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Sustainable Energy Development and Sustainable Economic Development in EU Countries

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Abstract: Sustainable development is the subject of many economic analyses, but so far no attempt has been made to identify the main mechanism of interdependence between sustainable energy development and sustainable economic development in the second decade of the 21st century. The particular role of energy in achieving the Sustainable Development Goals is due to the fact that the production, supply and use of energy underpin economic growth. The article fills this research gap and spawns both a better understanding of the essence of sustainable development as well as practical conclusions. The aim is to assess sustainable energy development and sustainable economic development in EU member states and to determine the correlation between the two in the EU. Substantive and formal methods were used to select diagnostic variables, including: the parametric method, the standardized sums method, and correlation analysis. The analysis period covers the years 2014–2021. The conducted research demonstrated a significant variation in the level of sustainable energy development and sustainable economic development among EU countries.

Keywords: Sustainable Development Goals; sustainable energy development; sustainable economic development; multi-dimensional comparative analysis; EU countries

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1. Introduction

In recent years, we have seen a surge in interest in a multidimensional approach to economic reality. One of the characteristics of contemporary development conditions is the existence of significant disparities in economic potential. Determining the state and prospects of sustainable economic development in the context of sustainable energy development is an important research problem, both in economic theory and in economic practice. Identifying the nature of these changes requires their measurement using specific, empirically tested instruments.

The concept of sustainable development is beyond the stage of theoretical analyses and deliberations on its meaning and justification. It is now in the implementation phase, determining the directions of development of EU economies. The effective application of this concept requires adoption of its principles in individual economic sectors. In the context of energy development, sustainable development can be assumed to have three main objectives: keeping energy prices as low as possible, limiting the negative impact of energy on the environment, and ensuring the security of energy supplies. All this results in major challenges for the EU's economy, but may also create new opportunities for development.

The idea of sustainable development, which is the basis of development processes in the EU, assumes that further economic development can only take place within the limits of nature's tolerance. Hence, attention is drawn to the need for selective economic development, marked by an increased role of certain areas and a decreased role of other areas (e.g., development of renewable energy carriers and abandoning the use of conventional energy carriers), improved efficiency, coherent policy, and ensuring the sufficiency of natural resources, including energy. A sustainable approach to the management of energy resources is indicative not only of their importance in the process of economic development but also of the limitations of conventional energy carriers and the negative effects of resource management on the environment and future development.

Sustainable energy development and sustainable economic development overlap on many levels. Energy policy is an element of the state's economic policy. Hence, the debate on the development of energy policy, especially in the context of energy transformation, is also frequently related to broadly understood economic policy. Initially, the energy policy of the EU covered selected energy sources and was aimed primarily at guaranteeing the security of supplies of raw materials to individual Member States. Only over time did the development of this policy begin to be perceived in a broader scope, taking into account not only environmental but also social aspects, and the term "sustainable energy policy" became the subject of large debate [1]. This issue seems to remain current and stimulating to this day given that, despite numerous studies on the sustainable aspects of economic processes, the development gap between EU economies has not been bridged.

The inspiration for the subject of this paper springs from the still limited cognitive possibilities of exploring the surrounding economic reality and the need to isolate the main causative factors of sustainable energy development and sustainable economic development. Currently, energy markets are experiencing various types of instability that will disturb the conditions for harmonious economic development of countries that depend especially on energy imports. These instabilities may result from various causes. They may be the result of political games played by producers of energy and energy resources, the result of an increase in demand for these raw materials and global competition for access to them, or the result of the outbreak of the COVID-19 pandemic and the war between Russia and Ukraine. All this is reflected primarily in the increasingly higher prices of raw materials and the growing uncertainty of their supplies. Hence, identifying the relationship between sustainable economic and energy development is an innovative research endeavor. Economic issues are related primarily to the development of new energy technologies and the price of energy raw materials, which de facto determine the country's development potential. The proper and undisturbed economic growth of every economy depends on access to raw materials and their prices. In 2014, the European Commission, in order to ensure stable energy supplies, adopted the Energy Security Strategy [2]. Part of the strategy was to conduct an "Energy Security Stress Test" by all member states, which assumed two scenarios related to the interruption of energy supplies: (1) complete cutting off of gas supplied from Russia to the EU and (2) interruption of gas imports from Russia through Ukraine via the transit route. The research showed that a long-term break would have a huge impact on the EU economy. Therefore, energy issues are of fundamental importance for the functioning of the EU economies.

The above considerations have not yet been widely reflected in the literature on the subject. Hence, the study is an attempt to capture the issues indicated above into one research problem. Our aim is to assess sustainable energy development and sustainable economic development in EU member states and to determine the correlation between the two in the EU. To this end, substantive and formal methods for selecting key variables were used (including the parametric method), the multi-dimensional method (standardized sums method) and correlation analysis. The analysis period covers the years 2014–2021 (Eurostat has been publishing data for all 27 EU countries since 2014, with the latest available data for 2021). The article is divided into two parts. The first part outlines the essence of sustainable energy development and sustainable economic development as presented in the literature and EU policy. The second part delves into research methods, including the way of selecting key variables and the linear ordering method used, and also shares the results of the empirical research.

2. Literature Review

2.1. The Concept of Sustainable Energy Development

An important component of sustainable development is the acquisition and use of energy. The 2030 Agenda for Sustainable Development sets 17 goals, most of which, directly or indirectly, relate to energy issues [3]. The Agenda's program goes far beyond the Millennium Development Goals adopted in 2000. In accordance with the 2030 Agenda, modernization activities should focus on eliminating poverty, including energy poverty, while achieving economic, social and environmental goals. In the area directly related to energy aspects, the following goals should be highlighted: Goal 7 and Goal 13. Goal 7 seeks to ensure access to affordable, safe, sustainable and modern energy for all [4]. Energy is necessary to perform work, ensure security (including energy security), counteract the negative effects of climate change, produce food and improve prosperity and economic development [5,6]. As part of the specific targets to be met by 2030, it was proposed to ensure universal access to affordable, reliable and modern energy services. The need to significantly increase the share of renewable energy sources in the global energy mix and to double the growth rate of global energy efficiency was emphasized [7]. By 2030, it is also envisaged to support the expansion of infrastructure and modernization of technologies enabling universal access to modern and sustainable energy in developing countries [1].

Sustainable development in the energy sector is a tough challenge for the EU, but it is an important direction in the development of the industry at large [8–10]. The EU's sustainable energy policy hinges on international obligations, as contained in both the Paris Agreement and the Sustainable Development Goals (SDGs). One of the key projects undertaken to this end at the EU level is the European Green Deal (EGD) [11,12]. To implement the EGD assumptions, the European Commission sought to cut net greenhouse gas emissions by at least 55% by 2030, bringing it closer to 1990 levels (European Council Conclusions). This will entail, among other endeavors, decarbonizing the energy system and therefore increasing the share of renewable sources in the energy mix and improving energy efficiency overall. The motivation is to achieve a 40% share of renewable energy sources in the Community's energy mix by 2030 and to reduce the consumption of final and primary energy by roughly 36–39% by 2030. At the same time, it was agreed that the entire EU should become climate-neutral by 2050 [13]. The EGD program is intended to transform the EU into a modern, resource-efficient and competitive economy [13], which will, firstly, achieve zero net greenhouse gas emissions by 2050; secondly, in which economic growth will be decoupled from resource consumption; and thirdly, in which no person or region will be left behind [14] (p. 40).

The sustainable development of the entire energy sector plays a vital role in implementing the concept of sustainable development. Many researchers [15–19] point out that this will require rethinking the entire world economy, and most importantly, the energy economy in particular. A sustainable energy sector is a much-needed direction of development, with the global economy being threatened by energy deficits, excessive cash transfers to raw-material economies, environmental devastation, climate change, and biodiversity loss.

The definition of sustainable energy development was coined by applying the concept of sustainable development to the energy sector [20]. Sustainable energy development should be considered as a method of energy management that will provide sufficient energy for both current and future generations, as well as minimize the negative impact on the environment [21]. K. Prandecki [22] (p. 240) defines sustainable energy as "the conversion of primary energy into electricity and heat and its delivery to the end consumer in a way that allows the needs of current and future generations to be met, taking into account the economic, social and environmental aspects of human development". It is worth emphasizing that, based on this term, issues related to sustainable energy consumption should be perceived as integral to energy policy rather than to energy itself. As such, it is an attempt to develop methods of processing and distributing energy that are the least harmful to the environment as possible, without detriment to the social or economic needs of current and future generations [22] (p. 247). Meanwhile, the International Energy Agency (IEA) defines sustainable energy as energy with a long-term, global vision of development that ensures competitiveness and economic efficiency, social responsibility and environmental protection [23]. The IEA also sets the directions of international policy in the area of sustainable energy, such as by striving to ensure the development of future generations, internalization of external effects, and ceasing subsidies for energy production.

Sustainable energy policy aims to provide an appropriate level of energy services to economic entities within the limits of nature's tolerance. From a long-term perspective, a sustainable energy policy should be shaped in such a way that [24,25]:

- It promotes equal emission of greenhouse gases;
- It favors a gradual reduction in energy consumption through the use of efficiency and sufficiency strategies;
- Fossil and nuclear sources are replaced by renewable energy.

The key goal of sustainable energy is to reduce the implications arising from the negative impact of energy on the environment through [26]:

- Supporting policies and projects that lead to the use of energy from unconventional renewable sources, because it is safe for the environment and beneficial for the economy;
- More effective and less harmful energy production, transmission and distribution.

A sustainable energy policy should both factor in the objectives of increasing the share of renewable energy sources in the energy mixes of individual countries, as well as improving broadly understood energy efficiency and providing affordable energy (electricity and heat) to consumers (to curb energy poverty, especially in households) [1].

Only a policy that favors increased energy security, efficiency and competitiveness while truly caring for environmental protection can be considered to be of added value to the sustainable development of the energy sector [27]. Unfortunately, it is anything but easy, economically, for all these to be met, especially in the initial period, as their implementation requires multiple investments. The use of modern low-emission technologies is very expensive, as is increasing the diversification of fuel and energy supplies, which does not bode well for the competitiveness aspect. Having said that, in the long-term perspective, the use of modern technologies and extensive diversification of fuel and energy supplies will significantly increase energy security, energy efficiency, and the competitiveness of the economy. It is important to initiate actions towards sustainable energy development gradually but systematically, making rational decisions that do not limit the possibility of achieving any of the mentioned goals [28].

2.2. The Concept of Sustainable Economic Development

Economic sciences distinguish between the concepts of "economic development" and "economic growth" [29]. While economic growth focuses on the aspect of quantitative changes, economic development—a broader concept—also concerns qualitative changes taking place in the economy and society [30–33]. An economy can exhibit economic growth without economic development, but not vice versa [34]. Economic growth is a process of quantitative changes in macroeconomic values in the economy, manifested by an increase in the volume of production throughout the economy as a result of increased economic potential [35]. According to M. Klamut [36] (p. 195), economic growth means "the process of creating and increasing the actual size of the social product". This process is accompanied by changes in the structure of the national product and the entire economy. Economic growth is a measurable economic variable that is generally defined in terms of the increase in the value of the annual production of goods and services in a given country. Economic growth is also a process of increasing the effects of management, which is measured by the economy's growth rate, generally equated with the gross domestic product (GDP) [31]. Economic growth is therefore viewed as a category that is used to describe quantitative changes taking place in a national economy. They can be determined quite accurately using formal and mathematical models, among which stands out the production function, which models the relations between output of goods and the underlying inputs [37]. According to the neoclassical growth theory, three factors influencing production growth can be distinguished: increasing the quantity and quality of work (through population growth and education), increasing capital (through savings and investments), and technical advancement [38,39]. This approach to economic growth factors is presented in the neoclassical model of economic growth developed by R. Solow, which assumes the existence of constant returns to scale, decreasing marginal productivity of capital, and the exogeneity of factors influencing growth. R. Solow gauges the rate of increase in the volume of production in a national economy using the production function, in which he makes economic growth dependent on the dynamics of technical progress, the rate of growth of capital resources and employment, taking into account the share of income from capital and labor inputs in national income [35]. Other exogenous models are an extension of the Solow model, including: the Mankiw–Romer–Weil or Ramsey–Cass–Koopmans models [40,41]. The former expands the Solow model by an additional variable in the form of human capital (education, skills, competencies and other factors increasing the productivity of labor resources). The latter, meanwhile, rejects the assumption of the exogeneity of the interest rate balancing investments and savings, treating it as an endogenous variable dependent on household decisions [41].

In mainstream economics, the key drivers of economic growth in the short term are consumer and investment demand, both domestic and foreign, while in the long term the drivers are sufficient supply and efficiency of production factors [42,43]. Therefore, to ensure sustainable economic growth, efficiency and productivity should be promoted and favorable conditions for domestic and foreign investments should be ensured, as one of the crucial sources of productivity growth is technical progress, enabling greater access to capital and new technological solutions, and investment dynamics. Other sources are also helpful in boosting economic growth, such as innovation, ensuring monetary stability and low taxes. Mainstream economists argue that the level of real GDP is a good measure of economic well-being and that real GDP growth is a viable measure of economic progress [44,45]. According to R. Solow [46], the "recipe for achieving growth" does not differ from country to country. Depending on needs, two basic types of growth can be distinguished: (1) "brute force growth", based on a quantitative increase in inputs (more labor and capital equals more output); (2) "smart growth", based on ongoing qualitative changes (e.g., technological progress) or institutional changes [47]. The key factor in qualitative growth is productivity growth.

The exogenous models adopted a short- and medium-term time horizon in the analysis of economic phenomena, which meant that the growth theories they hinged on were not applicable to the study of long-term changes occurring in a national economy or their sources [40]. The endogenous models (including the AK model, P. Romer model, RE Lucas model), meanwhile, were used to explain the long-term determinants of economic growth, but they, too, failed to address the question of the sources of the different rates of economic growth over time and across countries [41]. The failure of exo- and endogenous models to explain the causes of disparities in the level of development of individual countries prompted researchers to explore the so-called fundamental growth factors. These include geographical location, economic openness, and strength of institutions [32,48,49].

Explaining the causes of the currently observed differences in the level of development in the world is important for the correct shaping of the economic policies of individual countries, and thus supporting their development [50–55]. The economy of each country has its own growth potential (understood as a quantitative element of development), the pace of which depends on various objective and subjective factors [56]. The former include the state of natural resources, geographical location, demographic potential, societal psychology, and the level of economic development already achieved. They determine the size of this growth potential, which also depends on subjective factors. The latter include historical conditions, strength of state institutions, quality of economic law and economic policy concepts. It is subjective factors that determine the extent to which this potential will be used. One of the latest analytical approaches to economic growth factors is their division into the so-called shallow and deep determinants [57]. This division also plays an increasingly important role in explaining the ever-widening gaps in the overall economic development. The shallow determinants are factors resulting from the decomposition of growth into its components within the so-called growth accounting. Here, a distinction is made, first of all, between the accumulation of production factors: physical capital, labor, human capital and others, depending on the adopted structure of the production function and the residual value, i.e., not resulting from the process of accumulation of production factors. The deep determinants include geography, integration, and institutions. According to D. Rodrik et al. [48], the only deep factor determining growth of a strictly exogenous nature is geography, understood as a set of factors related to location, and thus related to, among others, geographical position on the globe, access to natural resources, climate, location above sea level or access to the sea, etc. Integration and institutions are partly endogenous. Geography primarily influences openness. The peripheral location in relation to other economies means a significant increase in transport costs and has a decisive negative impact on the intensity of exchange (according to gravity models of trade). With the ongoing process of globalization of the world economy, the degree of openness of national economies is itself on the rise, which means that economic growth is becoming increasingly dependent on interconnections [56].

Defining economic growth [38,42] as the increasing ability of a given society to produce goods and services that meet human needs, it is worth noting that the benefits of economic growth and development include an increase in the standard of living, a more robust social safety net and greater public safety. Economic growth can be treated as a process of increasing the resources of consumer goods and services, as well as an increase in the amount of consumer goods and services per inhabitant of a given country (e.g., GDP per capita) [58]. What is also important in economic growth is that it ensures an increase in the country's ability to produce goods and services desired by people. Since the production capacity of an economy depends primarily on the quantity and quality of its resources, as well as on the level of technology, economic growth must involve the expansion and improvement of these production factors. Particularly important factors are also the accumulation of capital through savings and investments, the improvement of human skills, and technical advancement.

Economic development is a broader economic term characterizing a complex economic and social process that leads to structural changes in the national economy and improvement of the living conditions of society [59]. At the heart of defining the concept of "economic development" is the meaning of the term "development". What different definitions of "development" seem to have in common is the belief that development vastly eclipses growth. A. Sen [60] argues that "development" is about providing people with a better life, which is why relevant analyses and policy-making should prioritize the quality of life and life expectancy. G. Myrdal [61] understands "development" as pro-growth changes of the entire social system, which implies elements such as: productivity, income, production conditions, standard of living, attitudes towards the way of living and working, institutions and politics. M. Todaro and S.C. Smith [62] formulate three development goals: raising the standard of living, increasing the availability of essential goods, and freedom from all types of dependence, including poverty, understood as material dependence.

One of the first economists to distinguish between economic growth and development was J.A. Schumpeter [63]. In his view, economic development is the result of changes that stem from the inside rather than from the outside—they occur under the influence of initiatives innate to an economy. The concept of economic development, in addition to quantitative changes in the sphere of production, consumption and employment, also includes qualitative changes. Economic development is the process of transforming low-income economies into modern industrial economies [64]. Economic development can also be considered as a multilayered process of changes in the rules of competition and economic cooperation, institutional shifts and the ability of society to embrace new solutions and changes in forms of organization [56]. According to G. Myrdal [61] (p. 439), development is an upward movement of the entire social system, not only production (division and method of production), but also the standard of living, institutions, human attitudes, and politics.

In the traditional approach, economic development factors most often include property (capital) resources, natural resources and demographic resources, which together create more or less favorable conditions for settling and conducting different economic activities [65]. But political changes, economic transformation, as well as scientific and technical progress have prompted completely new conditions for economic development. In addition to traditional prospects, there are the so-called modern development factors which cover: economic potential, including the structure of the economy and its ability to transform, and socio-political potential, which emphasizes the importance of social predispositions to progress and innovation, as well as the efficiency of the economic system [66]. Economic development is a measurable category, but due to its complex nature, it cannot be expressed using just one number, nor can it be measured directly. The complex nature of development processes in individual countries requires the use of various indicators reflecting the totality of key characteristics. In the literature, we find various ways of measuring economic development, as well as various types of measures, the number of which ranges from several to several dozen [67–74]. To present an image of spatial differences and a summary description of the economic situation, synthetic measures, forged through the use of taxonomic methods, are often used, and so are various methods for classifying multi-element sets.

3. Research Methods

The assessment of sustainable energy development and sustainable economic development in the EU member states was carried out using one of the linear ordering methods—the standardized sums method. Subsequently, synthetic indicators constructed based on the above method constituted the basis for examining the relationship between sustainable energy development and sustainable economic development in the EU. To this end, Spearman's rank correlation indices were calculated, whereas previous variables were organized into two sets:

(1) A set characterizing sustainable energy development;
(2) A set characterizing sustainable economic development.

The final sets were established after a substantive and formal analysis of the studied phenomena and based on the availability of data. The following criteria were used to select variables:

(1) Substantive, based on researchers' knowledge;
(2) Formal, using statistical methods.

The surveyed population consisted of 27 EU countries. The research period covered the years 2014–2021, which coincide with the implementation period of the "Europe 2020 Strategy" [75]. In line with that strategy, sustainable development rests on the idea of creating a low-emission economy that uses resources efficiently all while being environmentally friendly and more competitive. The energy sector plays a particular role in fulfilling the assumptions of the EU sustainable development strategy. This role resulted from the strategic importance of the energy sector in keeping the EU economy competitive, protecting the environment, and securing energy supplies in the EU. The study used data provided by Eurostat—sustainable development indicators assigned to 17 goals of the 2030 Agenda. Variables were selected in line with substantive, formal and statistical criteria. Using a substantive criterion based on the knowledge of researchers, the principle was adopted that the set of indicators would include variables denoting individual goals of the 2030 Agenda in the area of economic and energy development. Then, using the formal criterion, i.e., availability of data for all 27 EU countries in all examined years, two sets of potential diagnostic variables were developed (Table 1).

Table 1. Potential diagnostic variables (source: own study based on Eurostat data).

Symbol	Indicator Name	Agenda 2030 Goal and Number
	Potential variables characterizing sustainable energy development	
E1	Primary energy consumption (tonnes of oil equivalent per capita)	SDG 07.10
E2	Final energy consumption (tonnes of oil equivalent per capita)	SDG 07.11
E3	Final energy consumption in households per capita (kilograms of oil equivalent)	SDG 07.20
E4	Energy productivity (purchasing power standard per kilogram of oil equivalent)	SDG 07.30
E5	Share of renewable energy in gross final energy consumption (%)	SDG 07.40
E6	Energy import dependency (% of imports in total energy consumption)	SDG 07.50
E7	Population unable to keep home adequately warm by poverty status (%)	SDG 07.60
	Potential variables characterizing sustainable economic development	
G1	Real GDP per capita (chain-linked volumes (2010), euro per capita)	SDG 08.10
G2	Young people neither in employment nor in education and training (% of the population aged 15 to 29)	SDG 08.20
G3	Employment rate (percentage of total population, from 20 to 64 years)	SDG 08.30
G4	Long-term unemployment rate (% of total active population)	SDG 08.40
G5	Fatal accidents at work (number per 100 000 workers)	SDG 08.60
G6	In work at-risk-of-poverty rate (% of employed persons aged 18 or over)	SDG 01.41
G7	Gross domestic expenditure on R&D (% of GDP)	SDG 09.10
G8	R&D personel (% of active population)	SDG 09.30
G9	Patent applications to the European Patent Office (number per million inhabitants)	SDG 09.40
G10	Share of buses and trains in inland passenger transport (% of passenger km)	SDG 09.50
G11	Tertiary educational attainment (%)	SDG 04.20
G12	High-speed internet coverage (% of households)	SDG 17.60

Subsequently, formal criteria based on statistical methods were applied. The formal approach consisted of two stages. The first stage involved analyzing diversity using the coefficient of variation. The variability criterion was used to check whether a given diagnostic variable has the ability to discriminate between the examined EU countries, i.e., whether it carries sufficient variability. The selection process using this criterion consisted in eliminating from the potential indicators those for which the coefficient of variation was lower than the adopted critical value V* = 20%. It was considered that such variables exhibit insufficient variability. As a result, only one variable representing sustainable economic development (G3) was removed from the set.

The second step in the formal approach involved the use of the parametric method [76]. This method involves, first, creating a matrix composed of correlation coefficients between potential diagnostic features, then determining the critical value of the correlation coefficient r*, which is a classification criterion, after which clusters are formed. Clusters are subsets of the set of potential diagnostic variables in which the minimum similarity between the variables is not less than r*. In each cluster, there is one central variable and several satellite variables whose similarity to the central variable is not less than r*. Variables that do not belong to clusters are isolated variables. Central variables and isolated variables create the underlying system and are considered diagnostic variables [77].

The following algorithm of the parametric Hellwig method was used In the research:

1. The correlation matrix of variables characterizing sustainable energy development R_e and the correlation matrix of variables characterizing sustainable economic development R_g were calculated:

$$R_e = \lfloor r_{ij} \rfloor = [1 \ \ldots \ r_{1m} \ \ldots \ \ldots \ \ldots \ r_{m1} \ \ldots \ 1], \ (i,j = 1,2,\ldots,m; m^{-}\text{number of variables}; m = 7) \quad (1)$$

$$R_g = \lfloor r_{kl} \rfloor = [1 \ \ldots \ r_{1n} \ \ldots \ \ldots \ \ldots \ r_{n1} \ \ldots \ 1 \,], \ (k, l = 1, 2, \ldots, n; n^{-}\text{number of variables}; n = 11) \tag{2}$$

2. The threshold value of the correlation coefficient r* was determined for both sets of variables (based on an arbitrary decision, it was assumed that r* = 0.7).
3. The sum of the absolute values of the correlation coefficients of each column of the matrix R_e and R_g was calculated:

$$R_j = \sum_{i=1}^{m} |r_{ij}| \tag{3}$$

$$R_l = \sum_{k=1}^{n} |r_{kl}| \tag{4}$$

4. In the matrix R_e, the number of the column (p) for which the sum R_j is the largest is determined, and in the matrix R_g the number of the column (s) for which the sum R_l is the largest, were determined:

$$R_{p=max_j}\{R_j\} \tag{5}$$

$$R_{s=max_l}\{R_l\} \tag{6}$$

5. A classification of matrix variables was carried out: R_e (the variable number (p) is the central variable), the variables for which $|r_{ij}| > r^*$ are satellite variables (they form a cluster of highly correlated variables), R_g (the variable number (s) is the central variable), and the variables for which $|r_{kl}| > r^*$ are satellite variables (they form a cluster of highly correlated variables).
6. Rows and columns corresponding to the satellite variables and the column corresponding to the central variable were removed from the R_e and R_g matrix.
7. The procedure described in points 1–6 was repeated until the set of variables representing sustainable energy development and the set of variables representing sustainable economic development were exhausted.
8. Variables that are not included in any cluster in the set representing sustainable energy development and the set representing sustainable economic development are isolated variables (they form single-element clusters).
9. Central and isolated variables were qualified for further analysis in both sets of variables (satellite variables were rejected) (Tables 2 and 3).

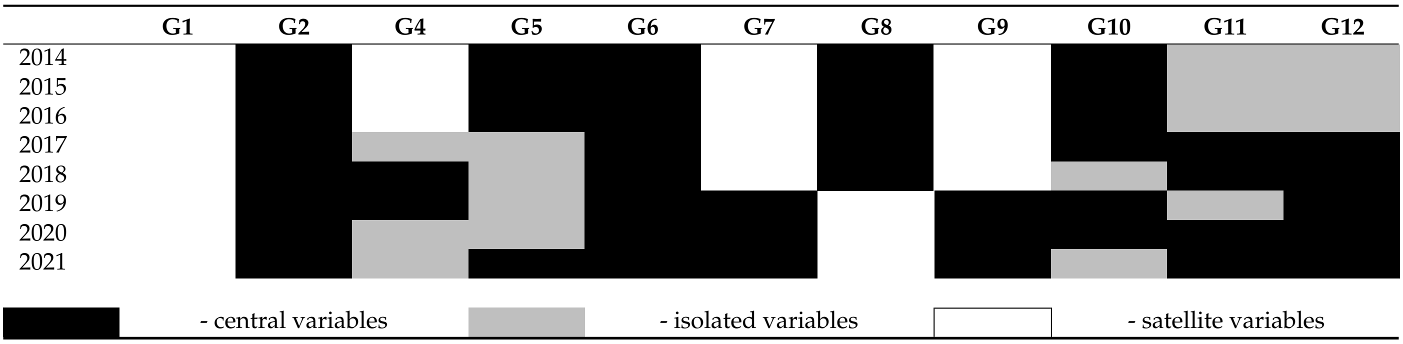
Table 2. List of central and isolated variables of the R_e matrix in 2014–2021 (source: own study).

	E1	E2	E3	E4	E5	E6	E7
2014	satellite	satellite	central	isolated	isolated	central	satellite
2015	satellite	satellite	central	isolated	central	central	isolated
2016	satellite	satellite	central	isolated	central	central	isolated
2017	satellite	satellite	central	central	isolated	central	isolated
2018	satellite	satellite	central	central	isolated	central	isolated
2019	satellite	isolated	central	central	isolated	central	central
2020	satellite	satellite	central	central	isolated	central	isolated
2021	satellite	isolated	central	isolated	central	central	central

■ - central variables; ▒ - isolated variables; □ - satellite variables

Ultimately, five variables representing sustainable energy development (E3, E4, E5, E6, E7) and eight variables representing sustainable economic development (G2, G4, G5, G6, G8, G10, G11, G12) were qualified for further research.

Table 3. List of central and isolated variables of the R_g matrix in 2014–2021 (source: own study).



In order to assess sustainable energy development and sustainable economic development in EU countries, the standardized sums method was used, which is a non-model linear ordering method [78]. This method assumes that all variables are stimulants (drivers) and standardized. Due to the fact that both sets of variables included destimulants (inhibitors), they were transformed into stimulants using the following formula: $x_{ij} = \frac{1}{x'_{ij}}$ (x_{ij} —destimulant after conversion to stimulant, x'_{ij}—original value of destimulant). Subsequently, the variables were standardized according to the following formula:

$$z_{ij} = \frac{x_{ij} - \underline{x}_j}{S_j},\ (i = 1,\ 2,\ \ldots,\ 27; j = 1,\ 2,\ \ldots,\ m) \tag{7}$$

where: x_{ij}—variable j for country i, $\underline{x}_j$—arithmetic mean of variable j, S_j—standard deviation of variable j.

The standardized sums method included two stages [79]:

(1) For each country, the sums of the values of variables characterizing sustainable energy development (p_{e_i}) and sustainable economic development (p_{g_i}) were calculated:

$$p_{e_i} = \sum_{j=1}^{m} z_{ij} \tag{8}$$

$$p_{g_i} = \sum_{j=1}^{m} z_{ij} \tag{9}$$

It was assumed that all variables have the same impact on the level of the analyzed phenomena.

(2) For each EU country, the measure of sustainable energy development (m_{e_i}) and measure of sustainable economic development (m_{g_i}) were calculated:

$$m_{e_i} = \frac{p_i - p_{-0}}{p_0 - p_{-0}};\ m_{g_i} = \frac{p_i - p_{-0}}{p_0 - p_{-0}},\ \mathrm{i}\ =\ 1,\ 2,\ \ldots,\ 27 \tag{10}$$

$$p_0 = \sum_{j=1}^{m} z_{0j} \times w_j;\ p_{-0} = \sum_{j=1}^{m} z_{-0j} \times w_j \tag{11}$$

$$z_{0j} = max_i\{z_{ij}\} \text{ – abstract country (model)} \tag{12}$$

$$z_{-0j} = min_i\{z_{ij}\} \text{ – abstract country (non-model)} \tag{13}$$

The higher the value of p_{e_i} and p_{g_i}, the higher the level of the studied phenomena characterizing EU countries. Accordingly, the EU countries were ordered from best to worst based on the obtained sum values.

The final stage of the research was to examine the relationship between sustainable energy development and sustainable economic development in the EU. To this end, a correlation analysis was performed. To eliminate possible outliers in the results of the correlation analysis, the non-parametric Spearman's rank correlation coefficient was calculated.

4. Research Results

Based on the analysis of the values of synthetic indicators, it can be concluded that the EU is marked by a significant regional variation in the level of sustainable energy development and sustainable economic development.

As for the former, in the years 2014–2021 the EU did not record lasting, positive changes. The average value of synthetic measures for sustainable energy development in 2014–2021 stood at approximately 0.2810. The highest levels were identified in Estonia, Sweden, Denmark, and Austria, and the lowest in Belgium, Hungary, Cyprus, and Slovakia. This translates into a more than twofold disparity between the highest and lowest scorers. Moreover, during the period under study, the value of both the minimum, maximum and average measures exhibited a downward trend.

Analyzing the dynamics of changes in the values of synthetic measures in individual countries, it can be observed that the vast majority of EU countries have not achieved lasting sustainable energy development. Using the 2014 value as the base value, it can be noted that in most countries (15) in the following years (2015–2021) these measures were at a lower level than in 2014. This means that in these countries, in the subsequent years 2015–2021, compared to 2014, there were no positive changes in the area of sustainable energy. The increase in the value of synthetic measures in all years from 2015 to 2021, compared to 2014, took place only in two countries, namely Estonia and Ireland. Analyzing the change in the value of the measures in subsequent years compared to the previous year, we see that no country recorded an increase in the value of this indicator in all the years examined. In all countries, the value of the measures would fluctuate up and down in subsequent years. In the vast majority of countries (24), the lowest value of the synthetic measure was reported in the last analyzed year, 2021. Moreover, in 2021, compared to both 2014 and the previous year, 2020, the vast majority of countries recorded the largest decreases in the value of the synthetic measure. The reported drop in 2021 is likely a consequence of the COVID-19 pandemic.

In the analyzed period, the value of the coefficient of variation calculated for the synthetic measures of energy development fluctuated between 20.8% and 26.1%. These measures were right-skewed throughout the entire analyzed period, which means that the values below the arithmetic mean of these measures were predominant. In most individual EU countries, sustainable energy development is therefore below the global EU average (Table 4).

Table 4. Measure of sustainable energy development (m_{e_i}) in EU countries in 2014–2021 (source: authors' computation).

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Austria	0.3251	0.3233	0.3437	0.3513	0.3663	0.3466	0.3696	0.2883	0.3393
Belgium	0.1854	0.1753	0.1897	0.1879	0.1727	0.1842	0.1830	0.1549	0.1791
Bulgaria	0.2693	0.2582	0.2488	0.2468	0.2345	0.2478	0.2492	0.1886	0.2429
Croatia	0.3050	0.2813	0.2834	0.2819	0.2632	0.2684	0.2676	0.2262	0.2721
Cyprus	0.2412	0.2203	0.2159	0.2259	0.2233	0.2147	0.2109	0.2061	0.2198
Czechia	0.2373	0.2338	0.2524	0.2564	0.2345	0.2425	0.2682	0.1994	0.2406
Denmark	0.4587	0.4319	0.4487	0.4394	0.3457	0.3598	0.3393	0.2907	0.3893
Estonia	0.3760	0.4025	0.4222	0.4414	0.4386	0.4488	0.4222	0.4310	0.4228
Finland	0.2949	0.3062	0.3434	0.3311	0.3101	0.3128	0.3265	0.2862	0.3139
France	0.2492	0.2385	0.2506	0.2529	0.2290	0.2288	0.2366	0.1872	0.2341
Germany	0.2558	0.2495	0.2688	0.2808	0.2717	0.2757	0.2210	0.2114	0.2543
Greece	0.2764	0.2438	0.2395	0.2454	0.2420	0.2387	0.2304	0.2096	0.2407
Hungary	0.2391	0.2221	0.2194	0.2201	0.2059	0.2094	0.2131	0.1641	0.2117
Ireland	0.3008	0.3250	0.3323	0.3658	0.3389	0.3407	0.3613	0.3255	0.3363

Table 4. *Cont.*

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Italy	0.2952	0.2631	0.2685	0.2667	0.2479	0.2485	0.2441	0.2069	0.2551
Latvia	0.3075	0.2930	0.2952	0.2988	0.2803	0.2805	0.2955	0.2491	0.2875
Lithuania	0.2780	0.2647	0.2540	0.2557	0.2300	0.2329	0.2247	0.1982	0.2423
Luxembourg	0.3713	0.3397	0.3181	0.3075	0.2694	0.2513	0.2278	0.2229	0.2885
Malta	0.2862	0.2803	0.3012	0.2980	0.2734	0.2675	0.2668	0.2435	0.2771
Netherlands	0.2539	0.2262	0.2545	0.2672	0.2462	0.2293	0.2518	0.2058	0.2419
Poland	0.2631	0.2580	0.2484	0.2385	0.2147	0.2364	0.2535	0.1977	0.2388
Portugal	0.3667	0.3490	0.3438	0.3480	0.3273	0.3259	0.3230	0.2976	0.3352
Romagna	0.4019	0.3877	0.3612	0.3434	0.3062	0.3240	0.3272	0.2482	0.3375
Slovakia	0.2610	0.2560	0.2560	0.2589	0.2342	0.2072	0.2118	0.1683	0.2317
Slovenia	0.2721	0.2579	0.2661	0.2784	0.2645	0.2994	0.2936	0.2748	0.2759
Spain	0.3052	0.2875	0.2991	0.3103	0.2780	0.2918	0.2809	0.2453	0.2873
Sweden	0.4127	0.4350	0.3867	0.4089	0.3553	0.3906	0.3853	0.3514	0.3907
MIN	0.1854	0.1753	0.1897	0.1879	0.1727	0.1842	0.1830	0.1549	0.1791
MAX	0.4587	0.4350	0.4487	0.4414	0.4386	0.4488	0.4222	0.4310	0.4228
Average	0.2996	0.2892	0.2930	0.2966	0.2742	0.2779	0.2772	0.2400	0.2810
Coefficient of variation	0.2081	0.2289	0.2148	0.2177	0.2136	0.2232	0.2204	0.2615	0.2120
Skewness	0.8639	0.8385	0.8137	0.8142	0.9242	0.9527	0.7119	1.2561	0.7731

Analyzing the second examined area, i.e., sustainable economic development, in the years 2014–2021 in the EU there were no significant changes in this area. The average value of the synthetic measure of sustainable economic development in EU countries in 2014–2021 stood at the level of approximately 0.39. On an annual average, the highest level was identified in the Netherlands, Denmark and Sweden, and the lowest in Italy, Bulgaria and Romania. As with energy development, indicators of sustainable economic development in the highest scorers were more than twice as high as the lowest scorers. During the period under study, there was a slight increase in the minimum value (by 1.3%) and a slightly larger increase in the maximum value (by 6.2%), while the average value decreased (by 3.6%). It can therefore be concluded that in the EU the gap between countries with the highest and lowest levels of sustainable economic development increased.

Analyzing the dynamics of changes in the value of measures in individual countries, it can be observed that most EU countries have not achieved sustainable economic development. Using the 2014 value as the base value, we see that in most countries in the following years (2015–2021) the measures both increased and decreased. The increase in the value of synthetic measures in all years from 2015 to 2021, compared to 2014, took place only in four countries, namely: Portugal, Poland, Slovenia, and Bulgaria. Analyzing the change in the value of the measures in subsequent years compared to the previous year, it can be noticed that no country recorded an increase in all the years examined. In the following years, in all countries, the value of the measures would fluctuate up and down. The largest number of countries (13) reached the lowest value of the measure in 2021, which is likely also due to the COVID-19 pandemic.

In the analyzed period, the value of the coefficient of variation calculated for the synthetic measures of economic development fluctuated between 20.4% and 23.5%. These measures were right-skewed throughout the entire analyzed period, which means that the values below the arithmetic mean of these measures were predominant. In most EU countries, sustainable economic development is below the average for the entire EU (Table 5).

Subsequently, based on the obtained values of the synthetic measures, EU countries were ranked according to the level of sustainable energy development and sustainable economic development from highest to lowest (Tables 6 and 7). Top spots for energy development were Estonia, Sweden, Denmark, Australia, while Belgium, Hungary, Cyprus, Slovakia and France came last. As for economic development, top spots were the Netherlands, Denmark, Sweden, Finland, while Italy, Bulgaria, Romania, Croatia, Greece and Portugal came last.

Table 5. Measure of sustainable economic development (m_{g_i}) in EU countries in 2014–2021 (source: authors' computation).

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Austria	0.4458	0.4322	0.3996	0.4275	0.4327	0.4216	0.4108	0.3763	0.4183
Belgium	0.4205	0.4065	0.3831	0.4046	0.4142	0.4622	0.4430	0.4471	0.4227
Bulgaria	0.2641	0.2763	0.2649	0.2871	0.2871	0.2879	0.2751	0.2673	0.2762
Croatia	0.2735	0.2531	0.2669	0.2854	0.3069	0.3190	0.3109	0.2859	0.2877
Cyprus	0.3213	0.3202	0.3171	0.3857	0.3453	0.3445	0.3067	0.3055	0.3308
Czechia	0.4597	0.4384	0.4509	0.5232	0.5376	0.4990	0.4555	0.4187	0.4729
Denmark	0.5769	0.5737	0.5626	0.5634	0.5397	0.5199	0.4801	0.4691	0.5357
Estonia	0.3549	0.3686	0.3583	0.4141	0.4099	0.3954	0.3473	0.3190	0.3709
Finland	0.4981	0.4711	0.4693	0.5065	0.5100	0.5073	0.4878	0.4604	0.4888
France	0.3727	0.3676	0.3500	0.3779	0.3872	0.3689	0.3682	0.3570	0.3687
Germany	0.3962	0.4041	0.3944	0.4150	0.4383	0.4357	0.4026	0.3875	0.4092
Greece	0.3154	0.2834	0.2661	0.2870	0.3177	0.3091	0.2848	0.2696	0.2916
Hungary	0.3993	0.3788	0.3722	0.4031	0.4147	0.3934	0.3746	0.3896	0.3907
Ireland	0.3854	0.3856	0.3826	0.4189	0.4495	0.4402	0.4316	0.4511	0.4181
Italy	0.2600	0.2511	0.2506	0.2664	0.2741	0.2699	0.2559	0.2635	0.2614
Latvia	0.3871	0.3724	0.3598	0.3804	0.3725	0.3649	0.3462	0.3153	0.3623
Lithuania	0.3587	0.3521	0.3539	0.3766	0.3862	0.3487	0.3250	0.3041	0.3507
Luxembourg	0.5287	0.4871	0.4610	0.4952	0.4806	0.4955	0.4671	0.4305	0.4807
Malta	0.3503	0.3418	0.3408	0.4531	0.4052	0.4652	0.3958	0.3923	0.3931
Netherlands	0.5359	0.5499	0.5332	0.5377	0.5739	0.6060	0.6132	0.6131	0.5704
Poland	0.3439	0.3427	0.3533	0.3953	0.4226	0.4384	0.3960	0.3630	0.3819
Portugal	0.2685	0.2750	0.2766	0.3226	0.3480	0.3423	0.3356	0.3354	0.3130
Romagna	0.2915	0.2826	0.2715	0.3029	0.2860	0.2801	0.2841	0.2700	0.2836
Slovakia	0.3423	0.3338	0.3395	0.3628	0.3857	0.3976	0.3535	0.3224	0.3547
Slovenia	0.3721	0.3718	0.3914	0.4168	0.4346	0.4355	0.4002	0.3985	0.4026
Spain	0.3218	0.3179	0.3243	0.3370	0.3487	0.3480	0.3189	0.3235	0.3300
Sweden	0.5414	0.5359	0.5474	0.5449	0.5490	0.5414	0.5042	0.4807	0.5306
MIN	0.2600	0.2511	0.2506	0.2664	0.2741	0.2699	0.2559	0.2635	0.2614
MAX	0.5769	0.5737	0.5626	0.5634	0.5739	0.6060	0.6132	0.6131	0.5704
Average	0.3847	0.3768	0.3719	0.4034	0.4095	0.4088	0.3842	0.3710	0.3888
Coefficient of variation	0.2352	0.2354	0.2329	0.2094	0.2037	0.2102	0.2165	0.2236	0.2140
Skewness	0.6198	0.6734	0.7103	0.2605	0.2911	0.3069	0.7207	0.8941	0.4987

Table 6. EU countries ranked by level of sustainable energy development (m_{e_i}) in EU countries in 2014–2021 (source: authors' computation).

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Austria	7	8	6	5	2	4	3	6	4
Belgium	27	27	27	27	27	27	27	27	27
Bulgaria	18	16	22	22	20	17	17	23	17
Croatia	10	12	13	13	15	13	13	13	14
Cyprus	24	26	26	25	24	24	26	18	25
Czechia	26	23	20	19	19	18	12	20	21
Denmark	1	2	1	2	4	3	5	5	3
Estonia	4	3	2	1	1	1	1	1	1
Finland	13	9	7	8	7	8	7	7	8
France	23	22	21	21	23	23	19	24	23
Germany	21	20	14	14	12	12	23	15	16

Table 6. *Cont.*

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Greece	16	21	24	23	18	19	20	16	20
Hungary	25	25	25	26	26	25	24	26	26
Ireland	11	7	8	4	5	5	4	3	6
Italy	12	15	15	17	16	16	18	17	15
Latvia	8	10	12	11	9	11	9	9	10
Lithuania	15	14	19	20	22	21	22	21	18
Luxembourg	5	6	9	10	13	15	21	14	9
Malta	14	13	10	12	11	14	14	12	12
Netherlands	22	24	18	16	17	22	16	19	19
Poland	19	17	23	24	25	20	15	22	22
Portugal	6	5	5	6	6	6	8	4	7
Romagna	3	4	4	7	8	7	6	10	5
Slovakia	20	19	17	18	21	26	25	25	24
Slovenia	17	18	16	15	14	9	10	8	13
Spain	9	11	11	9	10	10	11	11	11
Sweden	2	1	3	3	3	2	2	2	2

Table 7. EU countries ranked by level of sustainable economic development (m_{g_i}) in EU countries in 2014–2021 (source: authors' computation).

EU Countries	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
Austria	7	7	7	8	10	13	9	13	8
Belgium	8	8	10	13	13	8	7	6	7
Bulgaria	26	24	26	24	25	25	26	26	26
Croatia	24	26	24	26	24	23	22	23	24
Cyprus	21	20	21	16	22	21	23	21	20
Czechia	6	6	6	4	4	5	6	8	6
Denmark	1	1	1	1	3	3	4	3	2
Estonia	16	14	14	12	14	15	17	19	15
Finland	5	5	4	5	5	4	3	4	4
France	13	15	17	18	16	17	15	15	16
Germany	10	9	8	11	8	11	10	12	10
Greece	22	22	25	25	23	24	24	25	23
Hungary	9	11	12	14	12	16	14	11	13
Ireland	12	10	11	9	7	9	8	5	9
Italy	27	27	27	27	27	27	27	27	27
Latvia	11	12	13	17	19	18	18	20	17
Lithuania	15	16	15	19	17	19	20	22	19
Luxembourg	4	4	5	6	6	6	5	7	5
Malta	17	18	18	7	15	7	13	10	12
Netherlands	3	2	3	3	1	1	1	1	1
Poland	18	17	16	15	11	10	12	14	14
Portugal	25	25	22	22	21	22	19	16	22
Romagna	23	23	23	23	26	26	25	24	25
Slovakia	19	19	19	20	18	14	16	18	18
Slovenia	14	13	9	10	9	12	11	9	11
Spain	20	21	20	21	20	20	21	17	21
Sweden	2	3	2	2	2	2	2	2	3

From the presented analysis of the value of synthetic measures and the position of EU countries in the ranking of sustainable energy development and sustainable economic development in 2014–2021, it can be concluded that there is no relationship between these two areas of sustainable development. To test this hypothesis, a correlation analysis was performed. The values of Spearman's rank correlation coefficients were calculated between the synthetic measures of sustainable energy development and those of sustainable economic development (Table 8).

Table 8. Correlation between synthetic measures of sustainable energy development and of sustainable economic development in 2014–2021 ($p < 0.05$) (source: authors' computation).

	2014	2015	2016	2017	2018	2019	2020	2021	2014–2021
R Spearman	0.0080	0.0790	0.2880	0.3530	0.2290	0.1239	0.2204	0.2131	0.1770
T (N-2)	0.0397	0.3980	1.5046	1.8856	1.1744	0.6244	1.1297	1.0904	0.8994
p	0.9687	0.6939	0.1449	0.0710	0.2513	0.5379	0.2693	0.2859	0.3770

The data in Table 8 show that in all years of the studied period, the correlation coefficients are lower than the critical value of 0.3827 (the critical value of Spearman's rank correlation is 0.3827; $\alpha = 0.05$—significance level; $n = 27$—number of observations). This means that there is no statistically significant correlation between sustainable energy development and sustainable economic development.

5. Discussion

Sustainable development, including sustainable energy development and sustainable economic development, is addressed by many researchers in the literature. As shown above, discussion on sustainable energy development and sustainable economic development in EU countries has been ongoing for many years in various sciences, including economics. Despite the relative popularity of this topic, there is currently no research that would analyze these two key areas of sustainable development jointly. There are many studies that examine either sustainable energy development [9,15,17,18,80–83] or sustainable economic development [84–92], but none that presents research results regarding both, plus their mutual relationship. Only in selected European Commission documents can one find statements and conclusions indicating that, for example, a long-term interruption in energy supply would have a significant impact on the EU economy [93–95].

In light of all this, the conducted research, whose aim was to assess sustainable energy development and sustainable economic development in EU countries and to determine the relationship between them in the EU, constitutes a new contribution to the current knowledge and fills the gap existing in the literature. The study also reflects the global trends of new ways of measuring sustainable development. The set of variables proposed in the article to assess energy and economic development in the context of sustainable development may provide guidance in constructing such analyses.

6. Conclusions

The second decade of the 21st century brought sharp increases in energy prices and deepening instability in the EU energy market. This was caused by an increase in general awareness of the gradual depletion of global resources of energy raw materials, the indispensability of these raw materials and the impact of their prices on economic development. The analyses carried out present a new perspective on two key areas for the EU, namely sustainable energy development and sustainable economic development. Tracking changes that take place in these areas is an important source of information that determines the assessment and monitoring of the effectiveness of measures that are being pursued under the Common EU Policy [96].

In the presented research on the assessment of sustainable energy development and sustainable economic development in EU member states and determining their correlations, a method was used that enabled the determination of synthetic measures. These measures, in turn, enabled the assessment, comparison and ranking of EU countries in light of these two areas, as well as finding an answer to the question whether they are in fact correlated.

The study demonstrates that the EU saw significant regional disparities in both sustainable energy development and sustainable economic development in the years 2014–2021.

For both study areas, synthetic measures in the countries that reported the highest values were more than twice as high as among the lowest scorers. Analyzing the dynamics of changes in the values of these measures, it can be observed that the vast majority of EU member states have achieved neither lasting sustainable energy development nor lasting sustainable economic development. In most EU countries, both sustainable energy development and sustainable economic development were below the global EU average. The COVID-19 pandemic certainly had an impact on the decline reported in these two areas and the widening of the gap between the highest and lowest scorers. In 2021, most EU countries recorded the lowest values of the synthetic measures in both study areas. Other studies confirm that the COVID-19 pandemic had a significant impact on the EU's energy policy. Several aspects mentioned in the context of this impact were of key importance for energy policy, including: a decline in energy demand, acceleration of energy transformation, dynamics of energy markets, sustainable energy, and consumer behavior [97]. The pandemic accelerated the energy transition process, shifting attention to long-term sustainable development goals. Many governments introduced additional financial incentives and support programs to promote renewable energy and reduce greenhouse gas emissions.

The conducted research indicates the level of implementation of EU goals in the area of sustainable energy and economic development in EU countries. Based on the results, it can be concluded that the current EU policy has not brought the expected results. Important disparities were observed between EU countries, and most EU countries failed to record significant progress in implementing the sustainable development paradigm which was among the top priorities of the "Europe 2020 Strategy", the EU's long-term socio-economic program. The research also shows that in the EU there is no correlation between sustainable energy development and sustainable economic development. Meanwhile, EU policy assumes that a sustainable energy sector will stimulate economic growth. It is therefore recommended to develop and implement new instruments that will address disparities between countries and accelerate sustainable energy and economic development. In addition, it is noteworthy that the changes introduced in the energy sector have had a positive impact on economic development. At the same time, it is necessary to step up efforts geared towards pro-development activities, at the level of both individual EU countries and the EU as a whole.

The deliberations contained in the article are only a fragment of a broad spectrum of issues forming the collective sustainable development of the EU [98–109]. However, the conclusions drawn from the paper may help to improve policy-making in the EU and increase the territorial cohesion of the EU in the area of both sustainable energy development and sustainable economic development.

Having said that, this study has certain limitations. It relies only on complete sustainable development indices published by Eurostat for the adopted research period. Moreover, we are well aware that not all problems regarding sustainable energy development and sustainable economic development occurring in EU countries have been addressed or discussed to a sufficient extent in this paper. One must note, however, that the selection of variables in an international cross-section is difficult and was dictated primarily by the availability and completeness of statistical data in the Eurostat database. Nevertheless, the article can be a point of reference for new thoughts, deliberations, analyses, as well as for critical scientific discussion.

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