energies

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Is the European Union Making Progress on Energy Decarbonisation While Moving towards Sustainable Development?

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Abstract: Three-quarters of global greenhouse gas emissions come from burning fossil fuels for energy. To confront climate change, the world must move away from fossil fuels and decarbonise its energy systems. In the light of European Union documents, decarbonisation signifies the elimination of CO_2 emissions on account of their harmfulness to the environment. The European Union is planning that by 2030, these emissions will be 40% lower in comparison to 1990. A fundamental query arises here: do the achievements of EU countries give cause for optimism in this regard? The aim of the study is an attempt to determine the tendency of changes concerning energy decarbonisation as well as to distinguish typological groups of bodies (EU countries) with similar dynamics in the researched phenomenon. Trend functions and the distance matrices of the growth rate of the researched phenomenon were used for the dynamic classification. The conducted research confirmed that EU countries indicate spatial differentiation in terms of CO_2 emissions. It is related to the general socio-economic development of countries, their level of industrialisation, the quality of their natural environment, their degree of urbanisation, etc. The most favourable situation, in terms of the analysed phenomenon, i.e., the largest average decrease in CO_2 per capita in the analysed period, was characteristic of Ireland, Greece, and Cyprus. On the other hand, an adverse situation relating to an increase in the indicator occurred in five EU countries, specifically in Luxembourg and Lithuania.

Keywords: sustainable development; energy decarbonisation; reducing CO_2 emissions; energy policy; climate policy; socio-economic development; European Union; taxonomy; trend models; European Green Deal

Citation: Bąk, I.; Barwińska-Małajowicz, A.; Wolska, G.; Walawender, P.; Hydzik, P. Is the European Union Making Progress on Energy Decarbonisation While Moving towards Sustainable Development? *Energies* **2021**, *14*, 3792. https://doi.org/10.3390/en14133792

Academic Editor: Attilio Converti

Received: 2 June 2021
Accepted: 21 June 2021
Published: 24 June 2021

1. Introduction

The belief that action to protect the climate is a necessity is beginning to prevail in an ever-increasing number of countries in the world. Key activities in this area include so-called decarbonisation, which is understood in the light of European Union documents as the elimination of CO_2 emissions on account of their harmfulness to the environment. Decarbonisation of the entire economic system is an ambitious, extremely complex undertaking that requires the coordination of many activities. Providing more energy-efficient and less-emissive methods of management requires government intervention in each of the countries. Yang et al. present the notion of decarbonisation of the economy in the context of the scope of state intervention; they have taken the position that the state should direct its economic policy towards popularising decarbonisation, wherein orientation towards investments in low-carbon technologies is also necessary [1]. Therefore, specific decarbonisation activities implemented by the individual countries are necessary to achieve climate goals. Decarbonisation as a process contributes to the reduction of CO_2 emissions while simultaneously applying innovative solutions in the energy sectors, including the development of energy based on renewable sources and hydrogen energy [2], electromobility [3], etc. These processes are carried out with varying intensity in the individual countries as well as in individual sectors. This is due to many endogenous and exogenous factors as well as the structure of the economy and the specificity of the energy sector, especially the historical determinants of economic changes in the countries of Central and Eastern Europe. The climatic zone in which a given country is located is not without significance. The regionally different intensity of implementation of CO_2 emission reduction processes influences the overall effect achieved by the European Union. Today, many initiatives in the field of decarbonisation are taking place, for example: the European Hydrogen and Fuel Cell Association Hydrogen Europe report entitled "Green Hydrogen for a European Green Deal. A 2 × 40 GW Initiative" [4], which focuses on the advantages of hydrogen and its key role in energy transformation necessary for the deep decarbonisation of national economies; proposals for key changes to the gas sector in Europe launched by the European Commission, i.e., the Hydrogen and Decarbonised Gas Market Package as well as the Methane Strategy, the DecarbEurope initiative launched by the European Copper Institute and involving policy-makers from the realm of politics and industry [5] or for example, at COP24 in Poland. A speech by the Minister of Climate and Environment for the Republic of Poland, M. Kurtyka, emphasised that "climate change is a global challenge and there is no room for an arbitrarily selected local or national policy" [6]. The European Union assumes that in 2030, these emissions will be reduced by 40% in comparison to 1990.

With reference to the issues described above, it should be added that the "Agenda 2030" entitled "Transforming our world: The 2030 Agenda for Sustainable Development" published in 2015 by the United Nations Framework Convention on Climate Change [7] also emphasises the lack of effects of the planned activities towards the use of clean and environmentally friendly technologies and production processes, with the participation of all countries, in accordance with their capabilities. It highlights within it that the global nature of climate change requires the widest possible international cooperation aimed at accelerating the reduction of global greenhouse gas emissions and taking action in relation to adapting to the negative effects of climate change. The convention also asserts that there is a significant gap between the combined effect of the global annual greenhouse gas emission reductions declared by the parties by the year 2020 and the total emissions that would allow the global average temperature increase to be kept below 2 °C or 1.5 °C above pre-industrial levels [7].

Although strategic documents do not directly mention decarbonisation and the reduction of greenhouse gas emissions [7], this issue arises in many publications—among others, those concerning specific sectors of the economy. For instance, Von Stechow et al. draws attention to the side effects of decarbonisation, e.g., as part of energy security [8]. In turn, Sabine Fuss in her monograph "What Next for Sustainable Development? Our Common Future at Thirty" [9] points out that although there is extensive literature on the subject of the side effects of deep decarbonisation strategies on some goals of sustainable development, this issue is not fully recognised. Therefore, more comprehensive analyses are needed covering both the dimension of sustainability as well as a more complete set of indications for the impact of climate change mitigation strategies [9].

Accordingly, when assessing the progress of decarbonisation of the EU economy, it is also necessary to refer to issues related to sustainable development, which in its assumptions comprehensively includes the reduction of CO_2 emissions. Sustainable development treats three pillars as fundamental and interrelated: environment—CO_2 emissions, resource consumption, and waste are particularly taken into account here; economy—primarily energy prices, economic stability, and solidarity as a counterbalance for the sustainable development of the economy; and society—especially security issues, political stability, and solidarity. The above-mentioned pillars of sustainable development demonstrate that the areas included within it constitute the foundation of this concept and that an axiological approach is necessary.

The aim of the research, the results of which are presented in this article, is an attempt to determine the tendency of changes in the energy decarbonisation process and to distinguish typological groups of bodies (EU countries) with similar dynamics in the researched phenomenon. Trend functions and the distance matrices of the growth rate of the researched phenomenon were used for the dynamic classification. The variability of socio-economic phenomena over time, their fluctuations caused by the actions of random factors, including for example, weather conditions, that together with the passage of time, the relationships between individual objects may change as a result. It is expressed by the fact that the distances between the same research objects at specific periods or moments are on different levels. For some objects, it may be a fading of differences in the level of these distances, while for others, it may be the opposite—an increase. It simultaneously signifies that the composition of typological groups during particular units of time (years) may be different. Under these conditions, the correct classification of socio-economic objects should take into account changes and fluctuations occurring over time [10]. Taking into account time in the conducted research is made possible thanks to the use of methods of time-series analysis, the identification of countries where progress in energy decarbonisation has been observed as well as for those in which the situation has not been improving. This allowed the detection of several regularities that cannot be observed through methods that utilise the static approach. Only a comparative analysis conducted over a sufficiently vast period of time allows for an objective observation of the relationship between various objects. This type of approach was used in this study for the first time and thus constitutes a significant contribution by the authors to research related to the dynamic analysis of the similarity of socio-economic bodies (EU countries) as well as fills the existing research gap in this field. Apart from that, the conducted research also allowed filling the research gap, which is to show the effects of decarbonisation of the economy in EU countries as well as present these issues in an axiological aspect.

2. Literature Review

2.1. The Concept of Sustainable Development—Essence and Genesis

A category as important as development is essential in social sciences, especially in relation to theoretical aspects in the context of measuring the phenomenon [11], while at the same time being one of the conditions in the progress of civilisation [10,12,13]. States and international organisations consider development an important mainstream policy point to which specific sectoral policy objectives relate. An unprecedented period in the history of the world of economic growth and the multiplication of the population began in the second half of the twentieth century. Along with socio-economic development, problems arose in the developmental inequalities of individual countries and regions as well as the burdensome pressure of mankind on the environment.

The progressive violent pressure of mankind and the economy on the natural environment brought about a threat to the existence of many species and the emergence of civilisation diseases, which to a large extent resulted from the pollution of the natural environment as well as exceeding the limits of human interference in natural life processes. The consequences of environmental degradation, including the climate, have acquired a social dimension, e.g., through an increase in mortality, occupational, and civilisation diseases, or a deterioration of the quality of life. Unsustainable development caused by social and economic expansion became one of the main problems for humanity at the turn of the 20th and 21st centuries. Reactions to the existing state of affairs, undertaken by the international community, took place at the end of the 1980s (Bruntland Commission, 1987) [14]. In science, the problem of the interdependence between the economy and long-term environmental stability is the basis for determining sustainable development. In 1920, Pigou [15] had already noticed that the discrepancy between marginal costs and private benefits, and marginal costs and social benefits, creates a type of external effect, which is nowadays understood as side effects of transactions or the costs and benefits not included in a given price of goods or services. Pigou postulated a tax that would better reflect the complex costs and benefits in the price. Based on this assumption, Pigou [15], Porter, and van der Linde [16] claimed that environmental pollution is a consequence of the inefficient use of resources, which can be improved through innovation and strict environmental regulations [16]. Porter and Linde claimed that competitive advantage depends on the ability to innovate [17] and that sustainable development policy should take into account the sources of environmental degradation while stimulating economic development [17]. That is, a clean natural environment and its resources, such as water and air, constitute public goods that should be secured by the public sector. Hence, the international community has started to initiate market mechanisms to internalise the total cost of pollution and ensure long-term environmental sustainability; in other words, to ensure sustainable development [14].

The concept of sustainable development modifies to a certain degree the concept of management, indicating that it becomes possible to reconcile human aspirations to achieve a high level of economic development with care for the social and natural environment. Within the framework of sustainable development, it becomes necessary to shape the right proportions between human, economic, and natural capital [18], orientated on balancing the three main areas of human activity, i.e., the economy, society, and the natural environment, in such a way that the development of one of the elements does not pose a threat to the others [19]. One of the most commonly used definitions of sustainable development is the one proposed by the Brundtland Commission [14,20–23], according to which the goal of sustainable development is long-term economic and environmental stability achieved by taking into account economic, environmental, and social problems. The determinant essential for the implementation of long-term sustainable development is intergenerational justice, which is understood as fulfilling the needs of future generations [21,23]. An important factor is the application of the "polluter pays" principle, whereby governments require polluters to bear the cost of their pollution as opposed to imposing these costs on the other participants in social and economic life or the environment [21]. Furthermore, the principle that "in a case of serious threat or irreversible damage the lack of full scientific certainty shall not be a reason to postpone cost-effective measures to prevent environmental degradation" is vital [24]. In an important UN Document, the Rio Declaration, emphasis was placed on the importance of community responsibility for the environment, recognising the fact that every nation must play a role in the issue of sustainable development, with an emphasis on the conditions of developed and developing countries, while at the same time appreciating the future developmental needs of these less developed countries [21,24–26].

It should be noted that developed countries in particular should bear greater responsibility for the resources used and the pressures on the environment. The basic principle of sustainable development is to integrate environmental, social, and economic issues into all aspects of policy making. Therefore, policy making should be integrated [22,23]. The concept of integration distinguishes sustainable development from other forms of policy. It is emphasised that sustainable development requires the integration of economic, environmental and social goals in different sectors in different territories and takes into account different generations. Therefore, sustainable development requires the elimination of the fragmented approach to integrating environmental, social, and economic issues into policy-making processes in an integrated manner. Such activities determine the pursuit of development that is indeed sustainable [14].

2.2. The EU as an Important Player on the International Stage in Terms of Reducing CO_2 Emissions by Decarbonising Energy

Integrating economic, environmental, and social goals requires taking action at the supranational level while taking into account the interests of individual participants, especially states. In Europe, a highly developed community of states is the European Union, in which climate policy has gained importance since the 1990s. The EU is often regarded as the leader in adopting climate policies [27,28] and promoting them externally. The EU was also an influential participant in many climate conferences: 1997 (Kyoto, Japan), 2001 (Marrakesh, Morocco), and 2015 (Paris, France) [29].

The problem of the climatic effects of economic activity, with a particular emphasis on carbon dioxide, was discussed in scientific literature in the 1970s [30]. However, in 1990, the European Council called for the stabilisation of CO_2 emissions by 2000 to the 1990 level [31]. The EU has since adopted a number of regulatory instruments. Less than a year after the Kyoto conference, the so-called "Burden Sharing Agreement" [32] was adopted internally. In addition to illustrating the close link between international dynamics and domestic policy developments, the 1998 burden-sharing agreement also demonstrates that the national policies adopted by member states as part of coordinated action at the EU level are an essential element of the overall EU climate policy [33].

In 2003, the First ETS Directive was adopted [34]. The ETS is a political instrument whose goal is encouraging industrialists to reduce emissions through "carbon pricing" by exploiting market dynamics [35]. That is why, in line with the 'polluter pays' principle mentioned earlier, the ETS rationale is that industry pays for its carbon emissions. In the second half of the first decade of the 21st century, the evolution of internal climate policies continued. At the end of the first decade of the 21st century and in the first years of the decade following, the EU climate policy experienced many crises. Following the Copenhagen Conference (Copenhagen Summit, 2009), the EU's credibility as a world leader in the field of climate was seriously compromised. The most important document, the ETS Directive, had serious flaws, which at that time was accompanied by the climate of discussions about the economic crisis and not about the effects of climate change. As a result, the EU lost momentum in generating new ideas in the global political arena [36]. Despite these issues, the EU prepared its own internal policy framework and formulated the following goals: short-term—the 2020 climate and energy package; medium-term: climate and energy framework until 2030; and long-term—a roadmap to 2050 [29].

In December 2019, the EU adopted the Green Deal. It is a roadmap whose goal was to support the European Union's transition to a climate neutral economy by reducing carbon emissions to 55% by 2030 and achieving carbon neutrality by 2050 [37]. However, the green transition and its financing can only take place if it involves both EU actors and state actors as well as EU citizens who agree to bear the costs and participate in the process, especially within the framework of the announced Climate Pact. Increased solidarity in the green transition towards climate neutrality should be synonymous with the European Green Deal [38].

Taking into account a review of EU policies and global climate and energy agreements, it can be concluded that the EU creates a policy that takes the requirements of sustainable development into consideration by striving for climate neutrality, and one of the fundamental challenges is to reduce CO_2 emissions, which is achieved by decarbonising energy systems [39]. At the same time, it should be noted that the special emphasis placed on climate protection by the EU, a low-carbon economy, or decarbonisation of the economy causes sustainable development to currently be interpreted differently than its original concepts.

3. Materials and Methods

The analysis covered 26 current members of the European Union (except for Malta, for which not all statistical data were available during the period analysed) and Great Britain, which formally just left the European Union in 2021. The study consisted of five stages:

1. Analysis of the CO_2 emissions per capita indicator;
2. Determination of the trend function for the CO_2 emissions per capita indicator in the years 2000–2018 according to the following formulas: Linear trends of the form:

$$\hat{Y}_t = \hat{\alpha}_1 t + \hat{\alpha}_o \quad (1)$$

$$\hat{Y}_t = \hat{\alpha}_1 t + \alpha_2 t^2 + \hat{\alpha}_o \quad (2)$$

$$\hat{Y}_t = \hat{\alpha}_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \hat{\alpha}_o \quad (3)$$

exponential trends of the form:

$$ln\hat{Y}_t = \hat{\beta}_1 t + \hat{\beta}_o \quad (4)$$

$$ln\hat{Y}_t = \hat{\beta}_1 t + \beta_2 t^2 + \hat{\beta}_o \quad (5)$$

$$ln\hat{Y}_t = \hat{\beta}_1 t + \beta_2 t^2 + \beta_3 t^3 + \hat{\beta}_o; \quad (6)$$

3. Preparation of rankings of EU countries based on the regression coefficients of linear and exponential trends;
4. Comparison of the growth rate of the studied phenomenon with the help of a distance measure based on regression coefficients in exponential models:

$$d_{ij} = \frac{\beta_i - \beta_j}{max(\beta_i, \beta_j)}. \quad (7)$$

This measure assumes values from the interval $\langle 0, 1 \rangle$. Smaller values indicate the greater similarity of objects Oi as well as Oj due to the growth rate of the phenomenon under study. This measure can act as the distance between objects. For all pairs of objects, a distance matrix of the rate of change of the phenomenon under study is obtained:

$$D = \begin{bmatrix} 0 & d_{12} & \dots & d_{1N} \\ d_{21} & 0 & \dots & d_{2N} \\ \dots & \dots & \dots & \dots \\ d_{N1} & d_{N2} & \dots & 0 \end{bmatrix}; \quad (8)$$

5 Division of objects into typological groups with similar dynamics of the studied phenomenon, using the distance measure based on regression coefficients in exponential models. The distance-based methods between the compared objects can be broadly classified into hierarchical and non-hierarchical. Hierarchical methods consist in creating a sequence, i.e., a hierarchy. Depending on the method of obtaining the classification sequence, two groups of hierarchical methods stand out: hierarchical clustering methods (called cluster procedures) and hierarchical division methods. The first group of methods is one of the most popular classification methods. They assume that each object is initially a separate cluster, and then, their number is sequentially reduced by combining them into the so-called higher-order groups. The procedure ends when one cluster including all objects of the analysed set is received. The essence of the procedure is to search for "similar" objects among a given set of objects. In the iterative procedure, the "neighbourhood" of the objects (and after connecting them, the "neighbourhood" of clusters) is examined at each step, using an appropriate metric. In all hierarchical methods, it is possible to graphically present the division in the form of the so-called dendrogram (connection trees), which illustrates consecutive connections of clusters of increasingly higher order. The obtained hierarchy allows determination of the mutual position of clusters and objects contained within them. A significant drawback of the procedures of this group is the lack of an obvious stop criterion for determining the number of relatively homogeneous clusters of classes as well as, in some cases, the tendency for clusters in the form of a chain, and thus forming clusters of objects quite distant from each other. The work uses Ward's method, in which the distance between the clusters is the difference between the sums of squared deviations of the distances of individual units from the centre of gravity of the groups to which these points belong [40–42].

Determining the critical value of the distance at which class linkage was interrupted was made using the measure proposed by T. Grabiński [43,44]:

$$q_i = \max_i \left\{ \frac{d_i}{d_{i-1}} \right\} \tag{9}$$

where:

$i = 2,\ 3\ , \ldots,\ n-1$, i = 2, 3, . . . , n−1,

d_i—d_i length of i-this binding (i-that tree branch).

4. Results

Information on the CO_2 emission rate per capita in the years 2000–2018 was collected for the study. On their basis, selected descriptive parameters characterising the distribution of the examined indicator were determined (Table 1). Its average value in the period analysed was slightly fluctuating. Until 2008, it showed an upward trend, and then there was a decrease, but it did not apply to all subsequent years, e.g., slight increases were recorded in 2010, 2012, and 2018. In 2018, compared to 2000, the analysed indicator decreased by 5.68%. The levels of CO_2 emissions per capita in the EU countries are diversified, as evidenced by the high level of the coefficient of variation, ranging from 36.47% in 2011 to 79.63% in 2009. A consequence of the high differentiation is also a very high right-hand asymmetry, which in the case of the indicator being a destimulant, it is unfavourable, as it proves that in most countries, the level of the indicator exceeded the average value for all EU countries surveyed.

Table 1. Selected descriptive parameters for the indicator: CO_2 emissions per capita in the years 2000–2018.

Year	$\bar{x}$	M	Vs	A	Min	Max	R
2000	10.01	9.65	37.01	0.44	3.78	18.37	14.59
2001	10.05	9.37	37.55	0.63	4.04	19.01	14.96
2002	10.32	9.45	37.96	0.78	4.11	20.35	16.24
2003	10.72	9.64	41.43	1.28	4.35	24.58	20.23
2004	10.97	9.39	46.88	1.86	4.49	29.09	24.60
2005	11.08	9.55	48.47	2.27	4.96	31.68	26.72
2006	11.77	9.76	52.00	2.73	5.57	36.83	31.26
2007	11.20	10.14	37.88	1.33	5.39	23.20	17.81
2008	11.99	10.55	72.61	4.27	5.53	53.63	48.11
2009	10.88	9.74	79.63	4.44	4.37	52.96	48.60
2010	11.07	9.72	73.57	4.13	4.41	49.67	45.26
2011	9.92	9.66	36.47	1.28	4.57	20.40	15.83
2012	10.26	8.49	75.25	4.22	4.32	47.09	42.77
2013	9.84	7.99	75.32	4.09	3.84	44.83	40.99
2014	9.49	7.68	72.82	4.05	3.85	42.01	38.16
2015	9.38	7.61	73.08	4.16	3.87	41.90	38.03
2016	9.22	7.63	69.99	4.02	3.81	39.51	35.70
2017	9.33	7.84	68.44	4.02	3.99	39.29	35.31
2018	9.45	8.05	65.94	3.83	4.03	38.20	34.17

Source: Personal calculations.

The values of the CO_2 emissions per capita indicator in the years 2000–2018 were used to determine the trend of changes in the EU. It turned out that the best results in terms of the degree of adjustment to empirical data and the significance of parameter estimates were obtained with the use of first-degree linear and exponential models. These models were used in the dynamic classification.

A measure of the average increment of a taxonomic measure i—this object is the linear trend parameter $\hat{\alpha}_1$, while the measure of the average rate of change is the average rate of change parameter $\hat{\beta}_1$. Estimation results of these parameters are presented in Table 2.

Table 2. Evaluation of the parameters of the trend function of the CO_2 per capita emissions indicator in the years 2000–2018: the average absolute gain $(\hat{\alpha}_1)$ and the average rate of change $(\hat{\beta}_1)$.

Country	$\hat{\alpha}_1$	$\hat{\beta}_1$	Average Rate of Change w%
Austria	−0.1256	−0.0109	−1.085
Belgium	−0.2812	−0.0161	−1.599
Bulgaria	−0.0257	−0.0044	−0.436
Croatia	−0.0637	−0.0110	−1.099
Cyprus	−0.2544	−0.0307	−3.022
Czechia	−0.1310	−0.0122	−1.216
Denmark	−0.2546	−0.0238	−2.351
Estonia	−0.0171	−0.0012	−0.117
Finland	−0.2639	−0.0189	−1.871
France	−0.1455	−0.0185	−1.833
Germany	−0.1829	−0.0154	−1.527
Greece	−0.2476	−0.0325	−3.200
Hungary	−0.0722	−0.0101	−1.009
Ireland	−0.4996	−0.0415	−4.062
Italy	−0.1972	−0.0220	−2.177
Latvia	0.0440	0.0078	0.783
Lithuania	0.1319	0.0204	2.065
Luxembourg	1.2685	0.0425	4.337
Netherlands	−0.0879	−0.0083	−0.828
Poland	0.0215	0.0028	0.281
Portugal	−0.1676	−0.0259	−2.556
Romania	−0.0303	−0.0068	−0.673
Slovakia	0.0195	0.0023	0.233
Slovenia	−0.0485	−0.0053	−0.524
Spain	−0.1946	−0.0265	−2.613
Sweden	−0.1541	−0.0186	−1.845
United Kingdom	−0.2617	−0.0259	−2.555

Source: Personal calculations.

The parameters of the linear trend and the exponential trend were used to construct the rankings, but the trend parameters were transformed earlier in such a way that the obtained synthetic measures were within the range [0,1]. Transformations were applied for this purpose:

$$\alpha'_i = \alpha_i - \underset{i}{min}\alpha_i.\ \alpha''_i = \frac{\alpha'_i}{\underset{i}{max}\alpha'_i},\ i = 1, \ldots,\ n \tag{10}$$

$$\beta'_i = \beta_i - \min_i \beta_i.\ \beta''_i = \frac{\beta'_i}{\max_i \beta'_i},\ i = 1, \ldots, n. \quad (11)$$

The ranking of EU countries created on this basis is presented in Table 3. The higher the country's position in the ranking, the better its situation related to the CO_2 emissions per capita indicator. As can be seen from the table, where countries are ordered according to the average increase of the taxonomic measure $\hat{\alpha}_1$ as well as the average rate of change $\hat{\beta}_1$ there is no significant difference, the positions of the member states overlap or slightly differ in many cases. First place was taken by Ireland, where CO_2 emissions per capita decreased by an average of 4.06% year after year (comparing Tables 2 and 3). Greece and Cyprus also recorded an average decline of more than 3%. The worst situation could be found in Luxembourg and Lithuania. The dynamic analysis demonstrates that in these countries, during the analysed period, CO_2 emissions per capita increased on average by 4.34% and 2.06%, respectively, which placed these countries in the 27th and 26th positions, both in terms of absolute gain as well as in average rate of change.

Table 3. Ranking of EU countries based on the parameters of linear and exponential trends.

Based on a Linear Trend			**Based on an Exponential Trend**		
Country	$\hat{\alpha}_1$	Position in the ranking	Country	$\hat{\beta}_1$	Position in the ranking
Ireland	0.0000	1	Ireland	0.0000	1
Belgium	0.1235	2	Greece	0.1026	2
Finland	0.1333	3	Cyprus	0.1238	3
United Kingdom	0.1345	4	Spain	0.1725	4
Denmark	0.1386	5	Portugal	0.1793	5
Cyprus	0.1387	6	United Kingdom	0.1794	6
Greece	0.1425	7	Denmark	0.2037	7
Italy	0.171	8	Italy	0.2244	8
Spain	0.1725	9	Finland	0.2609	9
Germany	0.1791	10	Sweden	0.264	10
Portugal	0.1878	11	France	0.2654	11
Sweden	0.1954	12	Belgium	0.2932	12
France	0.2003	13	Germany	0.3018	13
Czechia	0.2085	14	Czechia	0.3389	14
Austria	0.2116	15	Croatia	0.3528	15
Netherlands	0.2329	16	Austria	0.3545	16
Hungary	0.2417	17	Hungary	0.3635	17
Croatia	0.2465	18	Netherlands	0.3851	18
Slovenia	0.2551	19	Romania	0.4035	19
Romania	0.2655	20	Slovenia	0.4212	20
Bulgaria	0.268	21	Bulgaria	0.4318	21
Estonia	0.2729	22	Estonia	0.4697	22
Slovakia	0.2936	23	Slovakia	0.5113	23
Poland	0.2947	24	Poland	0.5171	24
Latvia	0.3074	25	Latvia	0.5769	25
Lithuania	0.3572	26	Lithuania	0.7295	26
Luxembourg	1.0000	27	Luxembourg	1.0000	27

Source: Personal Calculations.

To compare the rate of growth of the indicator 'CO_2 emissions per capita in the years 2000–2018', the distance measure was used according to Formula (7), on the basis of which the distance matrix of the rate of change of the studied phenomenon was determined for all objects (Formula (8)). This matrix was used to prepare a dendrogram for the hierarchical classification of administrative districts using Ward's method (Figure 1). The vertical line marks the distances of bonds that allow distinguishing the division of EU countries into four clusters:

Cluster I: Greece, Cyprus, Spain, Portugal, United Kingdom, Denmark, Italy,

Cluster II: Finland, Sweden, France, Belgium, Germany, Czechia, Croatia, Austria, Hungary, Netherlands, Romania, Slovenia, Bulgaria,

Cluster III: Ireland,

Cluster IV: Estonia, Slovakia, Poland, Lithuania, Latvia, Luxembourg.

Cluster I applies to countries where, from year to year, the level of CO_2 emissions per capita in the analysed years displayed a downward trend, by at least 2%. The most numerous is Cluster II, focusing on countries also with a downward trend in the analysed indicator but much lower than in Group I (an average decline from 1.871% for Finland to 0.436% for Bulgaria). Ireland found itself in the one-piece third cluster, which is characterised by the highest decrease in the indicator level. In 2014, its level was 14.77%, while in 2018–8.59%, which signifies a decrease by almost 42%, and from year to year, it amounted to an average of 4.062%. In the final, fourth cluster, there were countries with unfavourable values for the carbon dioxide emission indicator, which showed a tendency to increase from year to year; except for Estonia, where on average, a very slight decline was recorded from year to year (about 0.117%).

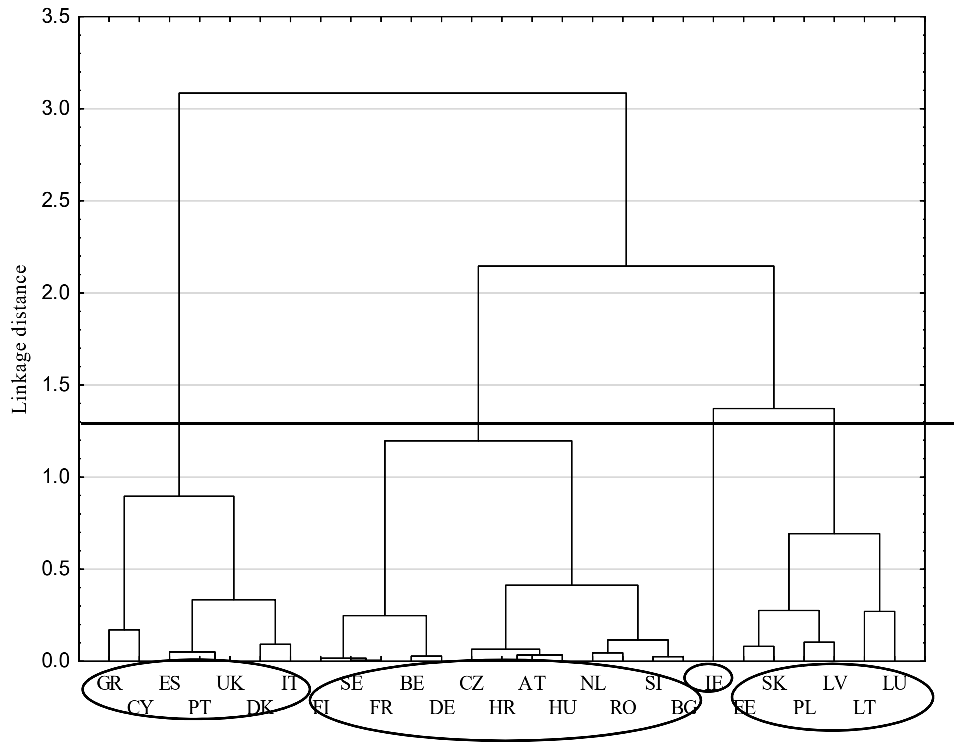

Figure 1. The results of Ward's method. Source: personal elaboration.

5. Discussion

An important factor having an influence on the reduction of CO_2 emissions is the implementation of climate policy by the individual countries. Internally, the EU has developed the most advanced and comprehensive regulatory framework in the world [29]. However, in the European Union, reigning signifies a discrepancy in discourse on climate change; there is the division of EU countries into a group of member states that support a strong climate policy and a coalition of countries reluctant to dynamically reduce CO_2 emissions [36,45]. The former group seems to be following the ecological modernisation paradigm; they consider a strong climate policy to be beneficial to economic growth, and countries such as Denmark, Estonia, Finland, France, Germany, Sweden, and Slovenia are included in this group. The latter group of countries reluctant to significantly reduce CO2 emissions consists mainly of Central and Eastern European member states, with their national energy systems heavily dependent on coal. Poland plays a leading role in this coalition, primarily arguing that an ambitious climate policy is detrimental to economic growth [46].

It should also be noted that both Poland and other countries of the former Eastern Bloc (as opposed to the West), in the year to which the emissions reduction target corresponds, for instance 1990, were in a deep recession and a decline in industrial production, and they also were entering a period of dynamic socio-economic and political changes. At the threshold of the 1990s, the average annual change in GDP in the Visegrad group countries amounted to −5.7%, and in the Baltic countries −10.8% [47]. This division between EU Member States became particularly visible in the context of the financial and economic crisis of 2008 [45]. Divisions are also visible between EU institutions, where appointments in the climate field, for example, the Directorate-General for Climate Action and the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs often differ [48,49]. Encompassing the described issues from a global perspective, it should be noted that countries that have leadership status due to their economic strength in the world also contribute to the reduction of CO_2 emissions. The United States plans to reduce emissions by 50–52% by 2030 and achieve climate neutrality by 2050. China has presented a five-year plan according to which CO_2 emissions are expected to peak in 2030 and climate neutrality is expected to be achieved by 2060. China assures that coal consumption and the development of coal-fired power plants in their country will be limited. Currently, China emits over 10 gigatons of carbon dioxide annually and is undeniably the world leader in emissions of this greenhouse gas (GHG). It is worth emphasising that so far, they emit almost twice as much carbon dioxide per year as the second largest polluters in this ranking—the United States (just over 5 gigatons of carbon dioxide per year), almost four times more than India (third place—2.6 gigatons of CO_2), and more than six times more than Russia (fourth place—1.7 gigatons of CO_2) [50].

Coming back to EU solutions, it should be emphasised that coal has long been superseded by the EU's energy and climate policy mechanisms, as evidenced by the rapidly rising prices of CO_2 emission allowances. At present, they have exceeded the price of EUR 40 per tonne, and forecasts indicate that in this decade, they will reach EUR 70 [51]. Even in 1990, among the EU countries (28), there were nine countries that based their energy balance on solid fuels (i.e., at least 50% of the energy produced came from this source). It was, among others, Poland with a coal share at a level of 96%, Denmark (91%), and Malta (56%). Over the next 28 years (1990–2018), most of them marginalised their importance. In 2007, only six countries based their energy generation system on solid fuels. In 2018, there were only two countries: Poland (77%) and Estonia (76%). Only in Croatia in the last 28 years has there been a meaningful increase of this source in the balance books by 3.7%, to 11%.

An example of activities indicating a gradual departure from solid fuels and a tightening of this process in the EU in the 21st century is a number of initiatives undertaken by governments and private entities. Taking into account the aspect of economic impact, France in this field has announced that it will no longer provide financial support to coal-fired power plants if they do not use environmentally friendly CCS technology [52]. At the same time, the largest EU energy companies have signed an agreement in which they have declared that they would not invest in the construction of new coal-fired installations. Scandinavian countries have made one of the most radical declarations in the EU regarding distancing themselves from solid fuels. The Swedes and Finns have declared that these processes will be completed by 2045 and 2029, respectively [53]. However, in Germany, the issue of switching from coal was highly controversial. Still, in 2015, the German Ministry of the Environment, fearing a public reaction, withdrew from the earlier plan to abandon coal within 20 years [54]. However, in 2016, a rehashed project anticipated a departure from solid fuels by 2050, from nuclear by 2022, the share of renewable energy sources (RES) at a level of 75% in 2030 in all generated energy, and a decrease in greenhouse gas emissions by 55% by 2030 and about 80–95% by 2050 [55]. In 2018, the strategy for changes to and development of the energy sector in Germany determined that the share of renewable energy sources was to be increased in 2030. The deadline for the elimination of coal as an energy source was also set for 2038 [56]. The initiative to accelerate this process was presented by Commerzbank, which is the second largest banking institution in Germany. The bank announced that it would not finance new coal mines and power plants, and from 2021, it would verify its business partners in terms of energy consumption sources and only cooperate with those for which coal is responsible for no more than 30% of energy consumption [57].

It is noteworthy that in 2020, there were 276 coal-fired power plants operating in the EU, including 110 using lignite coal and 166 using bituminous coal. More than half (63%) of all facilities were located in three countries: Germany, Poland, and Czechia. The largest power plants in terms of installed capacity are lignite-fired power plants in Bełchatów (5.030 MW), Grevenbroich-Neutrach (Germany, 4.424 MW), Niederaussem (Germany, 3.676 MW), and Jaenschwalde (Germany, 3.210 MW); while there is also a bituminous-fired power plant in Kozienice (3.994 MW) and both a lignite-fired and a bituminous-fired power plant in Opole (3.332 MW). Beyond that, there were other additional facilities among the twenty largest installations: six in Germany and one in Poland. In 2020, there were only three installations under construction or recently completed, including two for bituminous coal in Poland and Germany and one for lignite coal in Greece. It should be emphasised that the intensive decline in the importance of fossil fuels in the EU took place despite the high hopes placed on modern coal technologies. The EU has established the NER300 program, consisting of the selection of several dozen projects implementing innovative technologies by the European Investment Bank, among others, CCS, and financing half of their costs. In the first phase of the implementation of this program, none of the CCS projects received support from their national government, and no installation using this technology was ever constructed [58].

This approach has raised concerns, especially as in their analyses, both the EU and independent organisations perceive the use of CCS technology as one of the most important measures to reduce greenhouse gas emissions [59]. Europe is decidedly inferior to other regions of the world in the use of this technology. In 2015, only two advanced installations could be found (both in Norway and thus outside EU borders) [60]. In 2019, the situation improved slightly, and eight installations started operating within the EU: six in the UK (then part of the EU), and one each in Ireland and the Netherlands. The European Commission and the European Court of Auditors, independently of each other, issued an opinion that the investments undertaken were not positive, both technically and economically, and that the actions taken by the EU, unfortunately, did not lead to the use of CCS technology on a commercial scale [61]. In order to accelerate this process, the European Commission created a fund for "economically weaker" countries, i.e., those whose GDP is less than 60% of the average level in the EU. Appropriations from this fund are allocated to investments in the energy sector. Funds from the sale of ETS allowances from the reserve pool are proposed as a source of financing. According to a previous algorithm, 90% of the auction pool is to be distributed; the remaining 10% will be allocated to countries with GDP per capita not exceeding 90% of the EU average. The EU also allowed for the allocation of free allowances to the energy sector of no more than 40% of the auction pool in countries with GDP per capita less than 60% of the EU average. The process of granting them is controlled by EU institutions. Restrictions regarding energy markets were introduced as well. In order to deepen their integration, it was decided that in 2020, at least 10% of the cross-border capacity calculated on the basis of the capacity of the national power system should be achieved [62].

Unfortunately, the scientific consensus, as well as EU documents on climate crisis and biodiversity loss, does not translate into social consensus. The social aspect (also included in the assumptions of sustainable development) has been extremely neglected, even though it is important for society to understand why decarbonisation of the economy is important. This was confirmed by Fieschi in a report published in March 2021 [63]. This is the first development of a project aimed at identifying the hidden social and political risks related to climate and environmental policy. A similar opinion is expressed by Bendyk, who states that the reason for concern is the lack of social consensus on environmental issues. In his opinion, the promoters of ecoclimatic policy pay too much attention to surveys showing that the state of social awareness is changing and both awareness of threats and the readiness to take actions to reduce emissions and protect the environment is growing [64].

Research carried out by Obs'COP 2020 at the end of 2020 by Ipsos for the French energy company EDF in 30 countries of the world inhabited by two-thirds of the Earth's population indicates that 60% of respondents have increased their environmental awareness, while 62% are convinced that man's impact on the environment had an effect on the outbreak of the pandemic. Thus, the COVID-19 pandemic did not invalidate people's awareness of such challenges as the climate catastrophe. However, the health crisis and its consequences have changed social priorities, as clearly demonstrated by the same Obs'COP research. On a list of important matters, the environment found itself in sixth place, from 39% of the recommendations; earlier respondents indicated the problems of everyday life: the coronavirus—59%, the rising costs of living—47%, unemployment—45%, poverty and inequality—45%, and the state of health care—43%. This distribution reminds us of the catchphrase of the "yellow vests" about the end of the world and the end of the month, which in turn means that it is the vision of the end of the month that will be a stronger political argument than the prospect of fast and unfavourable climate change. This proves that the declared increase in consciousness does not keep up with the increase in knowledge. Of course, the EU, the USA, and NATO want to achieve climate neutrality in 2050, but, for example, when asked if they have ever heard about climate neutrality, half of Poles and 39% of the French responded negatively; while only 11% of Poles and 20% of the French can explain what is behind this catchphrase. The others had little knowledge on this subject [65]. This ignorance is the space for cultivating viable policies and a game of interests. Experts from the European Council on Foreign Relations (ECFR) draw special attention to this in their unpublished report on threats to climate policy in the EU [66]. In many countries, this may lead to a situation in which economic lobbies related to sectors at risk of change will resist, multiply analyses, demonstrating that an excessively fast eco-transformation means a loss of competitiveness and is economically very unprofitable.

By continuing to burn fossil fuels, future generations will have to deal with the enormous effects of climate change. In Europe, the persistent support of coal has ceased to be an economic argument [67]. The European Commission (EC) noticed that climate action must simultaneously be multi-vector and involve actions in many areas. Analysing the different situations of individual countries (e.g., a high degree of dependence on coal), the European Commission does not require member states to completely abandon the energy policy pursued so far, e.g., burning coal in power plants, but it sets conditions that question the legitimacy of such actions. It should be mentioned that the "greatest enemies of the climate" are the raw materials with the highest individual CO_2 emissions: lignite coal—101.2 kg CO_2/GJ, bituminous coal—94.6 kg CO_2/GJ, crude petroleum—74.07 kg CO_2/GJ and natural gas—56.1 kg CO_2/GJ [68]. The subject of Carbon Capture and Storage (CCS)—the technology of capturing and geologically storing CO_2—which reduces the amount of gas emitted to the atmosphere was undertaken as part of Directive 2009/31/EC. There is a plan to launch ten to twelve entities in Europe that use this technology [69].

Research on discourse related to the European Green Deal carried out, inter alia, on the internet indicates that the European Commission primarily communicates with itself and with a small group of experts from the world of think tanks and the media. As a result, Brussels accounts for as much as 25% of movement related to the European Green Deal and, for example, Poland accounts for only 1.8%. It is no better in Finland, Greece, or Portugal [64]. This unfortunately provides ideal material for politicians who specialise in governing ignorance and fear. As a result, climate activists are increasingly radicalising their demands and resorting to more and more spectacular forms of action, not to mention the Extinction Rebellion protests [70]. Moreover, what seems to be dangerous for humanity is that the current democratic system is increasingly criticised as being too slow and inadequate for the demands of our time.

Delreux and Ohler claimed that the measures taken have led to a reduction in EU greenhouse gas emissions yet will not be sufficient to meet the EU's long-term goals, requiring a major overhaul of some of the EU's underlying policies in sectors such as energy production, transport, agriculture, and industry [29].

6. Conclusions

There exists a significant diversity of the examined objects in relation to the measures that characterise them. Different groups of countries are characterised by a different pace of CO2 emission reduction. Ireland is the leader in this respect. Tobin [71] pointed out that this country is one of the countries that implement their goals of an ambitious climate policy. On the other hand, works [72] indicate Ireland as the second country after GB in achieving energy and environmental efficiency, taking into account the context of economic growth. Countries with significant emission reductions (right after Ireland) are Greece, Cyprus, Spain, Portugal, the United Kingdom, Denmark, and Italy. Note that these are countries geographically characterised by a coastal location, with a relatively high share of the coastline in the length of their border, and characterised by mild climatic conditions. Subsequent countries distinguished by the research are predominantly located in Europe and are countries with relatively good climatic conditions (with the exception of the Scandinavian countries and Czechia). These countries have also made progress in reducing emissions. Conversely, Estonia, Slovakia, Poland, Lithuania, Latvia, and Luxembourg are mostly characterised by unfavourable values of CO_2 emissions and additionally (with the exception of Luxembourg) are geographically located (among the analysed countries) mostly to the northeast. There are much harsher climatic conditions there than in most of the countries surveyed [73]. An assessment of the relationship between the exponential trend parameter of the emission reduction model (Table 3) and the average annual air temperature for a country (or capital city) indicates that the higher the temperature, the better the results a given country has achieved in reducing CO_2 (lower parameters of the exponential trend) (R Spearman = −0.45, p = 0.017). Furthermore, there is a correlation that the higher the position of a given country in the ranking (Table 3), the higher the average air temperature (R Spearman = 0.57, p = 0.003).

It should be noted that Luxembourg is a territorially small country where important transport routes intersect. The study [74] noted that the transport sector is of great significance for the level of CO_2 emissions, and in 2015, the road transport sector was one of the main sources of the total emissions of gases harmful to the climate, amounting to about 55%. One of the explanations for this trend may be its location in the heart of the main transport routes of Western Europe. Luxembourg is one of the focal points of international road traffic, and therefore, it has traditionally been characterised by heavy transit traffic for both goods (freight) and passengers (tourists on their way to or from southern Europe) [75].

However, despite the downward trend in most EU countries, the indicators for CO_2 emissions are still extremely high. This indicates the need to take effective measures to protect the environment and its rational shaping. Research on environmental issues requires not only a large amount of data but also a proper classification of issues. In a proper diagnosis of the state of the environment, methods of ordering and classification are used, thanks to which it is possible to determine the diversity of objects and to select homogeneous typological groups in terms of the analysed phenomenon.

Furthermore, the undertaken research proved that the consequences of extreme climate phenomena and social revolts are mainly caused by the extremely slow process of decarbonisation of the EU economy. These analyses also demonstrate that it is necessary to exit the linear economy as quickly as possible, as this model has many disadvantages throughout the process of generating electricity, starting from the extraction of raw materials until their recycling. It has been shown that solutions to accelerate decarbonisation in the era of a pandemic do not have a solid theoretical background and that they require the formation of an economic theory based on values, knowledge, social awareness, political will, and the rationalisation of economic policy.

The shaping of contemporary climate policy by the European Union in the field of decarbonisation undoubtedly requires in-depth research. In their specificity, it is most important that the obtained results—analysed on theoretical grounds—have a specific pragmatic and application transposition. Considering that each country has to face individual challenges resulting from specific historical, economic, and social conditions, great cognitive importance should be attributed to research aimed at identifying and analysing these conditions and an international comparative analysis of the results obtained in such research area including the following:

- The implementation of costly, low-emission processes by industrial producers in the context of weakening their competitive advantage over other market entities that have not decided to introduce similar changes;
- The ability of individual countries to introduce decarbonisation-friendly solutions (e.g., regarding changes in demand that can help prevent CO_2 emissions that arise from the production of industrial goods) or to expand the use of alternative fuels (such as hydrogen, biomass, and electricity) and utilising the process of capture and storage;
- The technical conditions and reasons that make it difficult for individual EU member states to reduce CO_2 emissions during industrial production.

Considering progressive changes in the climate as well as the different approaches to the issue of energy decarbonisation by individual countries, attention should be paid to the necessity of continuing the undertaken research, especially in the aspect of monitoring the progress of climate and energy policy and their application to decision making within the framework of inter-state agreements. The use of research techniques adequate to the problem, especially taxonomic and econometric, should be of particular importance for a correct diagnosis and prognosis, and the review of national policies should take into account these studies. Scientific research should also take into account the objective limitations of adapting to generally accepted climate and energy restrictions resulting from the endogenous potentials of individual regions, states, and international organisations. The obtained conclusions from scientific research can be taken advantage of, among others, by decision makers, e.g., when constructing negotiating positions.

Author Contributions: Conceptualization, I.B.; methodology, I.B.; software, I.B.; validation, I.B., A.B.-M., G.W., P.W. and P.H.; formal analysis, I.B. and A.B.-M.; investigation, I.B., A.B.-M., G.W., P.W. and P.H.; resources: I.B., A.B.-M., G.W., P.W. and P.H.; data curation, I.B., A.B.-M., G.W., P.W. and P.H.; writing—original draft preparation, I.B. and A.B.-M.; writing—review and editing, I.B., A.B.-M., G.W., P.W. and P.H.; visualization, I.B.; supervision, I.B. and A.B.-M.; project administration, I.B., A.B.-M., G.W., P.W. and P.H.; funding acquisition, I.B., A.B.-M., G.W., P.W. and P.H. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was partially funded by, West Pomeranian University of Technology, Poland; University of Rzeszów, Poland, University of Nicolaus Copernicus in Toruń, Poland, Pedagogical University of Cracow, Poand; Rzeszów University of Technology, Poland.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Source data is available from Eurostat database at https://ec.europa.eu/eurostat/data/database (accessed on 2 May 2021), https://pl.climate-data.org/europa/ (accessed on 21 May 2021).

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

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