" [3]. It is most often monitored by indicators that can be classified into four thematic areas [4]:

I. Natural assets base, including indicators describing the state of the natural environment;
II. The environmental and resource productivity of the economy—indicators showing the links between the natural environment and the economy have been included in this group;
III. The environmental dimension of the quality of life of the population—presenting indicators to monitor the links between the natural environment and the society;
IV. Economic opportunities and policy responses—including indicators that characterise economic and social impact instruments, creating the desired development directions to greening the economy.

In light of the considerations presented in this article, attention is drawn to the second group, which includes indicators on energy use, renewable energy sources, and greenhouse gas emissions, which are a consequence of human activities.

The negative effects of unsustainable consumption of natural resources and pollutant emissions have been experienced in virtually every country [5,6]. Therefore, many researchers point to the need for systemic solutions to reduce the negative effects of increased energy consumption on the environment. Countries around the world, including the countries of the European Union, are committed to reducing the extraction and use of emission deposits, replacing them with renewable energy sources (RES). They are considered clean energy sources, and their optimal use minimises the environmental impact, produces a minimum amount of secondary waste, and is sustainable in relation to current and future economic and social needs [7]. In addition, it contributes to increasing the country's energy security, which is vital given the soaring oil and gas prices in 2021, exacerbated by the war in Ukraine. According to the EU's assumptions, alternative energy sources are expected to constitute a significant share of Europe's energy balance in the future.

The article aimed to assess the situation of the European Union countries with regard to energy use. Indicators related to the implementation of SDG7 and environmental and resource productivity of the economy were adopted for the study. Energy efficiency related to the area of energy use is essential in the process of ensuring energy supply and ecological security. According to Shove [8], at a first glance, the goal of energy efficiency is simple: it is to reduce the amount of energy consumed and the carbon emissions associated with the design and operation of such things as buildings, household appliances, and heating and cooling technologies. National and international responses to climate change are dominated by policies promoting energy efficiency. According to the UK Climate Change Committee, there are two main ways of reducing carbon emissions: energy efficiency and the decarbonisation of supply [9].

The research presented in this article fits into contemporary debates on the effectiveness of implementing one of the SDG7: ensure access to affordable, reliable, sustainable, and modern energy for all. The analysis included 26 countries that have been in the European Union since 2010. The originality of the study lies in the use of primary data obtained from the Eurostat database for three research periods: 2010, 2015, and 2020, which will allow for assessing the situation of the surveyed EU countries in the area of energy use. In order to achieve the research objective, selected methods of descriptive statistics and vector measurement were used. The methods of descriptive statistics allowed for the analysis of the occurrence of statistical regularities, which is an important element for assessing the energy use of the studied countries in terms of structure, dynamics, or interdependence.

The statistical measures addressed the issues related to the implementation of the SDG7 guidelines. The application of a vector measure made it possible to rank the studied countries in terms of efficient energy use. The adopted procedure for determining the vector measurement allowed for the observation of changes over time in this respect. The results of the analysis indicated which countries have or have not improved their situation related to the phenomenon under study.

The layout of this article includes an introduction, which outlines the main purpose of the paper and explains the authors' key motivations for conducting research on energy use in EU countries. In addition, a review of energy use literature is provided. The following section discusses the statistical data used in the article and describes the research procedure. Finally, the results of the study, discussion, and conclusions of the study are presented.

2. Literature Review

The literature review was divided into two sections that logically complement each other in the context of the subject matter:

Section 1: synthetic characterisation of the essence and key features of the "green economy", with a focus on the SDG7;

Section 2: literature review on the use of energy with a focus on energy efficiency (definitions, factors, and activities improving energy efficiency, benefits resulting from rational energy use).

2.1. Section 1

The problems of environmental and resource productivity of the economy are part of the research work on sustainable development, in particular on the "green economy". Pearce, Markandya, and Barbier promoted the conceptual category of "green economy" [10]. Two key conceptual categories are mentioned in the literature on the subject, as well as in the political and scientific discussion: "green economy" (United Nations Environment Programme UNEP, European Environment Agency EEA) and "green growth" (OECD). Although the concepts of "green economy" and "green growth" developed in a similar period (at the beginning of the second decade of the 21st century), they have a slightly different audience, and, as Adamowicz [11] or Aldieri and Vinci [12] noted, a distinction should be made between the two terms. The former relates more to the state and structure of the economy and its mode of operation, while the second conceptual category concerns the use of ecological factors to increase economic effects and further applies to the acceleration of development processes.

The definitions of the green economy in the literature emphasise respect for the environment and consider the environmental costs in economic activity. According to the United Nations Environment Programme, the "green economy" is characterised by improving people's well-being, quality of life, and social equality while reducing environmental risks, ecological scarcity of resources, and carbon emissions and increasing resource productivity [13,14]. According to the OECD definition [15], "green growth" is synonymous with economic growth and development while ensuring that natural capital provides the environmental resources and services necessary to ensure people's quality of life.

The "green economy" highlights emission reduction and energy saving; moreover, it focuses on reasonable and inclusive economic growth. Among the definition approaches, three aspects of the green economy are clearly visible, i.e., the economic, ecological (mainly expressed in the reduction of CO_2 emissions, resource efficiency), and social aspects [16,17]. For example, Jacob et al. [18], reviewing the concept of the green economy, pointed out that all approaches have in common the perception of the green economy as a way of reconciling the three pillars of human activity, i.e., the economic, environmental, and social pillars [18,19]. In turn, Barbier [20], when describing the concept of the "green economy", emphasised the importance of environmentally friendly economic reforms. In doing so, he pointed out the preference for shaping a low-carbon, circular economy and bioeconomy.

The literature on the subject also pointed to the fourth—the political aspect of the "green economy" (the policy for building a green economy) [21,22].

The "green economy" is characterised by three basic features, i.e., being low-carbon, being resource-efficient, and having reasonable and inclusive economic growth (Figure 1). In practice, it is an economy where revenue and employment growth are driven by investments (public and private) aimed at reducing emissions of gases and pollutants, increasing energy and raw material efficiency, and preventing the loss of biodiversity and ecosystem services. These investments should be supported by targeted public expenditure, appropriate reforms, and legal regulations. Such a development path should maintain, strengthen, and, if necessary, rebuild natural assets seen as a fundamental economic resource and source of public benefits, especially for the poor, whose livelihoods and security heavily depend on nature [14].

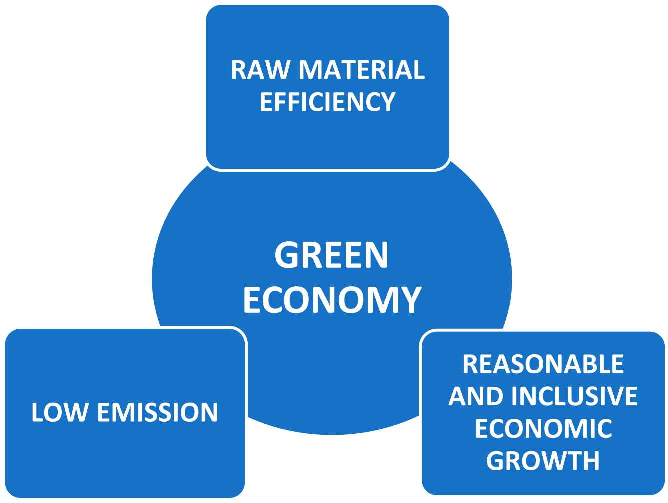


Figure 1. Features of a green economy. Source: own elaboration.

The idea of the green economy proclaimed as a new conceptual framework for building industrial production structures, and at the same time as a practical way of implementing the principles of sustainable development and fighting poverty, has found its support in the activities of many organisations and institutions, including the European Commission, OECD, or United Nations [23].

As already mentioned in the introduction, the UN General Assembly adopted in September 2015 the document "Transforming our world: a 2030 Agenda for sustainable development" [24]. Agenda 2030 identified 17 sustainable development goals (SDGs) [25], targeting, among other things, a global change in environmental awareness and environmentally oriented energy and food production. Goal 7: "Accessible and clean energy" (SDG7), in its general wording, is geared toward ensuring that all people have access to stable, sustainable, and modern energy sources at an affordable price by 2030. SDG7 identifies the need for tasks to ensure universal access to affordable, reliable, and modern energy services; significantly increase the share of renewable energy sources; and double the rate of the increase in global energy efficiency. Attention was also drawn to the need for increased international cooperation facilitating access to clean energy research and technology in the field of renewable energy. The importance of promoting investment in energy infrastructure and clean energy technologies was also emphasised. It also stressed the need to expand infrastructure and upgrade technology to enable access to modern and sustainable energy services for the people of developing countries, especially the least-developed countries, developing small island states, and landlocked countries [26].

Considering that reducing energy demand and sourcing a larger share of it from renewable sources are among the European Union's key measures to import energy, reduce greenhouse gas emissions, and encourage the use of green energy [27], it is worth mentioning that some of the EC's priorities coincide with the sustainable development goals formulated by the UN. For example, the "Energy Union and Climate" priority has common areas with seven SDGs, including the global energy target of SDG7 [28].

The concept of "green economy", considered from a conceptual and theoretical perspective, belongs to those sources that allow governments of individual countries to build strategies and create a policy of socio-economic development. It is therefore linked to the concept of sustainable and balanced socio-economic development, whereas it is more practical than the concept of sustainable development. It is part of the economic policy (energy and industry), and some of its elements are also implemented at the level of enterprises ("green enterprises"). The green economy, aimed at increasing the well-being, quality of life, and social equality, clearly indicates the need to achieve the practical objective of halting the depletion of natural resources and reducing ecological risks [29]. It is regarded as an operational category for the concept of sustainable development in the economic context of the objective [30]. It identifies concrete ways of moving the economy to a path that takes account of environmental constraints and makes progress indicators more specific. This application–implementation perspective enables the preparation and delivery of practical programs and activities for producing green products and services, implementation of green investments, or creation of green jobs [31,32]. In the literature on the subject, the green economy is often treated as a tool for sustainable development [30].

It is worth adding here that the prerequisite for sustainable socio-economic development is a sustainable energy policy shaped at the intersection of the three dimensions of sustainable development, i.e., economic efficiency, ecological sustainability, and social justice [33]. On the other hand, sustainable and efficient energy use is based on two complementary elements: energy efficiency and the use of renewable energy sources [34].

2.2. Section 2

Many debates and research works conducted by experts from various countries around the world focused on the issues of energy use and energy efficiency. The interest in this subject stems from the fact that in the context of both contemporary consumption patterns and production methods and capabilities, energy has a multidimensional impact on every type of economic activity [35–37]. In contrast, the ill-considered use of energy, renewable, and non-renewable natural resources and the emission of greenhouse gases entail many adverse effects of an economic, environmental, and social nature.

Due to the growing interest in energy efficiency, the term "efficiency" itself has acquired various meanings in recent years (to a more or less broad extent of the definition), which sometimes semantically overlap [38–40]. These definitions refer to various concepts, such as "efficient use of energy", "energy-saving", "energy efficiency", "resource efficiency", "the reduction of energy consumption", "the efficient and sustainable use of energy and energy raw materials", "inverse of energy intensity", and "minimisation of energy waste" [41–43]. As the International Energy Agency points out, energy efficiency is a relatively complex concept due to its vagueness and ambiguity [44]. There is no clear definition of energy efficiency in the literature on the subject. It is differently defined for the needs of different studies and different institutions. In the most general way, energy efficiency can be defined as reducing the amount of energy needed to perform a specific work (production of a product, implementation of a service). This approach is also a characteristic of the European Union. According to the Energy Efficiency Plan of the European Commission [45], technically speaking, "energy efficiency" means using less energy while maintaining an equivalent level of economic activity or services. In other words, this conceptual category can be defined as the "Ratio of outputs, services, goods or energy obtained to energy input" [46].

Energy efficiency is seen as one of the key technological drivers of sustainable socio-economic development. The level of energy efficiency that a country can achieve depends on several factors, including the degree of industrialisation, level of electrification, state of the automotive industry, scale and quality of the means of freight and public transport, and quality of human capital or state policy. The pace of achieving the set level of energy efficiency can be slowed down by sector- and technology-specific barriers, including the lack of knowledge, low energy and environmental awareness of the society, legal barriers, administrative barriers, and market position of the energy industry [47]. Therefore, in the activities of national governments and businesses and households, efficient energy management, especially the implementation of innovations that allow the removal (reduction) of the barriers mentioned above, must not be neglected.

Improving the energy management is a priority in energy efficiency. Energy efficiency improvement measures vary and depend on the nature of the end-user (industry, households, utilities). In the industry, such activities include, for example, the development of energy management and energy audit systems; use of innovative clean energy technologies in energy generation systems; introduction of financial incentives to support reforms aimed at increasing the use of energy-efficient equipment, reducing energy transmission losses; and re-use of waste energy. It is worth mentioning that when companies choose a business model, they can distinguish three main vectors (priorities) of company development, among which there is a focus on sustainable development and social responsibility [48]. In turn, energy efficiency measures taken by households can include, among others, the use of heat-saving solutions for heating (the thermo-modernisation of buildings, reduction of losses associated with heat generation and transmission), use of energy-saving lighting and household appliances and radio and TV equipment, or adjustment of the heat supply to the current demand [49].

Energy efficiency improvements include actions implemented in the framework of energy greening. The greening of energy is, in turn, a prerequisite for creating sustainable energy to ensure energy and environmental security for the world. The need to develop environmental awareness and improve energy knowledge is increasingly emphasised today. Raising environmental and energy awareness translates into choices made by producers and consumers not only through price but also by considering how goods are sourced and processed (the degree of environmental burden). Literature studies showed that various initiatives and projects are being undertaken in many countries to raise awareness of the need to more efficiently use renewable resources, as well as to disseminate a culture of low-carbon energy efficiency and environmental sustainability through the involvement of both energy consumers themselves and specialists in this field. For example, the University Hospital Authority St. Orsola-Malpighi Polyclinic of Bologna [50] developed a strategy for efficient use and conservation of energy based on different but converging lines of intervention, allowing for the appropriate use of their synergies (including energy efficiency measures for heating and lighting systems, the use of renewable energy sources, water conservation and waste reduction, and application of green procurement principles).

The efficient use of energy and pursuit of measures to reduce its consumption bring tangible benefits on the scale of individual households, enterprises, and entire countries. Energy efficiency directly contributes to reducing energy consumption and primary fuels, resulting in reduced air pollutant emissions, alleviated environmental pressures, and improved energy efficiency of production processes. Energy conservation is undoubtedly the fastest, most efficient, and cost-effective way to reduce greenhouse gas emissions and improve air quality. Therefore, the most important benefits of energy efficiency are environmental protection and the fulfilment by the EU member states of the reduction commitments under the Kyoto Protocol.

Efficient energy use means that economic operators can more efficiently and more economically operate and become more environmentally friendly. Many countries also recognise that energy efficiency is beneficial from a national security point of view, as it can contribute to reducing foreign energy imports and, at the same time, slow down the pace of depletion of national energy resources.

To sum up, the issue of energy management is complex, multifaceted, and interdisciplinary. In an era of growing energy demand and, at the same time, a growing economic crisis, energy rationalisation is indicated by experts on the one hand as a way to alleviate a country's energy problems and, on the other hand, as a practical solution leading to a reduction in operating costs. The effectiveness of efficient energy management requires a comprehensive approach to the issue and is determined by many factors. Among other things, the political and systemic circumstances of a country's economy play an important role. For many years, some countries and entire communities (e.g., socialist countries) have operated in a system that did not enforce efficient behaviour related to energy use. The energy was cheap and readily available, and negative consumption habits still inherent in social consciousness were formed. It is worth mentioning that the conclusions of some research works indicated that the implementation of energy conservation programs has led to greater energy efficiency in the EU member states. At the same time, other researchers highlight that they have caused greater inequality in energy standards [51,52]. The diversity of these effects primarily results from different management specificities and various development determinants of individual countries. Energy management and the implementation of green sustainability concepts require the consideration of developmental conditions specific to each country, as well as extensive investment and educational support (it is essential to change the consumer behaviour towards more economical ones; these behaviours can be changed by showing the possibilities and benefits of reducing electricity consumption).

3. Results of the Research

3.1. Stages of the Applied Research Procedure

The article used a three-stage research procedure to assess the situation of the European Union countries due to energy use, as shown in Figure 2. In the first stage, statistical data on indicators related to the implementation of SDG7 and environmental production efficiency were collected. After a detailed description of the indicators adopted for the study, the distributions of the indicators were analysed using the selected measures of descriptive statistics.

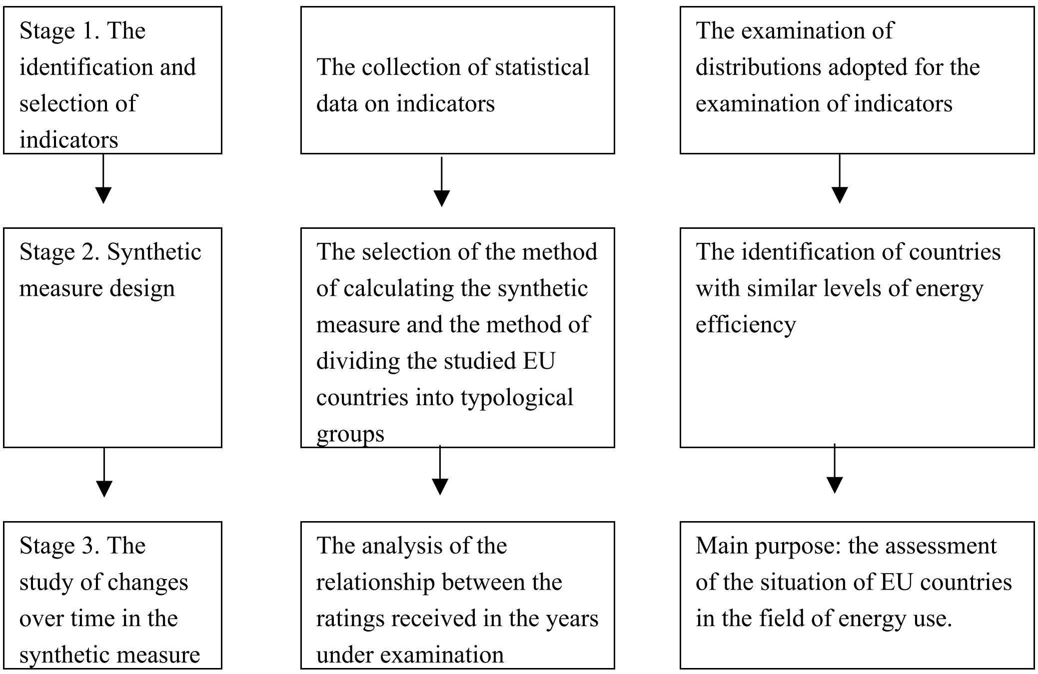


Figure 2. Research procedure chart.

In the next stage of the study, a synthetic measure was constructed, based on which typological groups of countries with a similar level of the studied phenomenon were determined. This way, it was possible to characterise the EU countries in the created typological groups.

Then, using the correlation measures, it was checked whether there were relationships between the positions of EU countries in the rankings constructed for three research periods (2010, 2015, and 2020). Considering the values of the synthetic measure for individual EU countries and the typological groups created on their basis, the situation of these countries in the area of energy use was evaluated.

3.2. Statistical Materials

Table 1 presents a list of diagnostic features used in the study. They concern indicators describing aspects related to the production and use of energy and greenhouse gas emissions. The influence of each characteristic on the analysed phenomenon was also indicated by classifying it into a set of characteristics stimulating the development in the area (symbol *S*) or destimulating the development (symbol *D*). It should be noted that most indicators are destimulants; they constitute 64.3% of all indicators adopted for the study.

Table 1. Base of indicators.

Symbol	Name of the Indicator	Indicator Description
Y_{1D}	Average CO_2 emissions per kilometre from new passenger cars	The indicator is defined as the average carbon dioxide (CO_2) emissions per kilometre by new passenger cars in a given year. The reported emissions are based on type-approval and can deviate from the actual CO_2 emissions of new cars.
Y_{2S}	Energy productivity (euro per kilogram of oil equivalent (KGOE))	The indicator results from the division of the gross domestic product (GDP) by the gross available energy for a given calendar year. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP. For the calculation of energy productivity, Eurostat uses the GDP either in the unit of million euros in chain-linked volumes to the reference year 2010 (at 2010 exchange rates) or in the unit million purchasing power standards (PPS).
Y_{3D}	Greenhouse gas emissions per capita	The indicator measures total national emissions of the so called "Kyoto basket" of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the so-called F-gases (hydrofluorocarbons, perfluorocarbons, nitrogen triflouride (NF_3), and sulphur hexafluoride (SF_6)).
Y_{4D}	Primary energy consumption (mln t of oil equivalent)	The indicator measures the total energy needs of a country excluding all non-energy use of energy carriers (e.g., natural gas used not for combustion but for producing chemicals). "Primary energy consumption" covers the energy consumption by end-users such as industry, transport, households, services, and agriculture, plus energy consumption of the energy sector itself for production and transformation of energies, losses occurring during the transformation of energies (e.g., the efficiency of electricity production from combustible fuels), and the transmission and distribution losses of energy).
Y_{5D}	Greenhouse gas emissions intensity of energy consumption (index2000 = 100)	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 certain economy per unit of energy that is being consumed.
Y_{6D}	Gross available energy by product (per capita)	The gross available energy is one of the most important aggregates of the energy balance. For the total of all energy products, this is the total energy delivered/consumed in a country.

Table 1. *Cont.*

Symbol	Name of the Indicator	Indicator Description
Y_{7D}	Final energy consumption in households (per capita)	The indicator measures how much electricity and heat every citizen consumes at home excluding energy used for transportation. Since the indicator refers to final energy consumption, only energy used by end consumers is considered. The related consumption of the energy sector itself is excluded.
Y_{8D}	Share of energy consumption in agriculture in total energy consumption (%)	This indicator covers the energy consumed by users classified as agriculture, hunting, and forestry according to the International Standard Industrial Classification (ISIC).
Y_{9D}	Share of energy consumption in industry in total energy consumption (%)	Industrial energy consumption includes the following subsectors: iron and steel, chemical and petrochemical, non-ferrous metals, non-metallic minerals, transportation equipment, machinery, mining and quarrying, food and tobacco, paper, pulp and printing, wood and wood products, construction, textiles and leather, and any manufacturing sector not listed above.
Y_{10D}	Share of energy consumption in transport in total energy consumption (%)	Energy consumption in transport covers all transport activities (mobile engines) irrespective of the economic sector.
Y_{11S}	Share of renewable energy in gross final energy consumption by sector (%)	The indicator measures the share of renewable energy consumption in gross final energy consumption under the Renewable Energy Directive. Gross final energy consumption is the energy consumed by final customers (final energy consumption) plus grid losses and the plant's own consumption.
Y_{12S}	Share of energy from renewable sources (%)	Renewable energy sources include hydropower, geothermal, solar, wind, tidal, and wave sources. Energy from solid biofuels, biogasoline, biodiesel, other liquid biofuels, biogas, and renewable fraction of municipal waste are also included.
Y_{13S}	Share of energy from renewable sources in transport (%)	The share of RES energy in energy consumed in transport is calculated as the quotient of the value of renewable energy consumption in transport and the total value of energy consumption in transport (after applying the algorithms of Directive 2009/28/EC applicable to the calculation of the share of renewable energy in transport).
Y_{14S}	Share of energy from renewable sources in electricity (%)	Renewable energy sources include wind energy, solar energy (thermal, photovoltaic, and concentrated), hydropower, tidal energy, geothermal energy, ambient heat energy captured by heat pumps, biofuels, and the renewable part of the waste.

In the next step, the indicators adopted for the study were characterised by determining their selected descriptive characteristics (Table 2). The results of the preliminary analysis of the diagnostic characteristics showed significant disparities between countries due to the indicators studied. It is indicated by the high values of the coefficient of variation (V_s) and asymmetry coefficient (As). The coefficients of variation for most features (11 in 2010 and 10 in 2015 and 2020) exceeded 30%. The primary energy consumption (Y_{4D}) index had the highest level of variation throughout the study period, its value exceeding 130%. Only for one indicator (Y_{1D}—average CO_2 emissions per kilometre from new passenger cars) in 2010 and 2015 the level of differentiation did not exceed 8%, and in 2020, it was at the level of 10.38%. All analysed indicators, except Y_{1D} (the distribution was close to symmetrical in 2010 and moderate left-sided asymmetry in 2015 and 2020), were characterised by moderate or strong right-sided asymmetry, which means that most of the studied countries performed below average. In the case of indicators marked as destimulants, this is a favourable situation. The situation is different for features that are stimulants, where right-hand asymmetry indicates a lower level of indicators for most countries studied, i.e., a lower level of development regarding the phenomenon studied.

Table 2. Selected descriptive characteristics of indicators adopted for the study in years 2010, 2015, and 2020.

Symbol	$\bar{x}$	V_s (%)	As	$\bar{x}$	V_s (%)	As	$\bar{x}$	V_s (%)	As
Y_{1D}	144.12	7.05	−0.09	121.25	7.96	−0.41	111.10	10.38	−0.51
Y_{2S}	5.96	42.97	0.44	6.99	46.35	1.20	7.95	53.88	1.85
Y_{3D}	10.65	40.10	2.01	9.33	35.10	1.55	8.00	32.58	1.58
Y_{4D}	55.71	138.41	2.30	51.75	140.41	2.34	47.25	134.96	2.25
Y_{5D}	94.96	9.87	1.67	88.58	11.19	0.32	79.96	13.23	0.65
Y_{6D}	3.98	41.73	1.25	3.59	36.45	1.01	3.41	35.68	1.03
Y_{7D}	2.59	56.40	2.79	2.37	49.70	2.57	2.23	45.00	2.38
Y_{8D}	2.71	57.29	1.75	2.74	60.20	1.61	2.96	56.89	1.98
Y_{9D}	24.17	30.04	0.45	25.01	28.83	0.61	25.01	28.86	0.46
Y_{10D}	31.19	27.98	1.09	31.96	24.64	0.92	30.84	22.97	0.71
Y_{11S}	20.36	81.21	1.19	27.81	65.63	0.87	34.53	54.51	0.79
Y_{12S}	16.02	66.25	0.96	20.02	58.32	0.93	24.10	47.27	1.48
Y_{13S}	4.17	61.91	0.62	6.74	79.02	2.20	10.53	44.90	3.59
Y_{14S}	20.36	81.21	1.19	27.81	65.63	0.87	34.53	54.51	0.79

3.3. Method

In assessing the complex phenomena, aggregate measures are quite universally applicable. These include, for example, the study of the level of socio-economic development, where Hellwig [53] should be considered the precursor of the method. Also noteworthy in this area are the studies conducted in [54–56]. Using such measures also gives interesting results in research related to energy use or sustainable energy development [57–59]. The universality of the method is also visible in applications in the financial market [60,61]. There are a lot of different kinds of multidimensional methods. In the proposed research, the proper type of methods that can be used is a group of hierarchical methods, e.g., the technique for order preference by similarity to ideal solution (TOPSIS), synthetic measure of development (SMR), and generalised distance methods (GDMs).

Vector measures can be classified as aggregate and multidimensional measures. The multidimensional approach allows for describing a complex, multidimensional phenomenon using a single synthetic variable. This variable, through adopted operations, aggregates and transforms many variables into one. Thus, it is the resultant of the factors (variables) forming it. In the case of a vector measure, the vector calculus is used for its construction. A vectoral measure in the literature and economy is the most popular in regional research [62]. The method was chosen because it is an alternative method to the classic TOPSIS, SMR, or GDMs. Moreover, the choice of the vectoral method resulted from its properties and advantages. The method's properties also met the authors' expectations in achieving the set research goal. The advantage of the vectoral measure is the versatility of applications and the simplicity of calculations [57,58]. Thanks to the use of vector calculus properties, the method allows the study of dynamics and use of real patterns. The method also enables adding objects (from outside of the sample) to the research sample without needing to change the reference point. The significant advantage is that the vectoral method is more sensitive to fluctuations and changes in time, which is important for studying the dynamics of changes.

Generally, constructing a vector measure requires several steps: the selection, elimination, and normalisation of variables; determination of the pattern and anti-pattern; and measurement of vector aggregates.

3.3.1. Selection and Elimination of the Variables

At the stage of selection and elimination of variables, statistical and formal procedures or heuristic methods may be used. The expert approach relying on the experience and knowledge of an analyst is a valuable element in this field. The existing economic theory or guidelines for the problem under consideration are also important. They provide a basis for selecting variables and arranging their set to best reflect the analysed problem. In general, the stage of selection (elimination) of variables is crucial for building synthetic measures of various types [53,63,64], including a vector measure [62], with the help of which it is possible to analyse and evaluate complex phenomena (such as the level of socio-economic development, investment attractiveness, or fundamental strength). At the stage of selection (elimination), the variables are set in the observation matrix [62]:

$$X = \begin{bmatrix} \underset{1}{x_1} & \underset{1}{x_2} & \cdots & \underset{1}{x_k} & \cdots & \underset{1}{x_M} \\ \underset{2}{x_1} & \underset{2}{x_2} & \cdots & \underset{2}{x_k} & \cdots & \underset{2}{x_M} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \underset{i}{x_1} & \underset{i}{x_2} & \cdots & \underset{i}{x_k} & \cdots & \underset{i}{x_M} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \underset{N}{x_1} & \underset{N}{x_2} & \cdots & \underset{N}{x_k} & \cdots & \underset{N}{x_M} \end{bmatrix} \tag{1}$$

N—the number of objects;
M—the number of variables;
$\underset{j}{x_i}$—the value of the i-th variable for the j-th object.

3.3.2. Normalisation

The next step is to normalise the variables. The variables used in the research are usually not homogeneous. It is because they describe different properties of objects. Therefore, they can be expressed in various measurement units, making it difficult to perform the arithmetic calculations necessary for individual procedures. Hence, the necessary step in constructing aggregate measures, including the vector measure, is the normalisation of the variables. This leads to the elimination of measurement units and equalisation of the values of the variables. In this case, formulas such as the following can be used:

$$\underset{j}{x'_i} = \frac{A_i}{\sigma_i}, \tag{2}$$

where the numerator A_i can be defined at will, for example:

$$A_i = \underset{j}{x_i} - \overline{x}_i, \tag{3}$$

where $\underset{j}{x'_i}$ is a normalised value of the i-th variable for the j-th object.

3.3.3. Determination of a Vectoral Measure

The values of the variables of the examined objects in the vector space are interpreted as vector coordinates. Each object therefore determines a specific direction in space. The pattern and anti-pattern difference is also a vector that determines a certain direction in space. Along this direction, the aggregate measure value for each object is calculated. This difference can be treated as a monodimensional coordinate system, in which the coordinates are calculated based on the formula [62]:

$$c = \frac{\left(\vec{A}, \vec{B}\right)}{\left(\vec{B}, \vec{B}\right)}, \tag{4}$$

In turn, $\vec{A}$ and $\vec{B}$ are vectors, and $\left(\vec{A}, \vec{B}\right)$ is the scalar product, which can be defined as follows:

$$\left(\vec{A}, \vec{B}\right) = \sum_{k=1}^{n} a_k b_k \tag{5}$$

where:

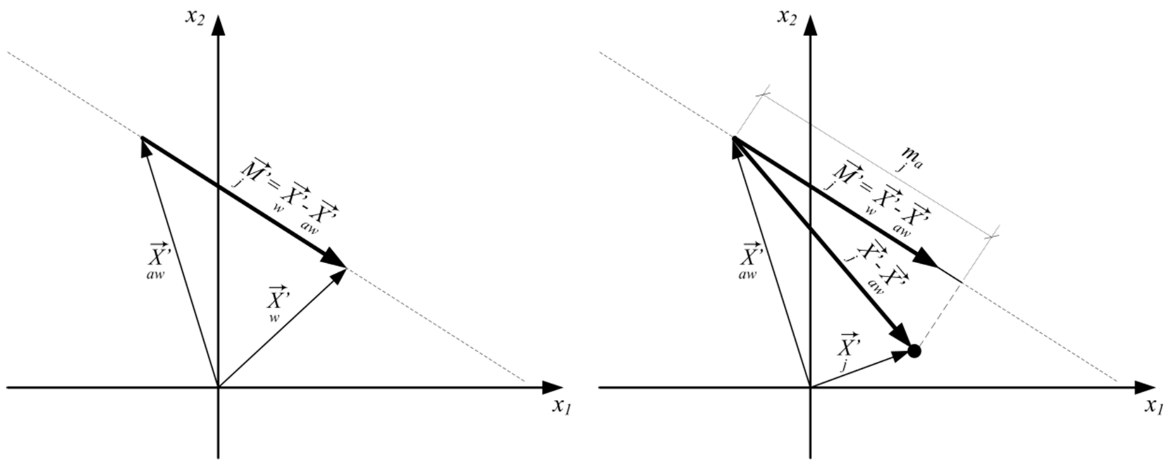
a_k, b_k,—coordinates of the appropriate vector $\vec{A}$ and $\vec{B}$.

We consider the $\vec{B}$ vector as the monodimensional coordinates system; thus, it represents a difference between the pattern and anti-pattern. By entering the coordinates of the pattern and anti-pattern as well as the object into Formula (4), the result is as follows:

$$m_{a \atop j} = \frac{\sum_{i=1}^{m}\left(x'_{i \atop j} - x'_{i \atop aw}\right)\left(x'_{i \atop w} - x'_{i \atop aw}\right)}{\sum_{i=1}^{m}\left(x'_{i \atop w} - x'_{i \atop aw}\right)^2} \tag{6}$$

For a synthetic measure so constructed, all objects that are better than the anti-pattern and worse than the pattern will have the measure value in the range from zero to one. The pattern will have the value equal to one and anti-pattern equal to zero. It is also possible to specify the value of the objects' measure better than the pattern. They will have values greater than one. Objects that are worse than the anti-pattern will have a negative value of measure. Thanks to this, the position of the object in the ranking in relation to the pattern and anti-pattern will be easy to determine.

In the VMCM method, a measuring vector $\vec{M'}_{j}$ is a difference between the vector of the pattern $\vec{X'}_{w}$ and the vector of the anti-pattern $\vec{X'}_{aw}$ (Figure 3a). The vector $\vec{M'}_{j}$ determines a monodimensional coordinates system having the origin in the point determined by the end of the vector of anti-pattern $\vec{X'}_{aw}$. The synthetic measure $m_{s \atop j}$ is the component (the value of the projection) of the vector $\vec{X'}_{j\,\vec{X'}_{aw}}$ on the vector $\vec{M'}_{j}$ (Figure 3b).



(**a**) (**b**)

Figure 3. We measure value depending on the object's position. Source: [57].

The values of the aggregate measure allow for ranking objects; thus, it is possible to determine which of them are "better" and which are "worse", which can also be used in terms of fundamental strength.

4. Results of the Research

All variables and indicators used in the process of vectoral measure calculation were selected using the expert approach, including indications and recommendations from previous studies and existing directions of activities within the EU energy policy. An important element was also the inclusion of the guidelines within SDG7. The vectoral measure calculation procedure considers the standardisation of the variable titles. In the case of the measure utilised, the standardisation procedure was used. In multivariate methods, such as the vector method, it is possible to use the variable weighting procedure. The study adopted the variant without weighting the variables. Each of the variables is equally important.

Applying the above procedure made it possible to determine the vector measure (VM-REM) of efficient energy use. In order to illustrate the changes in the scope of the studied phenomenon, the measure was determined in dynamic terms, while the base year adopted for comparisons was 2010. It means that the pattern and anti-pattern for the vector measure were determined based on data from this year. The adoption of such a framework has made it possible to observe changes in energy use in relation to the base year. Energy management is a process that requires not only commitment and the setting of theoretical guidelines but also their implementation. Implementation takes time, which is especially typical of changes in energy use and management infrastructure. Based on the arithmetic mean and standard deviation of the vector measure, four classes of membership of EU countries were determined, characterising their level of energy use:

Class 1 $(< \overline{x} + S(x);\ \infty)$—countries that efficiently use energy;
Class 2 $(< \overline{x};\ \overline{x} + S(x))$—countries that use energy well;
Class 3 $(< \overline{x} - S(x);\ \overline{x})$—countries with poor energy use;
Class 4 $(-\infty;\ \overline{x} - S(x))$—countries that inefficiently use energy.

Where:
$\overline{x}$—the arithmetic mean of the determined vector measure;
S(x)—the standard deviation of the vector measure.

Table 3 presents the results of a survey of selected EU countries in the field of vector energy use (VM-REM). Columns 2–4 contain the levels of the VM-REM metre for the analysed countries. In general, the higher the metric level, the better the results a given country achieves in terms of efficient energy use. Positive and high values of the measure are desirable. Negative values indicate the opposite direction of the metre, which is not beneficial from the perspective of assessing efficient energy management. Columns 5–7 show the ranking of countries in the surveyed years. The level of the vector measure for the studied countries is also shown in Figure 4, which allows the observation of the level of the VM-REM metre in a visual way in the studied period.

Class 1 is a class of countries that efficiently use energy. It is the highest class where the energy use process can be considered the best. This group includes Sweden, Luxembourg, and Austria. These countries qualified for Class 1 throughout the whole research period. Finland was in Class 1 in 2010 and 2015, while in 2020, it fell to Class 2. Observing the dynamics of change in the VM-REM (columns 8 and 9), it is puzzling that Luxembourg and Austria, although they retained their membership in Class 1, obtained negative dynamics of change in the measure. It should therefore be read as a deterioration of energy management in these countries. At the same time, it may be a signal for these countries to pay attention to the energy management process and identify the symptoms responsible for the deterioration in performance. In the case of Luxembourg, there has been an improvement in energy performance, representing a positive increase in the measure in 2015 and 2020. Class 2 includes countries that use energy well. Among them are Denmark, Germany, and Latvia. These countries retained their class affiliation in the studied years. Given the dynamics of change, Denmark and Germany have improved their energy efficiency, which is evident in the increase in the level of the measure over the period under study. In Latvia's case, the change dynamics were negative in 2015 and virtually unchanged in 2020 (0.003%).

Table 3. Vector metric for energy use in EU countries 2015–2020.

Country	VM-REM			Classification of EU Countries according to VM-REM			Change 2010 = 100	
	2010	2015	2020	2010	2015	2020		
1	2	3	4	5	6	7	8	9
Austria	1.337	1.168	1.120	1	1	1	−13%	−16%
Belgium	0.466	0.518	0.593	3	3	3	11%	27%
Bulgaria	0.497	0.560	0.578	3	3	3	13%	16%
Cyprus	0.468	0.411	0.665	3	3	2	−12%	42%
Czechia	0.420	0.446	0.431	3	3	3	6%	3%
Denmark	0.606	0.706	0.643	2	2	2	17%	6%
Estonia	0.535	0.642	0.422	3	2	3	20%	−21%
Finland	1.087	1.140	0.825	1	1	2	5%	−24%
France	0.479	0.426	0.351	3	3	3	−11%	−27%
Germany	0.770	0.830	0.815	2	2	2	8%	6%
Greece	0.457	0.200	0.270	3	4	4	−56%	−41%
Hungary	0.174	0.203	0.212	4	4	4	17%	22%
Ireland	0.450	0.657	0.749	3	2	2	46%	66%
Italy	0.544	0.559	0.492	3	3	3	3%	−10%
Latvia	0.747	0.731	0.744	2	2	2	−2%	0%
Lithuania	0.478	0.484	0.593	3	3	3	1%	24%
Luxembourg	1.054	1.067	1.138	1	1	1	1%	8%
Malta	−0.083	−0.067	−0.082	4	4	4	−18%	−1%
Netherlands	0.605	0.515	0.655	2	3	2	−15%	8%
Poland	0.408	0.437	0.573	3	3	3	7%	40%
Portugal	0.665	0.641	0.593	2	2	3	−4%	−11%
Romania	0.415	0.532	0.472	3	3	3	28%	14%
Slovakia	0.435	0.479	0.351	3	3	3	10%	−19%
Slovenia	0.669	0.539	0.652	2	3	2	−19%	−3%
Spain	0.650	0.562	0.632	2	3	2	−14%	−3%
Sweden	1.356	1.306	0.996	1	1	1	−4%	−27%

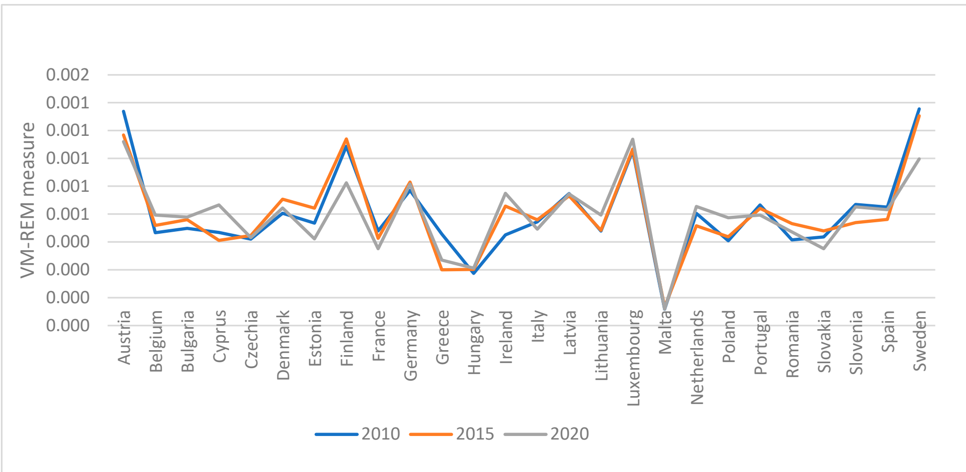


Figure 4. VM-REM for EU countries in 2010, 2015, and 2020.

The countries that can be described as having poor energy use are grouped in Class 3. It means that measures aimed at improving energy management are required in these countries. It may include not only measures to improve awareness of energy management processes, including the energy balance, but also changes in the infrastructure responsible for energy use. Among the Class 3 countries are Belgium, Bulgaria, the Czech Republic, France, Italy, Lithuania, Poland, Romania, and Slovakia. The positive dynamics of change in the period under review were achieved by Belgium, Bulgaria, the Czech Republic, Lithuania, Poland, and Romania. It means that they have improved the energy use process over the period under study. On the other hand, France's dynamics of change were negative throughout the period considered. It is not beneficial and does not positively indicate about the energy use management.

In Class 4 are countries that inefficiently use energy. These are Hungary, Malta, and Greece, which were in Class 3 only in 2010. Hungary has generally improved its energy use during the research period, which is seen in the positive dynamics of change. However, this did not increase the class of affiliation. Still, this should be read as a positive signal toward improving energy management. For Malta and Greece, the dynamics of the changes over the research period were negative, which is not favourable. Moreover, due to the direction of vector measurement, Malta has a different energy use direction than other countries. Countries in Class 4 need to implement fundamental changes in energy use, which, as in the case of Class 3, require the intensification of activities in this area.

Overall, based on the data in Table 3, it can be seen that there is little change in the movement of countries between classes of affiliation in the studied years. It can be clearly seen in Figures 5–7. The slight differences in the classification results were also confirmed by the high estimates of the coefficients of correlation of Pearson and τ Kendall (Table 4).

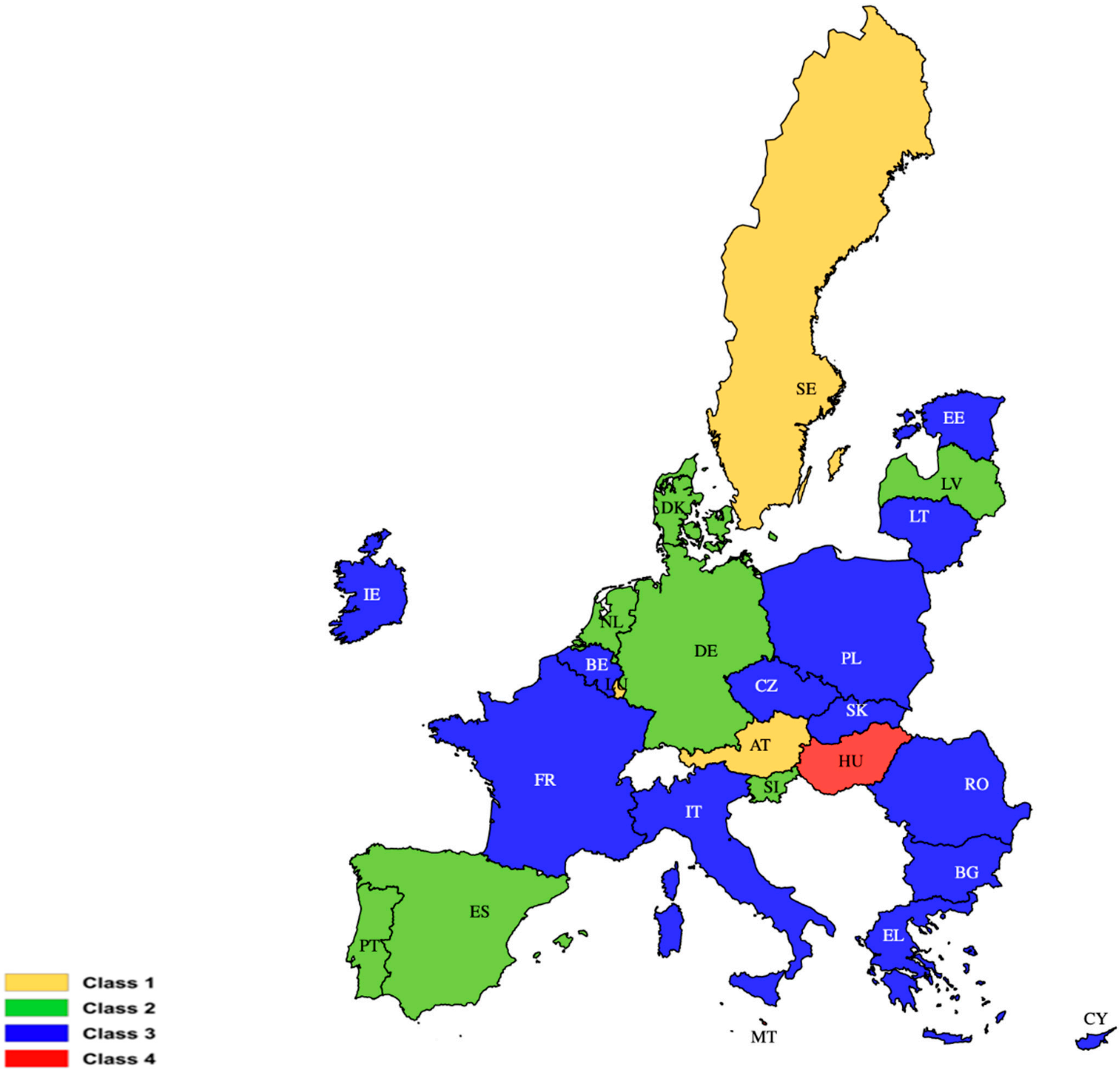


Figure 5. EU countries by typology in 2010.

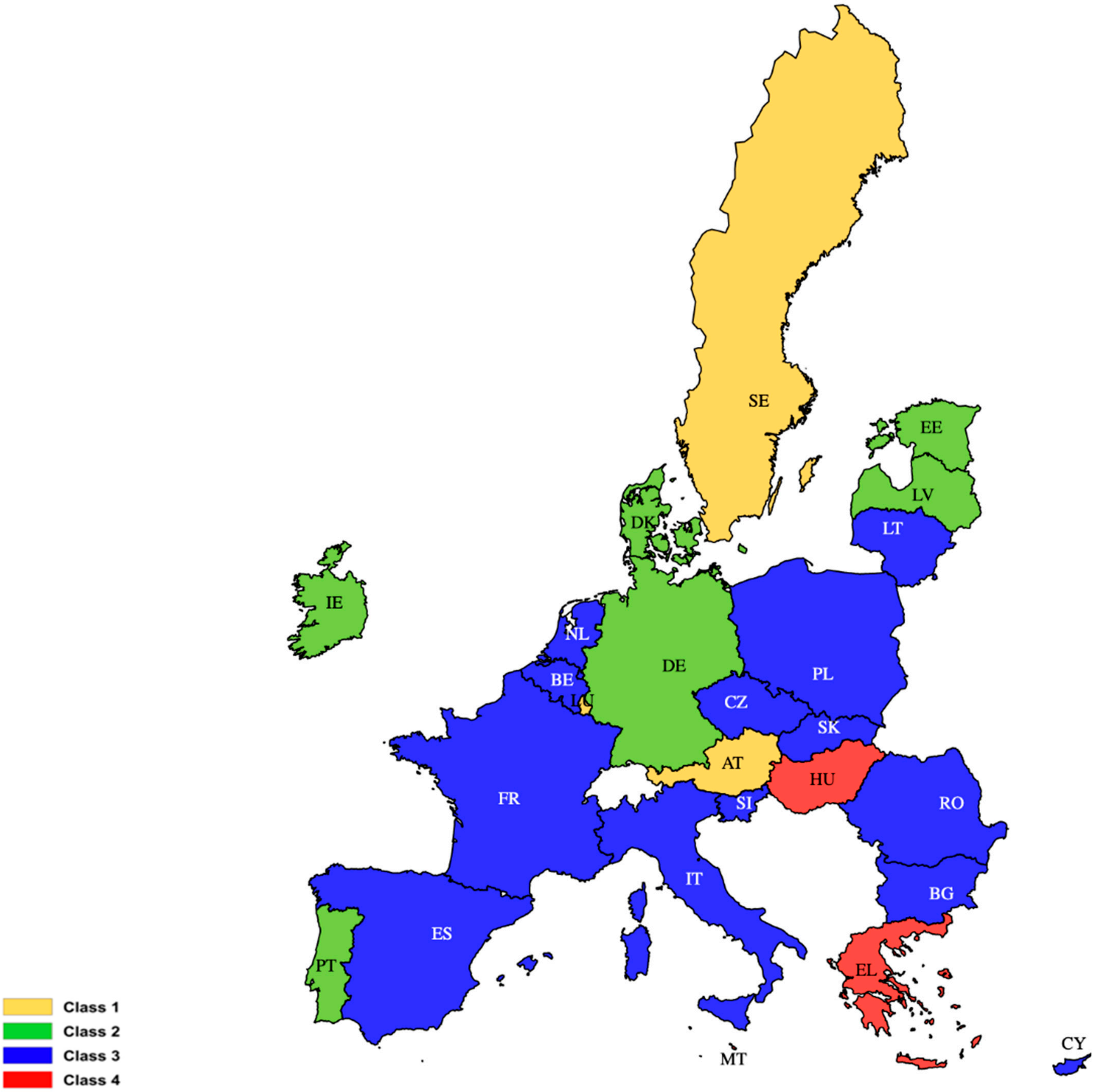


Figure 6. EU countries by typology in 2015.

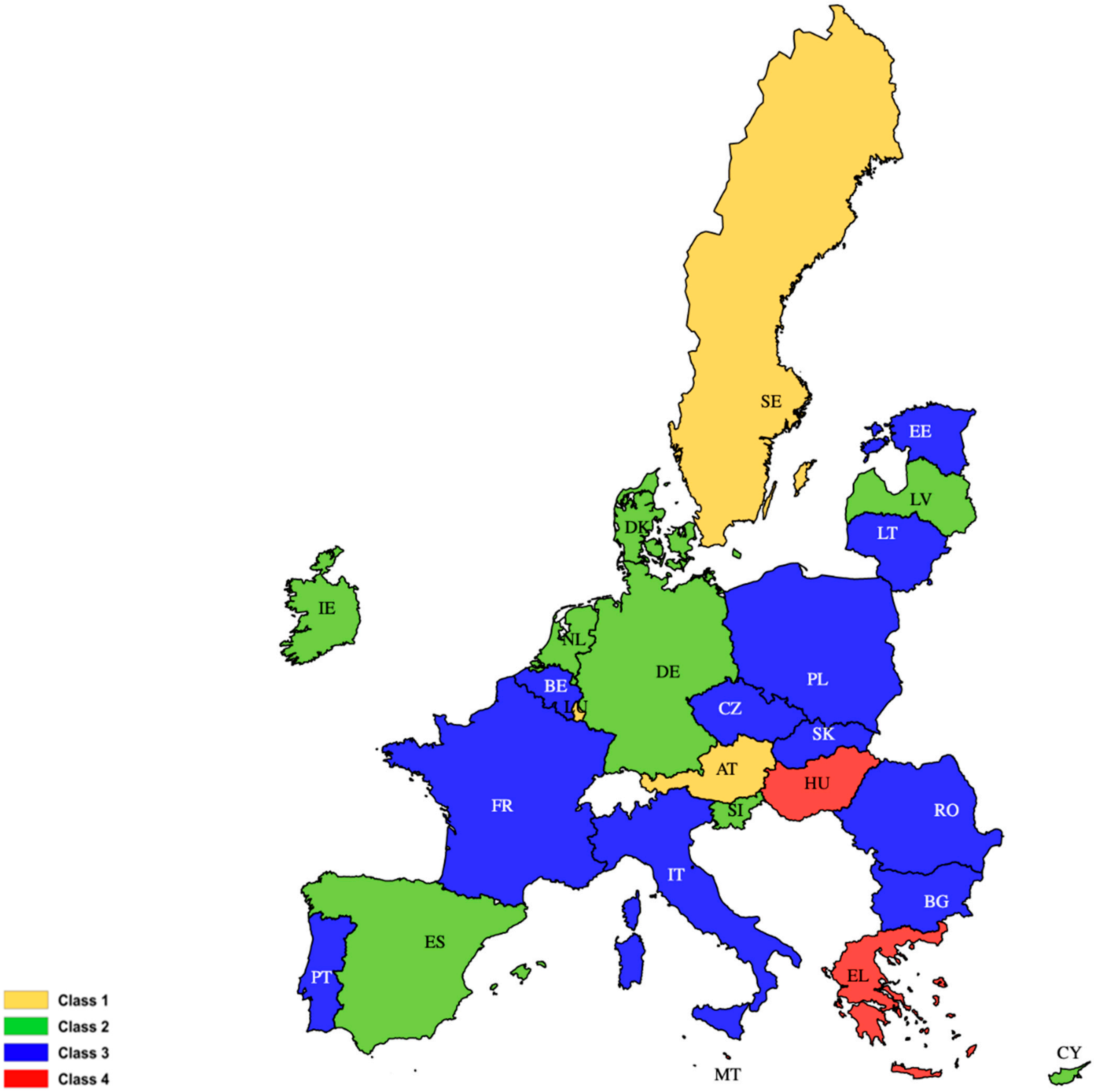


Figure 7. EU countries by typology in 2020.

Table 4. Matrix of Pearson correlation coefficients for values of taxonomic measure of development and for the results of ordering of EU countries in years 2010, 2015, and 2020.

Years	**Pearson**			**Kendall**		
	2010	**2015**	**2020**	**2010**	**2015**	**2020**
2010	1.000	0.953	0.889	1.000	0.756	0.819
2015	0.953	1.000	0.902	0.756	1.000	0.732
2020	0.889	0.902	1.000	0.819	0.732	1.000

5. Discussion

The concept of environmental performance measurement is based on indicators to determine the efficiency of a specific decision-making unit as better than another if it produces more desired positive and fewer undesirable effects (pollution or other environmentally harmful effects) for the same amount of inputs [65]. Public opinion is increasingly concerned about the need to coordinate action between economic growth and environmental protection. Therefore, the need to incorporate increasingly stringent green and sustainable development criteria into economic practice is being advocated [66].

The original research assessed the energy use in the European Union countries and its changes. The analysis of changes in indicators over time is shown in Table 2. The first of these indicators is the average CO_2 emissions per kilometre from new passenger cars (Y_{1D}). The transport sector belongs to the most polluting sectors, focusing on carbon dioxide emissions. Reducing CO_2 emissions from passenger cars is an essential objective of sustainable development policy, both at the member states and EU level. A critical aspect in shaping a strategy for sustainable transport is the arrival of new cars in the transport fleet with lower CO_2 emissions and greater fuel efficiency associated with technological advances. The subject's literature also draws attention to changing consumer preferences and abandoning the purchase of ever larger and more powerful cars. Not without influence here are tax solutions on the price of new cars, taxes on the purchase of new cars, and technological innovations [67–73]. The results of an analysis of data on average CO_2 emissions per kilometre from new passenger cars (Y_{1D}) in the European Union showed that there has been a significant decrease in the level of this indicator (Table 2). In 2020, this ratio was almost 23% lower than in 2010.

The next indicator analysed is energy productivity (Y_{2S}). Energy efficiency is crucial to making the global energy system more sustainable. Improving energy efficiency is necessary to reduce local air pollution and global climate change while improving the security of the energy supply. Energy use efficiency has made significant progress in recent decades. It is estimated that energy consumption would be 50% higher than it is today without the measures implemented so far, with the steady trend of economic growth observed worldwide requiring an increase in energy supply [74,75]. This indicator should be considered one of the most important indicators and is one of the main objectives of the European Union's climate policy. However, policies to improve energy efficiency may have some negative consequences, one of which is that it may result in lower energy prices, thus increasing energy consumption. It is called the ground effect, first suggested by Jevons in 1865 [76] (which is highly debatable) and it may not lead to a reduction in CO_2 emissions due to the increased energy consumption [77]. Improvements in this indicator may result from not only technological advances but also improvements in the quality of electricity use, the structure of energy inputs, and a reduction in losses during the distribution [78].

Furthermore, the economy's energy efficiency is an important determining factor not only for the environmental benefits but also, to a large extent, for the competitiveness of the national economy in foreign trade and energy security [79]. The Y_{2S} used in our study has some limitations. It is a measure of economic and technical efficiency, not an indicator of economic or technical efficiency. The literature points to the possibility of changes in the level of the energy productivity index, but this is not necessarily caused by changes in technical efficiency itself [80]. It may be due to changes in the sectoral mix in the economy [81], which is why the Y_{8S}, Y_{9S}, and Y_{10S} indicators were used in the analysis to minimise the limitations of the Y_{2S} indicator. One can also point to the substitution of energy by human labour [82]. However, due to changes in the price relations of the production factor [83] in EU countries, this should be considered at the country level as unrealistic or sporadic and rather occurring at the level of individual enterprises. At the same time, the issue of to what extent energy inputs are substitutes for labour and capital is also addressed. A study by Patterson [84] noted that energy and labour inputs acted as mild substitutes for each other, and energy and capital inputs were mild complements to each other. Attention is also drawn to changes in the energy input mix [78,85] that can influence movements in the GDP/energy ratio. Despite the indicated weaknesses of this indicator, it should be considered important for measuring techno-economic efficiency. The ratio of the GDP expressed in currency to the amount of energy consumed in natural units to produce this output enables a more accurate reflection of the economy's energy efficiency.

The indicator has improved (Table 2), as it was 33.4% higher in 2020 than in 2010 in the countries of the European Union in the research period. At the same time, the coefficients of variation for the Y_{2S} assumed high values, which indicates a high differentiation of energy productivity in the European Union countries, and the value of the coefficient of asymmetry (*As*) indicates right-handed asymmetry, which for the stimulants indicates a lower level of indicators for most of the countries studied. Both the coefficient of variation and coefficient of asymmetry are increasing in the analysed period, which may indicate growing disparities within the European Union countries.

Increasing energy efficiency is associated with increasing the use of renewable energy sources and reducing GHG emissions. These are also the main goals of the European Union's energy policy [86,87]. The authors' original research found a decrease in greenhouse gas emissions per capita (Y_{3D}) and greenhouse gas emission intensity of energy consumption (Y_{5D}) over the years analysed (Table 2). These results confirmed the studies of other authors on the European Union [86], but this is differentiated globally. Greenhouse emissions most often decrease in countries with a higher level of development and increase in countries with a lower level of development. Meanwhile, in poorer countries, the greenhouse gas emissions per capita ratio are lower than in countries with higher levels of development [88]. The subject's literature draws attention to factors that reduce greenhouse emissions. These are factors related to economic development, green investment levels, technical progress, or institutional arrangements [89–96]. The question is what ways to reduce greenhouse emissions are the most cost-effective. The principles of economics deliver a crisp answer: reduce emissions to the point that the marginal benefits of the reduction equal its marginal costs. This response can be implemented through the application of the Pigouvian tax. However, most countries in the world do not place an economy-wide tax on carbon and instead have an array of greenhouse gas mitigation policies that should consider or restrict these types at specific technologies or sectors [97].

Renewable energy sources can meet the energy demand. The increase in the share of renewable energy sources improves energy efficiency and offers the opportunity to diversify energy resources, increasing energy security [98,99]. Directive (EU) 2018/2001 (the Renewable Energy Directive, RED II) established a common framework for the promotion of energy from renewable sources in the EU and set a binding target of 32% for the overall share of energy from renewable sources in the EU's gross final consumption of energy in 2030 [100,101]. The data analysis in Table 2 shows that the indicators of the importance of renewable energy in the economy of the EU countries (indicators Y_{11S}, Y_{12S}, Y_{13S}, and Y_{14S}) have increased over the period under consideration. This situation is favourable, with high coefficients of variation and right-sided asymmetry for stimulants showing significant disparities among the EU member states and the predominance of countries with lower levels of indicators. It is also worth noting that these indicators differently behave over the analysed period. In the case of the Y_{11S} and Y_{14S} indicators, the coefficients of variation and asymmetry coefficients are decreasing in value, indicating a levelling off of disparities within the EU member states. However, for the Y_{12S} indicators and especially Y_{13S}, the coefficients of variation and asymmetry show an upward trend, indicative of increasing disparities among the EU countries. These disparities may be due to poor technology transfer mechanisms and knowledge gaps [102–104], which require specific research. It is also worth mentioning that the increase in the share of renewable energy reduces the negative externalities associated with pollution from traditional energy production. This way, current and future generations' long-term quality of life is improved [105]. Thus, it allows for positive externalities, which should also be considered in the economic calculation of energy efficiency and cost-effectiveness analysis of such investment projects.

Further analysis and the adoption of appropriate methods for estimating the value of positive externalities are required. The relevant literature also draws attention to the need for a comprehensive approach to developing renewable energy both at the national and international levels. Energy policy tools for developing a clean energy program require national specificities to be taken into account, among other things, in the area of selecting the most appropriate renewable energy source, assessing the available RES resources, selecting the optimal location for RES installations, and optimising the structure of RES [106,107].

Energy is a vital resource for the development of the economy. In recent years, energy demand and consumption have increased due to rapid development, particularly in countries with lower levels of economic development. The most commonly mentioned factors influencing energy consumption growth are urbanisation, population, and economic growth [108–110]. On the other hand, increasing electricity consumption should be offset by increasing the share of renewable energy [111] and increasing energy production efficiency. When analysing data on primary energy consumption Y_{4D} and final energy consumption in households Y_{7D}, the level of these indicators has been decreasing (Table 2). That should be considered favourable, with high values of coefficients of variation indicating significant variations within the EU member states.

On the other hand, the high right-hand asymmetry for the listed destimulants is favourable and indicates a considerable advantage for countries that perform below average. When analysing the Y_{4D} and Y_{7D} indicators, attention should also be paid to the indicators for energy efficiency (Y_{2S}) and indicators characterising the importance of renewable energy in the economy of EU countries (indicators: Y_{11S}, Y_{12S}, Y_{13S}, and Y_{14S}). Positive relationships between these indicators can be observed. It also requires further research into the strength of these relationships and the direction of impact.

Gross available energy by product (Y_{6D}) was characterised by a decline in the EU member states during the period under review (Table 2). Oil (crude oil and petroleum products) continued to be the most significant energy source for the European economy, despite a long-term downward trend, while natural gas remained the second-largest energy source. Both oil and natural gas were on the decline in 2020, decreasing by 12.6% and 2.4%, respectively. The contribution of renewable energy sources continued to grow [112].

Structural changes in the economy cause changes in the structure of energy use and consumption. In turn, changes in the energy use and consumption pattern reflect changes in the structure of the economy [113–115]. The following three indicators analysed relate to energy consumption in three sectors: agriculture (Y_{8D}—the share of energy consumption in agriculture in the total energy consumption), industry (Y_{9D}—the share of energy consumption in the industry in the total energy consumption), and transport (Y_{10D}—the share of energy consumption in transport in the total energy consumption). In the case of agriculture, attention is drawn to its decreasing importance in creating the gross domestic product, but this does not mean a decrease in production levels but a faster development of non-agricultural sectors. It also points to technological and economic differences between the EU member states, especially between Western and Eastern European countries [116–118], which is reflected in energy efficiency and energy sources in agriculture [118]. In agriculture in the EU countries, the process of labour substitution by capital is also indicated [83,118,119], which causes an increase in energy demand, despite implementing modern technical solutions in agricultural production. The Y_{8D} indicator in the analysed period (Table 2) showed a slight increase from 2.71% in 2010 to 2.96% in 2020. At the same time, the right-sided asymmetry has increased, which is regarded as beneficial for the destimulants. High right-sided asymmetry can be linked to the significant variation in agricultural development in the EU countries, as confirmed in the studies cited above. In the case of Y_{9D} and $Y_{10D,}$ no significant changes were made in the studied years. At the same time, a moderate right-sided asymmetry was recorded for the Y_{9D} indicator, which is favourable for a destimulant and indicates not much variation within the EU member states. Similarly, for Y_{10D}, its level in the years analysed was stable, but the asymmetry factor decreased, indicating a decreasing share of energy consumption in transport in the total energy consumption within the member states.

6. Conclusions

The European Union is an organisation seeking to implement its own objectives, internationally representing the most advanced regulations for adapting to climate change and countering adverse climate change, where energy production and consumption are important factors [120]. Nowadays, energy and climate change are closely related since energy production (mainly from the processing and combustion of fossil fuels) and its use (e.g., for industry, households, and transport) account for 79% of European Union greenhouse gas emissions [121].

However, within the European Union, there is a gap between countries supporting ambitious climate policies and those showing restraint on the issue [122,123] and even arguing negative consequences for economic growth [124]. Based on the results obtained (Table 3 and Figures 4–7), there is a significant variation in space and time in the evolution of the energy system of the European Union's member states toward sustainable development. Rational energy use is primarily the domain of north-western European countries, with Sweden and Austria always leading the rankings. However, this does not mean that in these countries, in spite of their high position in the ranking, the levels of indicators in 2015 and 2020 as compared with 2010 did not deteriorate. For instance, the VM-REM for Austria decreased by 13% and 16%, respectively, which results from the deterioration of the values of some indicators, e.g., the share of energy consumption in industry in the total energy consumption (Y_{9D}) and share of energy from renewable sources in transport (Y_{13S}). A similar situation occurs in other countries, e.g., Sweden (a decline of VM-REM by 4% and 27%, respectively) or Finland for which, in 2015, the VM-REM increased by 5% and, in 2020, it decreased by 24%. This means that attention should be paid to the energy use and management process and the identification of signals responsible for deteriorating the outcomes.

A similar analysis should be conducted in the case of the countries with the worst situation in terms of energy efficiency. These include, first of all, the countries of Southern Europe, including Malta, which is forever in the last position. Despite the negative values of most of the indicators adopted for the study, it should be noted that positive changes can also be noticed in this country. Although the VM-REM is negative, its absolute value has significantly decreased (from 18% to 1%), which is the result of a significant improvement in indicators related to the share of energy from renewable sources.

The method based on the vector calculus used in the work makes it possible to allow measuring multidimensional, complex phenomena and expressing them using one synthetic variable. The method also allows for a dynamic examination. Thanks to this, it is possible to observe the dynamics of changes in complex phenomena, which facilitates the process of their analysis and diagnosis. The research results can help diagnose the results obtained so far and correct the European Union's climate and energy policy in the future. Given the significant diversity of the studied countries in terms of progress in energy efficiency, in determining the direction and implementation of energy and climate policy, it is crucial to consider the specifics and level of development of individual regions of the European Union.

Based on the results obtained and the analysis conducted in the article, further possible research areas can be indicated. Further research efforts may, for example, be focused on issues such as the need to maintain a balance between energy security, meeting social needs, the competitiveness of the economy (the competitiveness of enterprises), and environmental protection, or exploring the level of energy and environmental awareness of the users of goods and energy. Raising awareness should contribute to consumer choices made not only through the prism of price but also by considering how goods are obtained and processed (the degree of environmental burden).

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