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Assessment of Impact of Use of Renewable Energy Sources on Level of Energy Poverty in EU Countries

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Abstract: The share of renewable energy sources (RES) in the global energy system is systematically increasing, making them the most important element of the energy transformation. Their use enables rational management of limited resources, reduction of environmental pollution, and has a significant inhibitory effect on energy poverty by improving energy efficiency. The aim of this article is to assess the impact of the use of renewable energy on the level of energy poverty in the European Union countries in 2010, 2015, and 2022. A taxonomic measure of development based on the Weber median was used to examine the relationship between the results achieved by individual EU member states in terms of the impact of the use of renewable energy on the level of energy poverty. The research results clearly indicate the existence of disproportions between the countries of the "old" EU and the countries that joined it in 2004 and later. These disproportions concern both the use of energy obtained from renewable sources and energy poverty. In the countries of the "old" Union, a positive moderate relationship was identified between the use of renewable energy and energy poverty, which means that a higher share of the use of energy from renewable sources in these countries reduces energy poverty. In the countries of the "new" Union, however, this relationship was very weak (2010) or non-existent. Since the renewable energy sector is subject to government policy and regulations, the results presented in this paper should be of interest to decision-makers. A stable, long-term policy should provide an appropriate investment climate that provides support for renewable energy projects and reduces the level of energy poverty.

Keywords: renewable energy sources; energy poverty; European Union; Weber median

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1. Introduction

The main reasons for the ongoing process of energy transformation in the global economy are technological development and the growing ecological awareness of societies striving to preserve the Earth's natural environment for future generations [1,2].

According to the Eurostat definition, renewable energy sources are those that are naturally replenished. They are divided into two basic groups: non-combustible (hydropower; tide, wave, ocean energy; geothermal energy; wind energy; solar energy; ambient heat (heat pumps)) and combustible renewables (biofuels; renewable municipal waste) [3]. Renewable energy sources can be a solution to the problem of waste discharged into the environment and its reuse in industrial cycles. This enables rational use of limited resources, reduction of environmental pollution, and reduction of poverty [4]. According to Zhao et al. [5], renewable energy affects the level of global energy poverty by improving energy efficiency. The development of the green energy industry creates new jobs and contributes to economic growth. In many cases, the use of renewable energy sources leads to significant energy savings [6,7]. Rational management of natural resources, including the use of energy from renewable sources, is in line with the principles of sustainable development [8]. Sustainable energy is crucial for the success of the 2030 agenda [9]. The global energy goal 7 (SDG 7) [10] includes three key goals: ensuring affordable, reliable, and universal access to modern energy services; significantly increasing the share of renewable energy in the global energy mix; and doubling the global pace of improving energy efficiency.

In turn, energy poverty, in accordance with the Social Climate Fund Regulation [11] and the Energy Efficiency Directive [12], is defined as "the lack of access by a household to basic energy services that provide a basic and decent standard of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances, in the relevant national context, applicable social and other relevant policies, caused by a combination of factors including, among others, lack of affordability, insufficient disposable income, high energy expenditure, and low energy efficiency of homes".

According to estimates by the International Energy Agency, from 1.3 to 2.6 billion people worldwide experience energy poverty, suffering from its numerous negative consequences for the social, economic, and environmental sectors [13]. Energy poverty is a problem that affects all EU Member States to varying degrees [14] and is a growing concern about unequal access to and consumption of energy between affluent and low-income communities [15].

The aim of the article is to assess the impact of the degree of use of renewable energy sources on the level of energy poverty in the EU countries in 2010, 2015, and 2022, taking into account the division into "old" and "new" countries, i.e., those that joined the EU in 2004 and later. The use of such division in the study can be considered an added value of the article, because in previous studies of this type, the focus was primarily on the countries of the "old" Union [16,17], or on the "new" countries [18–20], or the studies concerned all EU countries [21,22]. The authors' approach fills the research gap in this area. Moreover, the assessment of the relationships between the analyzed phenomena is a significant novelty of this work and fits into the broad discussion on the use of renewable energy from sources and its impact on society and the economy. The differences in the impact of the use of renewable energy sources on energy poverty between the "new" and "old" Member States also positively distinguish the authors' research from other studies.

It is worth emphasizing that due to the available data on variables characterizing the use of energy from renewable sources and energy poverty, this study was limited to households, i.e., it omitted the business sector, which has access to energy from renewable sources and constitutes a significant consumer sector.

The synthetic taxonomic measure based on the Weber median was used to study the relationships between two analyzed phenomena—the use of renewable energy and energy poverty. Application of this method to classify objects allows for eliminating the interference caused by outlier (atypical) observations. This is particularly important in the case of such a politically and economically diverse structure as the European Union.

The structure of this article includes six parts. Section 1 (Introduction) presents the main objective of the work and explains the authors' main motivations for conducting research on the impact of renewable energy on energy poverty. Section 2 (Literature review) is related to the research topic that is made. Section 3 presents two sets of diagnostic features used in this study and the research procedure used in the work. The article ends with a presentation of the research results (Section 4), a discussion (Section 5), and conclusions (Section 6).

2. Literature Review

Fossil fuels are created from organic matter as a result of biochemical and thermal processes and contain chemical energy, which is released during combustion along with various pollutants. Therefore, there is a need to obtain energy in an environmentally friendly way. In this situation, the only rational alternative to fossil fuels is renewable energy sources [23]. Switching to renewable energy sources such as solar, wind, and water energy significantly reduces the emission of greenhouse gases and other air pollutants compared to traditional fossil fuels. This can lead to improved air quality, reduced respiratory diseases, and a healthier environment [24]. In addition, renewable energy can provide two-thirds of the total global energy demand and contribute to the reduction of greenhouse gas emissions, which is needed to limit the average increase in global surface temperature below 2 °C by 2050 [25]. The inexhaustibility, universality, and availability of renewable energy resources, as well as effectively implemented energy policy, encourage their increasing use in energy production in the world, including in the countries of the European Union [26]. It is estimated that by 2050 solar and wind energy will provide more than 95% of energy, and the corresponding expenditure will decrease from EUR 54/MWh in 2015 to EUR 53/MWh in 2050 [27].

According to Amer and Daim [28], renewable energy resources such as wind, sun, and biomass can also be useful tools for the electrification of remote locations, as they could generate electricity for people living in remote and off-grid areas, which would help raise the standard of living of the population and contribute to the development of the regional economy. Investments in renewable energy can become a new stimulus for economic growth, increasing national income, improving the trade balance, developing industry, increasing employment, and also reducing energy poverty.

Energy poverty first entered the vocabulary of the EU institutions in the process of preparing the Third Energy Package, when political action in the European Parliament led to the inclusion of the issue of energy poverty in Directives 2009/72/EC and 2009/73/EC of the European Parliament and of the Council "concerning common rules for the internal market in electricity and natural gas supply" [29].

According to Doukas and Marinakis [13], energy poverty is caused by the interaction of three main factors, namely: low income, high energy demand (due to inefficient housing construction), and high energy prices. Biernat-Jarka et al. [14] share a similar opinion, emphasizing the role of investments in renewable energy sources, which can have a positive impact on reducing the scale of energy poverty.

It is difficult to provide a definition of energy poverty that is broad enough to encompass all these factors, especially considering the energy problems in developing countries [30]. As mentioned in the Introduction, energy poverty is a situation in which households do not have sufficient access to modern energy services or cannot afford to heat their homes and meet other basic energy needs, such as lighting, cooking, or water heating [31]. This situation can be caused by various factors, such as low income, high energy prices, and inefficient or outdated energy equipment and buildings [20]. According to the International Energy Agency (IEA), energy poverty is the lack of electricity, clean fuel, and energy facilities in a country and a high dependence of households on conventional fuels. The definition may also vary depending on the level of development of countries. In developing countries, the concept of energy poverty is accepted as the lack of access to modern energy services, while in some developed countries it is defined as the costs of energy consumption that negatively affect households for reasons such as high energy costs, low household income, and inefficient energy use [32].

The problem of energy poverty is not limited to developing countries but increasingly also affects developed countries, including Europe [33–35]. It is estimated that in Europe between 50 and 125 million people live in energy poverty [20]. However, the majority of people affected by poverty live in rural areas of Sub-Saharan Africa and South Asia [36]. Banerjee et al.'s [37] research conducted among 50 developing countries showed that lower energy poverty in these countries is associated with better health and educational outcomes. However, lack of access to electricity remains a serious obstacle to achieving greater economic development.

One of the options to solve the problem of energy poverty is to increase the use of renewable energy sources. Tutak and Brodny [1] examined the use of renewable energy in the economic sector in the EU-27, EU-14, and EU-13 countries and found that the use of renewable energy has a positive impact on economic growth, reduction of greenhouse gas emissions, and the use of conventional energy. Moreover, it also provides an opportunity for greater energy independence and the possibility of energy production for countries without conventional energy resources. Nasir et al. [38] found that environmental tax policies affect energy consumption and energy poverty. Halkos and Gkampoura [39], using panel data from 28 European countries for the period 2004–2019 and static and dynamic regression models, showed that GDP per capita and fossil fuels are inversely related to energy poverty conditions.

Simionescu et al. [21] studied energy poverty (arrears of utility bills) in the EU from 2003 to 2021. In 2021, almost 7% of the population could not heat their homes adequately (Eurostat). The most affected European countries included Bulgaria, Cyprus, and Greece, but also Spain and Portugal, and even the Baltic States (Lithuania and Estonia). Patents and renewable energy consumption per person contributed to the increase in arrears of utility bills. On the other hand, foreign direct investment and energy efficiency contributed to the reduction of these arrears.

The profound implications of energy poverty for quality of life worldwide have led to the development of a wide range of indicators to measure it. There is no consensus on a standardized method for measuring poverty [40]. It is a major challenge that is difficult to quantify, monitor, and effectively address through policy measures. There is no universally accepted measure of energy poverty in developed countries. However, commonly used measures include household expenditure or subjective assessments of energy availability.

Energy poverty is becoming increasingly visible in EU policies within the framework of energy efficiency and economic decarbonization. In particular, initiatives such as Fit-for-55 aim to adopt a 55% emission reduction by 2030 and achieve climate neutrality by 2050. It is therefore not surprising that an increasing number of publications on the issues discussed above have appeared. The Web of Science (WoS) database identified 8385 publications on renewable energy sources since 1992 and 1480 publications that addressed energy poverty and started to appear in the database since 2007. Only 107 publications indexed in WoS contained the phrases "renewable energy sources" and "energy poverty" in their titles, abstracts, or keywords. The evolution of the number of publications and citations of these works in the period under review is presented in Figure 1.

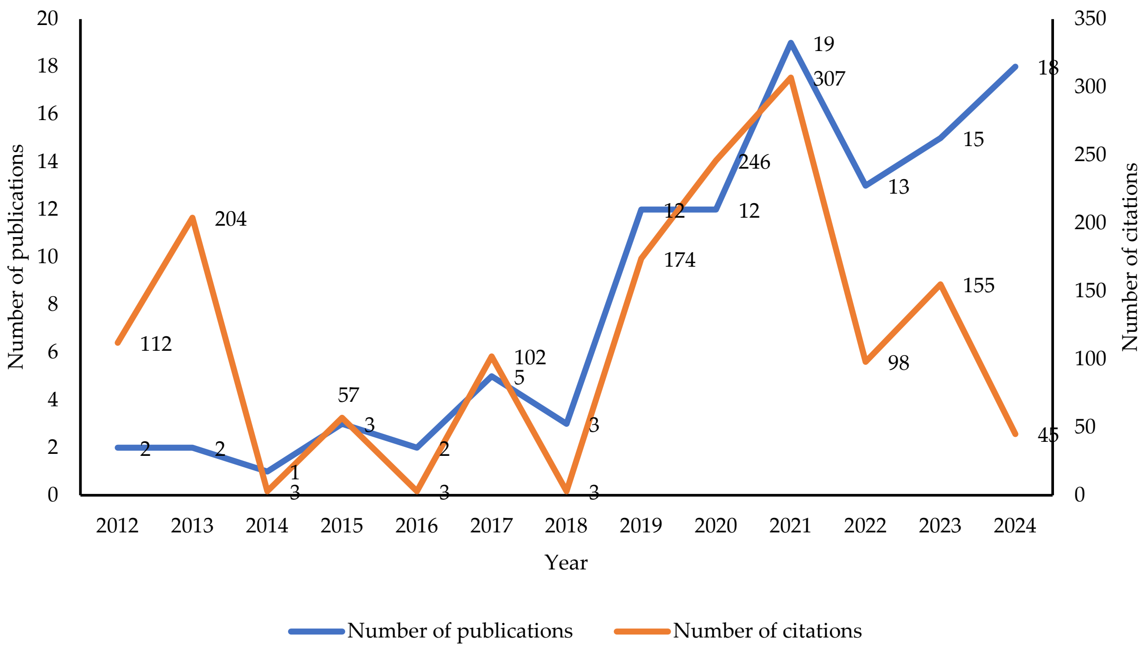

Figure 1. Total publications and citations related to the problem of energy poverty by year. Source: own elaboration based on Web of Science.

As can be seen from Figure 1, the first two articles in this field appeared in 2012. Since 2019, their number has increased significantly, with the largest number related to 2020. The published works were cited over 1500 times; the largest number of citations appeared in 2021 (307 citations). Of the discussed publications, only 26 concerned EU countries. The first one appeared in 2015, but their number began to increase only from 2020. Most of them appeared in 2021 and 2023 (6 publications each), and by October 2024, 5 publications were listed in the database. Articles in this field were published, among others, in journals such as *Energies*, *Energy Research and Social Science*, *Energy Efficiency*, and *Sustainability*. Table 1 presents information on the most frequently cited publications in this field.

Table 1. The most frequently cited publications related to the problem of energy poverty.

Paper	Author/Year	Journal	Total Citations
Energy Poverty and Low-Carbon Just Energy Transition: Comparative Study in Lithuania and Greece	Streimikiene, D., Kyriakopoulos, G., L., Lekavicius, V., Siksnelyte-Butkiene, I.	*Social Indicators Research* [41]	75
Climate Change Mitigation Policies Targeting Households and Addressing Energy Poverty in European Union	Streimikiene, D., Lekavicius, V., Balezentis, T., Kyriakopoulos, G.L., Abrham, J.	*Energies* [42]	70
Community Energy Companies in the UK: A Potential Model for Sustainable Development in Local Energy?	Saintier, S.	*Sustainability* [43]	35
Innovative but unjust? Analyzing the opportunities and justice issues within positive energy districts in Europe	Hearn, A.X., Sohre, A., Burger, P.	*Energy Research and Social Science* [44]	33
The Role of Renewable Energy Sources in Alleviating Energy Poverty in Households in Poland	Biernat-Jarka, A., Trebska, P., Jarka, S.	*Energies* [14]	26
The Analysis of The Innovative Potential of the Energy Sector and Low-Carbon Development: A Case Study for Poland	Dzikuc, M., Goraczkowska, J., Piwowar, A., Dzikuc, M., Smolenski, R., Kulyk, P.	*Energy Strategy Reviews* [45]	21
Assessing Fossil Fuels and Renewables' Impact on Energy Poverty Conditions in Europe	Halkos, G., Gkampoura, E.C.	*Energies* [39]	19
A Novel Energy Poverty Evaluation: Study of the European Union Countries	Hasheminasab, H., Streimikiene, D., Pishahang, M.	*Energy* [46]	16
Renewable Energy Technologies in Households: Challenges and Low-Carbon Energy Transition Justice	Streimikiene, D.	*Economics and Sociology* [47]	14
From Measuring Fuel Poverty to Identification of Fuel Poor Households: A Case Study in Greece	Lyra, K.; Mirasgedis, S.; Tourkolias, C.	*Energy Efficiency* [48]	11

Source: own elaboration based on Web of Science.

The following issues were discussed in the articles presented in Table 1:

- measurement and assessment of energy poverty [41,42,46,48];
- development of renewable energy sources and prospects for the development of a low-emission economy [45];
- impact of renewable energy sources on energy poverty [14,39];
- the barriers and state policies and measures for the support of renewable energy microgeneration technologies in households [43];
- energy justice and sustainable energy sources [44].

3. Research Method

In this study of the impact of the use of renewable energy on the level of energy poverty in the 27 EU countries, data from the Eurostat database [49] were used, relating to the years: 2010, 2015, and 2022. The choice of the first and last period was related to the desire to compare and analyze changes, taking into account the widest possible time period, and was limited by the availability of statistical data. Moreover, when selecting the two extreme periods, the stability of the studied group was taken into account, i.e., the membership of the same Member States in the compared years, with the starting point being the countries belonging to the EU in 2022. On the other hand, 2015 was added due to the fact that the Paris Agreement [50] was signed that year, which had a significant impact on the energy transformation process in the EU countries.

Tables 2 and 3 present selected diagnostic features characterizing the use of renewable energy and energy poverty, respectively. When selecting the features related to the use of energy from renewable sources, we relied on the Eurostat study [51], while in the case of features characterizing energy poverty, we used the Energy Poverty Advisory Hub 2023 [52] publication. All features included in Table 2 are stimulants, while all features included in Table 3 are destimulants. The nature of the diagnostic features used in this study affects the calculation and interpretation of the values of synthetic measures calculated on their basis.

Table 2. Diagnostic features characterizing the use of energy from renewable sources.

Symbol	Name	Definition	Unit
$X_{1.1}$	Share of energy from renewable sources	The ratio of renewable energy used in a country/region to the total amount of energy used by the country/region. It is calculated based on the level of gross available energy, gross energy consumption in the country, and total energy supply [51]	Percentage
$X_{1.2}$	Final consumption of energy from renewable sources	The total energy consumed by end users, such as households, industry, and agriculture. It is the energy that reaches the final consumer's door and excludes that which is used by the energy sector itself [53]	Percentage
$X_{1.3}$	Gross electricity production from renewable sources	Refers to the process of producing electrical energy. It is the total amount of electrical energy produced by transforming other forms of energy, for example, nuclear or wind power. Total gross electricity generation covers gross electricity generation in all types of power plants [54]	Gigawatt-hour/ 10,000 persons
$X_{1.4}$	Gross heat production from renewable sources	The total heat produced by the installation includes the heat used by the installation's auxiliaries, which use a hot fluid (space heating, liquid fuel heating, etc.), and losses in the installation/network heat exchanges, as well as heat from chemical processes used as a primary energy form [55]	Gigawatt-hour/ 10,000 persons

Source: own elaboration based on Eurostat.

Table 3. Diagnostic features characterizing energy poverty.

Symbol	Name	Definition	Unit
$X_{2.1}$	Households having arrears on utility bills	The indicator represents the share of (sub-) population with arrears on utility bills, based on the question "In the last twelve months, has the household been in arrears, i.e., has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.) for the main dwelling?" [56]	Percentage
$X_{2.2}$	At-risk-of-poverty rate (cut-off point: 60% of median equivalised income after social transfers)	The at-risk-of-poverty rate is the share of people with an equivalised disposable income (after social transfer) below the at-risk-of-poverty threshold, which is set at 60% of the national median equivalised disposable income after social transfers [57]	Percentage
$X_{2.3}$	Heating degree days	Heating degree day (HDD) index is a weather-based technical index designed to describe the need for the heating energy requirements of buildings [58]	Number

Table 3. *Cont.*

Symbol	Name	Definition	Unit
$X_{2.4}$	Cooling degree days	Cooling degree day (CDD) index is a weather-based technical index designed to describe the need for the cooling (air-conditioning) requirements of buildings [58]	Number
$X_{2.5}$	Households that are unable to keep homes adequately warm	The share of the population who declare if they can afford or not to keep their homes at a suitable temperature. This situation is usually considered one of the most obvious consequences of being in energy poverty [59]	Percentage
$X_{2.6}$	Households making ends meet with great difficulty	The share of the population who declared great difficulty with making ends meet [56]	Percentage
$X_{2.7}$	Overcrowding rate	The overcrowding rate is defined as the percentage of the population living in an overcrowded household [60]	Percentage
$X_{2.8}$	Total population considering their dwelling as too dark	The percentage of the total population considering their dwelling as too dark and not having enough light [61]	Percentage
$X_{2.9}$	Total population living in a dwelling with a leaking roof, damp walls, floors, or foundation, or rot in window frames or floor	The indicator represents the share of the population with a leak, dampness, or rot in their dwelling, based on the question "Do you have any of the following problems with your dwelling/accommodation? a leaking roof; damp walls/floors/foundation; rot in window frames or floor [62]	Percentage
$X_{2.10}$	Unemployment rates	The unemployment rate is the number of people unemployed as a percentage of the labor force [63]	Percentage
$X_{2.11}$	Average annual electricity prices for household consumers (with consumption from 2500 kWh to 4 999 kWh)	The indicator presents average annual electricity prices charged to final consumers living in medium-sized households with annual consumption between 2500 and 5000 kWh [64] PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the euro [65]	PPS

Source: own elaboration based on Eurostat.

In this article, a taxonomic measure of development based on the Weber median was used to examine the relationship between the results achieved by individual EU member states in terms of the impact of the use of renewables on the level of energy poverty. This method is not new [66,67], but it should be emphasized that it has unquestionable advantages related to the possibility of eliminating disturbances caused by outlier (atypical) observations. This is particularly important in the case of such political and economic structures as the European Union, which is formed by significantly diversified European countries [68].

The Weber median is a multi-dimensional generalization of the classical median. It minimizes the sum of the Euclidean distance of the data points representing the considered objects [69]. In the case of positional linear assignment of features, the standardization formula is based on the quotient of the deviation of the diagnostic feature value from the appropriate Weber median coordinate and the weighted absolute deviation of the median [70]:

$$z_{ij} = \frac{x_{ij} - \theta_{0j}}{1.4826 \cdot m\tilde{a}d(X_j)} \tag{1}$$

where $\theta_0 = (\theta_{01}, \theta_{02}, \ldots, \theta_{0m})$ is the Weber median, $m\tilde{a}d(X_j)$ is the absolute median deviation, in which the distance from the features to the Weber vector is measured, i.e., $m\tilde{a}d(X_j) = \underset{i=1,2,\ldots,n}{med} |x_{ij} - \theta_{0j}|$ $(j = 1, 2, \ldots m)$, med is median, n—number of objects, m—number of diagnostic features.

When determining the Weber median we look for such a point $\theta_0 = (\theta_{01}, \theta_{02}, \ldots, \theta_{0m}) \in R^m$, so that at the given points $\Gamma_1, \Gamma_2, \ldots, \Gamma_n \in R^m$, $\Gamma_i = (x_{i1}, x_{i2}, \ldots, x_{im})$, $i = 1,\ 2,\ \ldots,\ n$, representing the studied objects described by m features, the optimization equality of the form was satisfied [70]:

$$\sum_{i=1}^{n}\left(\sum_{j=1}^{m}(x_{ij}-\theta_0)^2\right)^{\frac{1}{2}} = \min_{\theta\in R^m}\left(\sum_{i=1}^{n}\left(\sum_{j=1}^{m}(x_{ij}-\theta_j)^2\right)^{\frac{1}{2}}\right) \quad (2)$$

Due to the computational difficulties of the optimization problem given by Formula (2) ready-made software is used. Useful functions can be found in the R environment. In the article, the l1median_NLM function from the pcaPP package was used to determine the Weber median.

The aggregate measure is calculated with the formula:

$$\mu_i = 1 - \frac{d_i}{d_-} \quad (3)$$

$$d_- = \mathrm{med(d)} + 2{,}5\mathrm{mad(d)} \quad (4)$$

where d = $(d_1, d_2, \ldots, d_n)$ is a distance vector calculated with the formula: $d_i = \underset{j=1,2,\ldots m}{med}\left|z_{ij}-\varphi_j\right|$ $i = 1, 2, \ldots, n$, $\varphi_j = \max_{i=1,2,\ldots,n} z_{ij}$ or $\varphi_j = \min_{i=1,2,\ldots,n} z_{ij}$ —the coordinated development pattern vector, which is constituted of the maximum values for stimulants and minimum for destimulants.

The assignment of objects with a positioning measure is the basis for a division of objects into four classes. The most commonly used grouping method in the positioning scope is called the three medians method. It involves indicating a median of vector coordinates $\mu = (\mu_1, \mu_2, \ldots, \mu_n)$, which is denoted $med(\mu)$, then dividing the population of objects into two groups: those, for which the measure values exceed the median and are higher than it. Next, the indirect medians are defined as $med_k(\mu) = \underset{i:\Gamma_i\in\Omega_k}{med}(\mu_i)$, where k = 1,2. This way the following groups of objects are created:

- Group I: $\mu_i > med_1(\mu)$,
- Group II: $med(\mu) < \mu_i \le med_1(\mu)$,
- Group III: $med_2(\mu) < \mu_i \le med(\mu)$,
- Group IV: $\mu_i \le med_2(\mu)$.

The first (best) and second groups include objects that have achieved results that are higher than the group median. These are objects characterized by a higher level of development than objects classified in the third and fourth groups (worst).

4. Results

The results obtained in this study were presented in three stages. The first stage analyzed the situation of EU countries in terms of the use of energy from renewable sources. The second stage analyzed energy poverty in the countries studied, while the third stage identified regularities concerning the impact of the use of renewable energy on energy poverty in EU countries in the years 2010, 2015, and 2022.

4.1. Analysis of the Situation in Use of Renewable Energy in EU Countries in 2010, 2015, and 2022

Before starting a detailed analysis of the situation in the use of renewable energy in individual typological groups, the changes that occurred in 2010, 2015, and 2022 in the level of individual indicators used to calculate the synthetic measure were assessed. Selected parameters characterizing the distribution of indicator values in the EU are presented in Table 4. It shows that over the studied years, all indicators are systematically increasing, which means that the situation in the use of renewable energy in the EU is improving. On the other hand, large and very large differences in indicator values indicate significant disproportions in these terms in EU countries, with this differentiation decreasing slightly from period to period.

Table 4. Basic descriptive measures of the distribution of indicators characterizing use of renewable energy in the EU countries in the years under study.

Indicators	Years	Mean	S	V_s [%]	Min	Max
$X_{1.1}$ [%]	2010	16.354	10.554	64.537	0.979	46.099
	2015	20.349	11.580	56.908	4.987	52.220
	2022	25.729	12.516	48.645	13.107	66.002
$X_{1.2}$ [%]	2010	10.850	5.959	54.919	1.210	23.610
	2015	12.279	6.303	51.336	2.900	25.570
	2022	13.905	6.274	45.117	5.250	29.400
$X_{1.3}$ [GWh/10,000 persons]	2010	16.469	18.712	113.617	0.016	87.879
	2015	20.040	21.140	105.487	2.317	105.153
	2022	25.613	22.466	87.714	5.709	113.093
$X_{1.4}$ [GWh/10,000 persons]	2010	5.539	10.694	193.082	0.000	40.604
	2015	7.353	11.911	161.990	0.000	40.836
	2022	10.226	14.628	143.052	0.000	48.271

Source: own elaboration.

Table 5 presents the values of synthetic measures characterizing the level of use of energy from renewable sources in the EU countries in the years under study, along with the ranking of countries and their membership in typological groups, which is also presented in Figure 2.

Table 5. Values of synthetic measures characterizing the level of use of energy from renewable sources in the EU countries in the years under study, along with the ranking of countries and their membership in typological groups.

n.	Country	RE_{2010}	Rank	Group	RE_{2015}	Rank	Group	RE_{2022}	Rank	Group
1	Belgium	0.129	22	3	0.168	21	3	0.086	25	3
2	Bulgaria	0.192	15	3	0.218	15	3	0.119	18	3
3	Czechia	0.154	19	3	0.179	20	3	0.117	19	3
4	Denmark	0.445	4	2	0.679	3	1	0.599	4	1
5	Germany	0.216	13	3	0.271	11	3	0.190	11	3
6	Estonia	0.261	11	3	0.525	5	2	0.620	3	1
7	Ireland	0.143	21	3	0.191	18	3	0.107	21	3
8	Greece	0.180	18	3	0.213	16	3	0.152	14	3
9	Spain	0.291	9	2	0.257	12	3	0.174	12	3
10	France	0.215	14	3	0.209	17	3	0.135	15	3
11	Croatia	0.367	7	2	0.310	9	3	0.210	10	3
12	Italy	0.225	12	3	0.238	14	3	0.101	22	3
13	Cyprus	0.091	26	3	0.125	25	3	0.090	24	3
14	Latvia	0.368	6	2	0.445	7	2	0.575	5	1
15	Lithuania	0.192	16	3	0.473	6	2	0.449	6	2
16	Luxembourg	0.103	25	3	0.118	26	3	0.275	8	2
17	Hungary	0.149	20	3	0.139	23	3	0.086	26	3
18	Malta	0.051	27	4	0.084	27	4	0.045	27	3
19	Netherlands	0.120	24	3	0.125	24	3	0.133	16	3
20	Austria	0.649	3	1	0.578	4	1	0.435	7	2
21	Poland	0.125	23	3	0.143	22	3	0.091	23	3
22	Portugal	0.400	5	2	0.354	8	2	0.267	9	3
23	Romania	0.266	10	3	0.257	13	3	0.128	17	3
24	Slovenia	0.354	8	2	0.299	10	3	0.162	13	3
25	Slovakia	0.185	17	3	0.182	19	3	0.115	20	3
26	Finland	0.762	2	1	0.909	2	1	0.850	2	1
27	Sweden	1.000	1	1	1.000	1	1	1.000	1	1

Source: own elaboration.

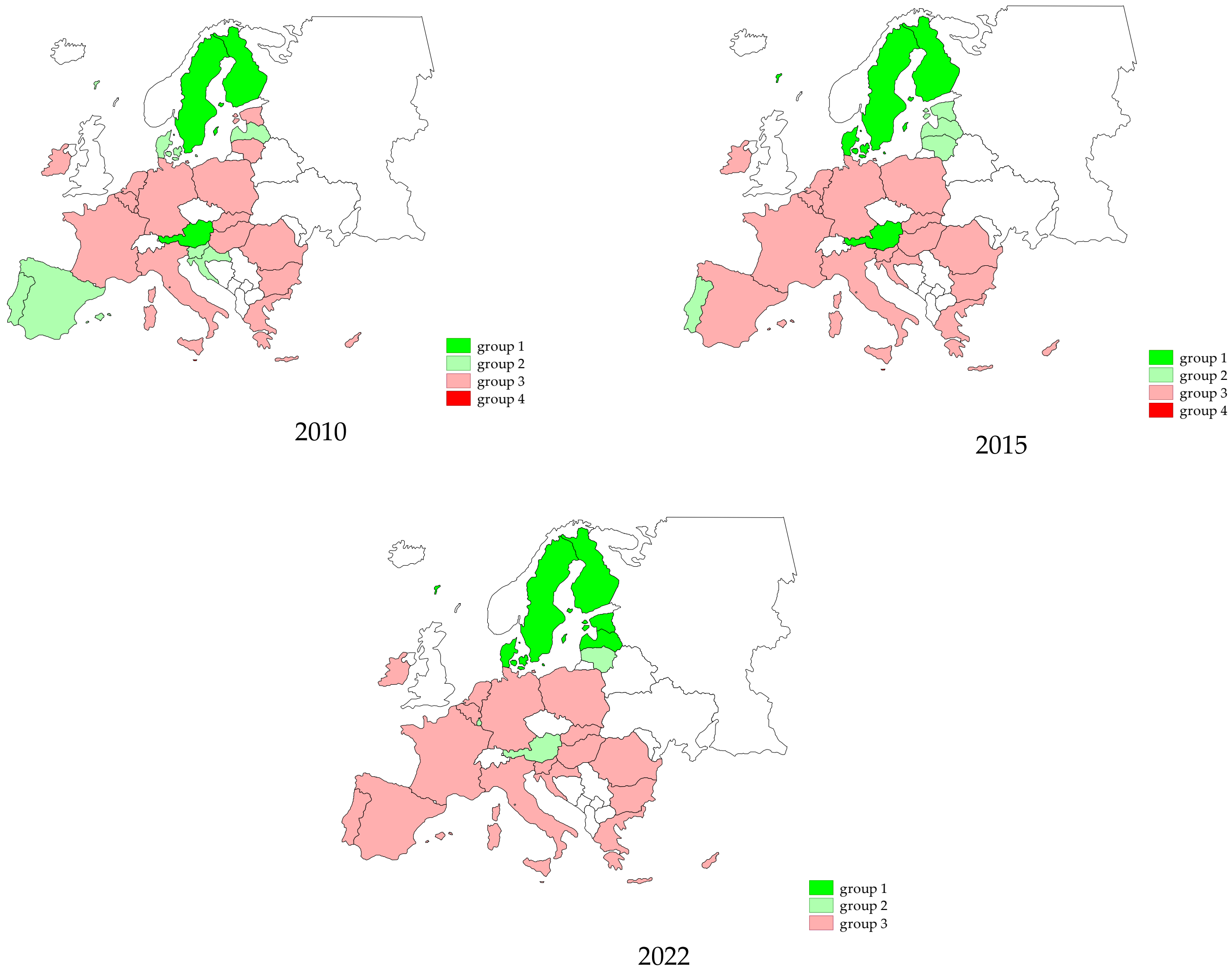

Figure 2. Spatial distribution of EU countries in terms of the value of the synthetic measure related to the level of use of energy from renewable sources in 2010, 2015, and 2022. Source: own elaboration.

Table 5 and Figure 2 show that in each year under study, the largest typological group was group 3, with 17, 18, and 19 countries in each year, respectively, while the smallest group was group 4, which included only Malta in 2010 and 2015, while in 2022 no country was in this group. Malta was in last place in each year, i.e., it had the lowest values of all indicators used to calculate the synthetic measure, while in 2022 the situation in terms of renewable energy improved in this country to such an extent that the values of two indicators (share of energy from renewable sources ($X_{1.1}$), final consumption of energy from renewable sources ($X_{1.2}$)) were higher than in Ireland, and the values of the other two indicators were still at the lowest level. However, this improvement was enough for Malta to join the third group. It is worth mentioning that the countries' affiliation to the third group was primarily determined by the low level of the gross heat production from renewable sources ($X_{1.4}$) indicator, for which the average in this group in individual years was, respectively, 1.7, 1.3, and 1.6 GWh/10,000 persons (in group 1 it was 29, 31, and 38 GWh/10,000 persons, while in group 2 they were 5.5, 12.8, and 18.8 GWh/10,000 persons).

In 2010, group 1 (the best) included three countries (Austria, Finland, Sweden); in 2015 the number of countries increased to four (Denmark, Austria, Finland, Sweden); and in 2022, this number was five (Denmark, Estonia, Latvia, Finland, Sweden). In all countries from group 1, the indicator values were significantly above the EU average; e.g., in Sweden, which was in first place in all years, the share of energy from renewable sources ($X_{1.1}$) ranged from 46 to 66%, final consumption of energy from renewable sources ($X_{1.2}$)—from 16.8 to 29.4%, gross electricity production from renewable sources ($X_{1.3}$)—from 88 to 113 GWh/10,000 persons, gross heat production from renewable sources ($X_{1.4}$)—from 40.6 to 40.8 GWh/10,000 persons. From period to period, the number of countries in the first group increased, supplemented by countries that were previously in the second group. In Denmark, a significant increase in all indicators was recorded already in 2015 compared to 2010, and this trend continued in 2022. In Estonia and Latvia, on the other hand, a significant improvement in the use of renewable energy occurred in 2022—for example, in Estonia, the share of energy from renewable sources ($X_{1.1}$) in 2010 was 24.6%, and in 2022 it was already at the level of 38.5%, and gross heat production from renewable sources ($X_{1.4}$) increased from 12.4 to 33 GWh/10,000 persons, while in Latvia the X1.4 indicator increased the most (from 5.6 to 26.3 GWh/10,000 persons). Austria's decline in 2022 from the first to the second typological group was not caused by a deterioration in the situation in the field of renewable energy but resulted from a lower dynamics of growth of individual indicators, which in turn resulted in Austria being overtaken by Estonia and Latvia, which are developing dynamically in this aspect. It is worth mentioning that in the second typological group, the number of countries decreased from period to period, and some countries (Denmark, Estonia, and Latvia) advanced to group 1, and some countries (Spain, Croatia, Portugal, and Slovenia) dropped to group 3. Luxembourg is worth noting, which in 2022 advanced from group 3 to group 2, which was caused by a significant increase in the values of individual indicators this year compared to 2015 (share of energy from renewable sources ($X_{1.1}$)—an increase from 5% to 14.4%, final consumption of energy from renewable sources ($X_{1.2}$)—an increase from 3.9% to 5.8%, gross electricity production from renewable sources ($X_{1.3}$)—an increase from 7.6 to 15.7 GWh/10,000 persons, gross heat production from renewable sources ($X_{1.4}$)—an increase from 3.1 to 18.5 GWh per 10,000 persons).

4.2. Analysis of Situation of Energy Poverty in EU Countries in 2010, 2015, and 2022

Table 6 presents selected descriptive measures of the distribution of indicator values used to calculate the synthetic measure characterizing the level of energy poverty in EU countries.

Table 6. Basic descriptive measures of the distribution of indicators characterizing energy poverty in the EU countries in the years studied.

Indicators	Years	Mean	S	V_s [%]	Min	Max
$X_{2.1}$ [%]	2010	11.785	8.283	70.283	2.100	31.600
	2015	11.841	9.676	81.717	2.400	42.000
	2022	7.648	6.693	87.515	1.500	34.100
$X_{2.2}$ [%]	2010	15.985	3.469	21.700	9.000	21.600
	2015	17.085	4.010	23.470	9.700	25.400
	2022	16.337	3.637	22.265	10.200	22.900
$X_{2.3}$ [Number]	2010	3201.628	1379.826	43.098	402.950	6179.750
	2015	2696.851	1034.018	38.342	543.900	5014.740
	2022	2658.396	1121.585	42.190	543.620	5276.820
$X_{2.4}$ [Number]	2010	123.913	169.822	137.050	0.000	745.530
	2015	147.276	180.396	122.488	0.000	685.340
	2022	155.829	212.049	136.078	0.030	841.720
$X_{2.5}$ [%]	2010	11.978	13.447	112.262	0.500	66.500
	2015	11.222	10.246	91.298	0.900	39.200
	2022	8.630	6.140	71.153	1.400	22.500
$X_{2.6}$ [%]	2010	13.052	8.132	62.307	1.900	29.000
	2015	12.574	9.572	76.127	2.500	38.200
	2022	7.030	6.681	95.047	1.500	36.800
$X_{2.7}$ [%]	2010	23.159	18.345	79.212	2.000	55.700
	2015	19.230	15.504	80.626	1.400	49.700
	2022	17.237	12.249	71.061	2.200	41.700

Table 6. *Cont.*

Indicators	Years	Mean	S	V_s [%]	Min	Max
$X_{2.8}$ [%]	2010	6.474	2.122	32.784	2.600	10.800
	2015	5.674	1.517	26.744	3.100	8.600
	2022	5.448	2.039	37.428	2.600	10.600
$X_{2.9}$ [%]	2010	16.867	6.519	38.649	5.000	32.400
	2015	15.448	6.383	41.317	4.400	28.100
	2022	14.067	7.335	52.144	4.500	39.100
$X_{2.10}$ [%]	2010	10.215	4.311	42.205	4.400	19.900
	2015	9.826	4.801	48.861	4.600	24.900
	2022	5.789	2.487	42.955	2.200	13.000
$X_{2.11}$ [PPS]	2010	0.141	0.037	26.338	0.078	0.217
	2015	0.146	0.034	23.188	0.070	0.206
	2022	0.218	0.080	36.692	0.124	0.456

Source: own elaboration.

Based on the results in this table, it can be seen that the average values of most indicators (except for cooling degree days ($X_{2.4}$) and average annual electricity prices for household consumers ($X_{2.11}$)) in the EU are decreasing from period to period, which indicates an improvement in the situation regarding energy poverty on a scale of the entire Union. The increase in the average value of the cooling degree days indicator ($X_{2.4}$) is related to the fact that over the years studied, the number of warm days during the year has increased, which is a result of global warming. On the other hand, the increase in the average value of average annual electricity prices for household consumers ($X_{2.11}$) is a consequence of the systematic increase in energy prices in all EU countries. The analysis of the differentiation measures indicates that the smallest differentiation in all the years studied concerned the indicators: at-risk-of-poverty rate ($X_{2.2}$), total population considering their dwelling as too dark ($X_{2.8}$), and average annual electricity prices for household consumers ($X_{2.11}$), which means that in a large part of EU countries, these indicators were at a similar level. However, significant disproportions can be observed in the case of the indicators of households having arrears on utility bills ($X_{2.1}$), cooling degree days ($X_{2.4}$), households that are unable to keep homes adequately warm ($X_{2.5}$), households making ends meet with great difficulty ($X_{2.6}$), and overcrowding rate ($X_{2.7}$) (V_s above 60%). It is worth mentioning that in 2022 these disproportions deepened for the indicators of households having arrears on utility bills ($X_{2.1}$), cooling degree days ($X_{2.4}$), and decreased for the remaining indicators in 2022.

Table 7 presents the values of synthetic measures characterizing the level of energy poverty in the EU countries in the years under study, along with the ranking of countries and their membership in typological groups, which is also presented in Figure 3.

Table 7 and Figure 3 show that Finland and the Netherlands were in group 1, which includes countries with the lowest energy poverty, in each year under review. In 2010, this group also included Austria, Denmark, and Sweden, while five years later, Austria and Sweden dropped to group 2 and were replaced by Germany. Austria's drop to the lower group was a consequence of the increase in the values of the following indicators: cooling degree days ($X_{2.4}$), overcrowding rate ($X_{2.7}$), and unemployment rates ($X_{2.10}$), while Sweden's drop resulted from the increase in the values of the following indicators: at-risk-of-poverty rate ($X_{2.2}$) and overcrowding rate ($X_{2.7}$). Germany moved from group 2 to group 1 because in 2015, compared to 2010, it recorded a drop in as many as seven out of eleven indicators. In 2022, group 1 consisted of four countries, namely the aforementioned Finland and the Netherlands, joined by Poland and the Czech Republic. The high position of these two countries was caused by a decline in the values of almost all indicators—in the case of Poland, a decline was observed for 10 indicators (only the heating degree days $X_{2.3}$ value increased), and for the Czech Republic, a decline was recorded for 9 indicators (only the average annual electricity prices for household consumers ($X_{2.11}$) and the risk of poverty rate ($X_{2.2}$) increased). It is also worth analyzing the reasons for Denmark's decline in 2022 from group 1 to group 2 and its only 10th place in the ranking. This decline was a consequence of an increase in as many as eight indicators this year compared to 2015, with the largest increase being in the average annual electricity prices for household consumers ($X_{2.11}$)—from 0.07 to 0.23 PPS.

Table 7. Values of synthetic measures characterizing the level of energy poverty in the EU countries in the years studied, along with the ranking of countries and their affiliation to typological groups.

N.	Country	P_{2010}	Rank	Group	P_{2015}	Rank	Group	P_{2022}	Rank	Group
1	Belgium	0.597	13	2	0.545	14	2	0.608	11	2
2	Bulgaria	0.177	24	4	0.044	25	4	0.024	25	4
3	Czechia	0.785	6	2	0.766	5	2	0.879	1	1
4	Denmark	0.905	1	1	0.859	1	1	0.610	10	2
5	Germany	0.742	7	2	0.831	4	1	0.641	6	2
6	Estonia	0.668	11	2	0.731	7	2	0.575	13	2
7	Ireland	0.561	14	2	0.452	15	3	0.557	14	2
8	Greece	0.274	21	3	0.002	26	4	−0.325	27	4
9	Spain	0.506	15	3	0.442	16	3	0.102	24	4
10	France	0.718	9	2	0.659	10	2	0.325	17	3
11	Croatia	0.245	22	4	0.110	24	4	0.230	21	3
12	Italy	0.488	16	3	0.151	22	4	0.143	22	3
13	Cyprus	0.358	18	3	−0.275	27	4	0.114	23	4
14	Latvia	0.040	27	4	0.158	21	4	0.332	16	3
15	Lithuania	0.127	26	4	0.327	19	3	0.268	19	3
16	Luxembourg	0.738	8	2	0.686	9	2	0.618	9	2
17	Hungary	0.228	23	4	0.266	20	3	0.254	20	3
18	Malta	0.413	17	3	0.603	12	2	0.545	15	2
19	Netherlands	0.878	3	1	0.834	3	1	0.750	3	1
20	Austria	0.812	5	1	0.714	8	2	0.621	8	2
21	Poland	0.348	19	3	0.566	13	2	0.739	4	1
22	Portugal	0.317	20	3	0.142	23	4	0.275	18	3
23	Romania	0.155	25	4	0.357	18	3	−0.012	26	4
24	Slovenia	0.619	12	2	0.439	17	3	0.630	7	2
25	Slovakia	0.683	10	2	0.654	11	2	0.582	12	2
26	Finland	0.880	2	1	0.846	2	1	0.780	2	1
27	Sweden	0.816	4	1	0.737	6	2	0.692	5	2

Source: own elaboration.

In group 2, the number of countries increased from period to period—in 2010 there were nine countries in this group, in 2015 ten, and in 2022 eleven. In each year under review, the following countries were repeated: Belgium, Estonia, Luxembourg, and Slovakia. In 2010 and 2015, this group also included the Czech Republic and France, with the Czech Republic advancing to group 1 in 2022 and France falling to group 3, which was caused by a deterioration in the level of as many as 9 indicators (a decrease was observed only for the indicators: heating degree days ($X_{2.3}$) and unemployment rates ($X_{2.10}$)). In 2015, this group was joined by, among others, Malta (advanced from group 3), Poland (advanced from group 3), Austria (downgraded from group 1), and Sweden (downgraded from group 1). In 2022, Denmark and Germany were relegated from Group 1 to this group, while Ireland advanced from Group 3. Poland, as mentioned earlier, advanced to Group 1 this year.

Group 3, with relatively high energy poverty, included seven countries in 2015 and 2022 and six countries in 2015. In principle, the composition of this group was different in each year studied—although Spain belonged to this group in 2010 and 2015, Lithuania and Hungary in 2015 and 2022, and Italy and Portugal in 2010 and 2022.

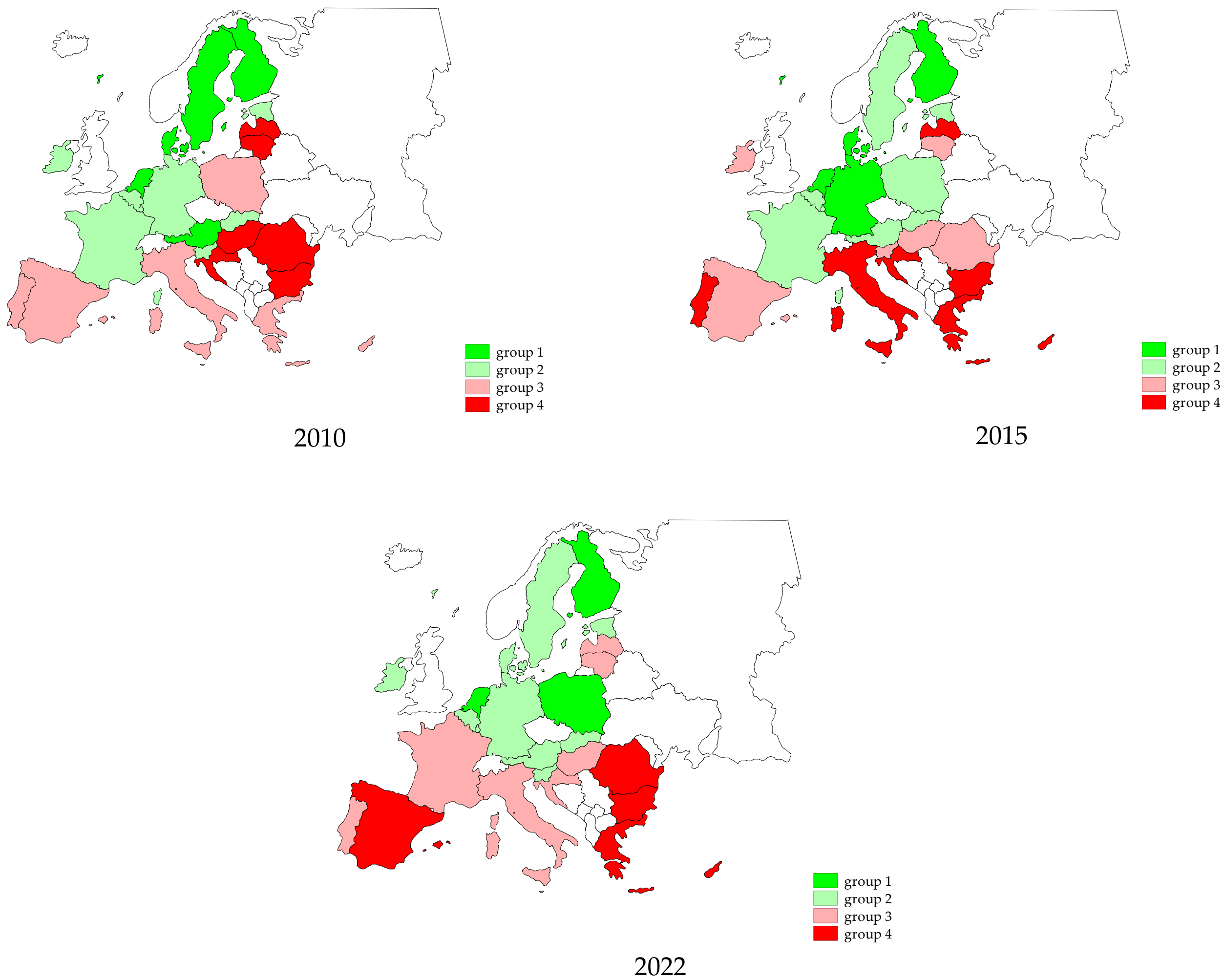

Figure 3. Spatial distribution of EU countries in terms of the value of the synthetic measure related to the level of energy poverty in 2010, 2015, and 2022. Source: own elaboration.

In all the years studied, Bulgaria was in group 4, with the highest energy poverty. Cyprus, Greece, Croatia, Latvia, and Romania were in this group twice. In 2010, Hungary and Lithuania were in this group, which in the following years advanced to group 3. In 2015, Italy and Portugal appeared in this group, which in 2022 advanced to group 3, while in 2022 Spain dropped from group 3 to this group. It follows from the above that all the countries that were in group 4 in the individual years were characterized by very high energy poverty because even if there was an improvement in this respect, it was so small that it only advanced these countries to group 3. It is worth mentioning that for three countries from group 4 (Cyprus—in, Romania, and Greece), the value of the synthetic measure was negative, which means that these countries significantly differed from other EU countries in terms of energy poverty.

4.3. Analysis of the Impact of Use of Renewable Energy on Energy Poverty in EU Countries in 2010, 2015, and 2022

A detailed analysis of the use of renewable energy and energy poverty in the EU countries clearly showed that in both these aspects, the countries that are members of the EU since its inception have been doing very well, while the countries that joined the EU in or after 2004 are doing much worse. This is confirmed by Figures 4–6.

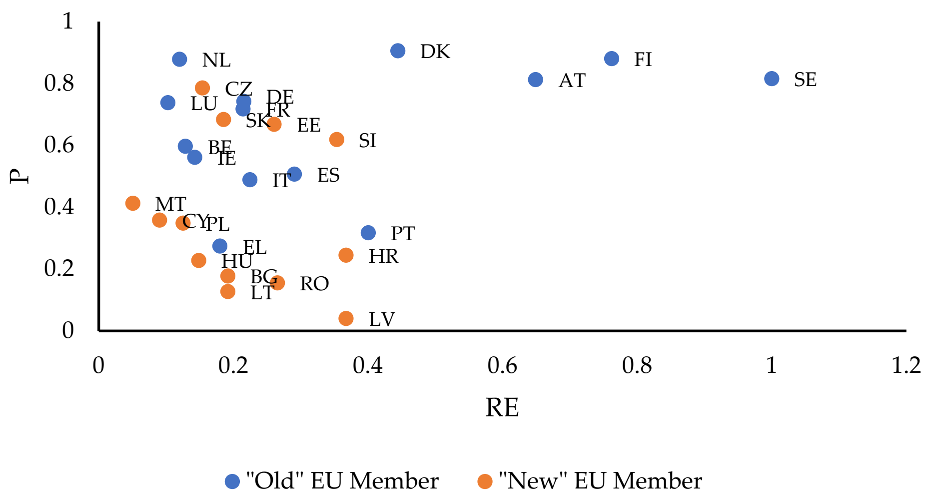

Figure 4. Scatter graph of synthetic measure values characterizing the relationship between the use of energy from renewable sources and energy poverty in 2010. Source: own elaboration.

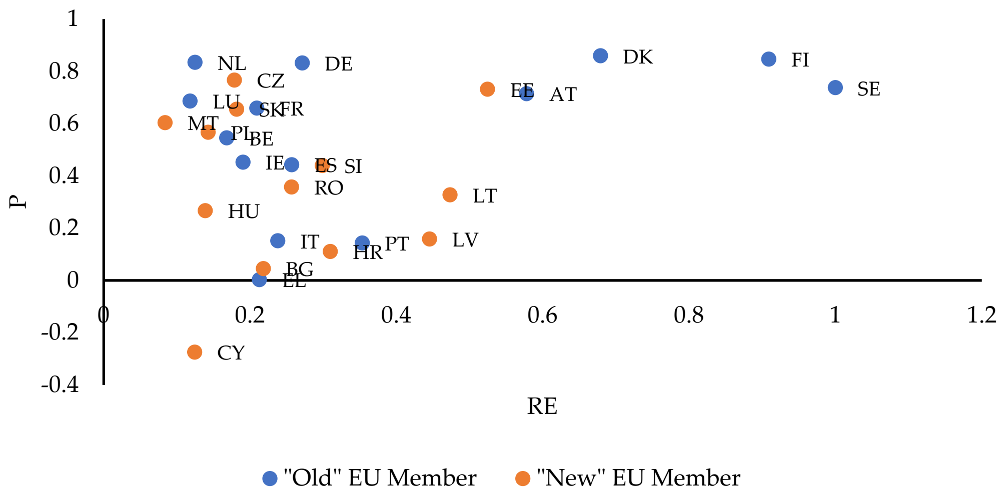

Figure 5. Scatter graph of synthetic measure values characterizing the relationship between the use of energy from renewable sources and energy poverty in 2015. Source: own elaboration.

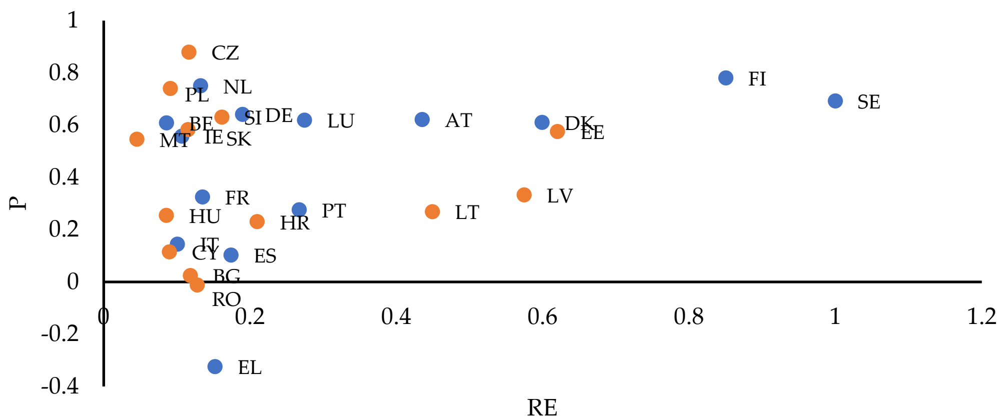

Figure 6. Scatter graph of synthetic measure values characterizing the relationship between the use of energy from renewable sources and energy poverty in 2022. Source: own elaboration.

The analysis of the above figures shows that the EU countries cannot be treated as a uniform entity. A clear distinction can be made between the “old” and “new” EU countries.

The first group is usually characterized by high values of the synthetic measure related to poverty, which means that energy poverty is relatively low in these countries. The second group, on the other hand, is characterized by low levels of the synthetic measure related to renewable energy, which means that its use is low. This division is noticeable in all the years analyzed.

At the same time, progress can be observed in countries that joined after 2004 in terms of the levels of the measure related to energy poverty. Interestingly, a slight regression can be observed for the remaining countries in this respect, which may be caused by the increase in energy prices.

The above observations prompted the authors to examine the relationship between synthetic measures characterizing the use of renewable energy and energy poverty, taking into account the division into "old" and "new" EU countries. All the more so because in the case of the analysis of interdependencies taking into account all EU countries, the relationships between these measures were positive and at a moderate level (Table 8). This direction of the relationship means that with the increase in the use of renewable energy, energy poverty decreases. In the case of dividing countries into two groups for the "old" EU countries, the strength of this relationship increases, and the direction does not change (Table 9). On the other hand, for the countries that joined the EU in 2004 and later, a very weak relationship can be observed between energy poverty and the use of energy from renewable sources in 2010 and no relationship in the remaining years (Table 10).

Table 8. Pearson linear correlation coefficients between synthetic measures related to renewable energy production and energy poverty in EU countries.

	$\mathbf{P_{2010}}$	$\mathbf{P_{2015}}$	$\mathbf{P_{2022}}$
RE_{2010}	0.332	0.266	0.222
RE_{2015}	0.329	0.330	0.256
RE_{2022}	0.310	0.350	0.299

Source: own elaboration.

Table 9. Pearson linear correlation coefficients between synthetic measures related to renewable energy production and energy poverty for the "old" EU countries.

	$\mathbf{P_{2010}}$	$\mathbf{P_{2015}}$	$\mathbf{P_{2022}}$
RE_{2010}	0.388	0.312	0.326
RE_{2015}	0.473	0.395	0.381
RE_{2022}	0.535	0.465	0.448

Source: own elaboration.

Table 10. Pearson linear correlation coefficients between synthetic measures related to renewable energy production and energy poverty for the "new" EU countries.

	$\mathbf{P_{2010}}$	$\mathbf{P_{2015}}$	$\mathbf{P_{2022}}$
RE_{2010}	−0.166	−0.104	−0.140
RE_{2015}	−0.159	0.061	−0.081
RE_{2022}	−0.151	0.074	−0.001

Source: own elaboration.

5. Discussion

The results presented in the article encourage a deep comparative analysis with the results presented in the works of other researchers. In the case of renewable energy, large disproportions between the countries of the old and new EU may result from the varying degrees of impact of barriers influencing the speed of their development. The types of barriers were presented and discussed in the work [71]. The authors, based on the extensive literature studies, distinguished, among others:

- administrative barriers,
- political barriers,
- infrastructure barriers,
- barriers related to the market and the level of economic development.

They also note that in countries with a high level of GDP per capita (e.g., Denmark, Finland, Sweden, Germany, Latvia), the share of energy from renewable sources in the energy balance is usually high. In the Czech Republic, Hungary, and Poland, the impact of the above-mentioned barriers is strongly discouraging and hinders the development of this group of energy sources.

Similar conclusions can be found in [72]. For the years 2007–2016, and in selected 25 European countries, the authors found a positive relationship between the level of use of renewable energy consumption and the level of gross domestic product. Interestingly, they also distinguished two groups of countries, one of which was mostly Central and Eastern European countries and the other Western European countries. Countries from the first-mentioned group were characterized by both a lower level of renewable energy consumption and a noticeably lower level of GDP than countries from the second group. As the authors point out, this is due to the fact that richer countries can afford to provide adequate financing for the development of new energy technologies.

Referring to infrastructure barriers, as the authors of the work [73] note, all ten economies of Central and Eastern Europe are characterized by operating costs of national energy systems above the EU average due to inefficient or outdated infrastructure. At the same time, in 2022, in Poland, Bulgaria, and Romania alone, green energy projects with a capacity of 141 GW were waiting to be connected to the power grid. In Hungary, in turn, the process of connecting all prosumer investments related to solar energy has been suspended until the end of 2024 [74]. So we can also see the operation of administrative barriers here, forced by the condition of infrastructure. However, it should be emphasized that the development of infrastructure for "green" energy in Western European countries is also not without problems [75].

Referring to the differences in spatial disproportions of the second of the analyzed phenomena—energy poverty—it should be clearly stated at the beginning of the discussion that this phenomenon is difficult to measure (see [76]). For example, based on the results of the research presented in [77], in 2020, countries such as Lithuania, Spain, and France have a clearly negative presentation, while a low level of this phenomenon was recorded for Germany and the Scandinavian countries. In turn, the authors of [78], based on a different set of features for 2022, obtained completely different results.

- The main causes of energy poverty are undoubtedly [79]:
- high energy prices,
- low energy efficiency,
- low income.

EU countries differ significantly in terms of energy prices. In the case of average electricity prices in 2022 [80], the highest were recorded in Greece (0.4561 PPS), Romania (0.3987 PPS), and Italy (0.2996 PPS), while the lowest were recorded in Hungary (0.1240 PPS), Finland (0.1258 PPS), and Luxembourg (0.1311 PPS). However, it is difficult to indicate a clear relationship between geographical location and price level.

Such a relationship is noticeable in the case of energy efficiency [81]. At the top of the classification for 2022, the first 10 places are occupied by the countries of the so-called old Union (Ireland, Denmark, Luxembourg, Italy, Germany, Austria, France, Sweden, the Netherlands, and Spain), while the last 10 are countries that gained accession in 2004 or later (Romania, Lithuania, Latvia, Slovakia, Hungary, Poland, Czechia, Malta, Estonia, Bulgaria).

A similar relationship is also noticeable for income [82]. In this case, the first 8 places are occupied by the countries of the old Union (Luxembourg, Netherlands, Austria, Belgium, Denmark, Germany, Finland, Ireland), and the income of the last in the classification—Bulgaria—is more than three times lower than that of Luxembourg.

Based on the above observations regarding barriers to the production of energy from renewable sources and factors influencing energy poverty, there are clear disproportions between countries before and after accession in 2004. This was also confirmed by the authors' research, which shows that in the old EU countries, the increase in the use of energy from renewable sources has an impact on the reduction of energy poverty. However, in the new EU countries, no such relationship is identified.

6. Conclusions

The research conducted by the authors clearly indicated the existence of disproportions between the countries of the "old" Union and the countries that joined it in 2004 and later. These disproportions concern both the use of energy obtained from renewable sources and energy poverty. Most of the countries of the "old" Union in all the years analyzed were classified into the first or second typological group and in both analyzed phenomena. The Scandinavian countries (e.g., Sweden, Finland, Denmark) and the countries of Western Europe (e.g., Austria, Germany, the Netherlands) were particularly high in the rankings, while the countries of Southwestern Europe, which belonged to the third or fourth group (e.g., Italy, Portugal), took a worse position in the rankings. The "new" EU countries were in most cases classified into the third or fourth group, in which the values of the analyzed indicators in the field of renewable energy were below the EU average, and the indicators characterizing energy poverty exceeded the EU average. The worst situation in the case of renewable energy was recorded in Malta (last place in the ranking in all analyzed years), while in the case of energy poverty, Bulgaria, Greece, Cyprus, and Romania were most often at the end of the ranking, while in the case of the last three countries, the synthetic measure was negative, which means that these countries significantly differed from other EU countries in terms of energy poverty. The observed disproportions influenced the relationship between the use of renewable energy and energy poverty. In the countries of the "old" EU, a positive moderate relationship was identified between these phenomena, which means that a greater share of the use of energy from renewable sources in these countries reduces energy poverty. However, in the "new" EU countries, this correlation was very weak (2010) or non-existent.

The results presented in the paper also indicate a serious potential problem related to the development of RES in EU countries. In countries with a high level of socio-economic development, it directly affects social phenomena such as energy poverty. This may result from the rationality and purposefulness of the energy transformation process by ensuring an appropriate level of financing, removing administrative barriers, and promoting RES in society. The state plays a significant role in this as a coordinator of the activities carried out. In the case of countries accepted to the EU in and after 2004, the transformation seems to be carried out using shortcuts, without a systemic plan. Problems with financing, artificial administrative barriers often resulting from irrational prejudices of part of society against RES, as well as an underinvested and outdated energy system dependent on non-renewable energy sources—all this makes the process of switching to "green" energy in their case difficult and at the same time detached from the natural pace of development of these societies. Additionally, this is despite activities carried out for over 20 years as part of the Cohesion Policy. It is therefore important to individually adjust the pace of renewable energy development to the current social and economic situation, as well as to promote and apply such an approach by community institutions and the governments of the member states.

Taking into account the main causes of energy poverty—high energy prices, low energy efficiency, and low income—renewable energy can have a direct impact on them. Its popularization, especially in rural areas, which, due to their nature, are at risk of such social exclusions and at the same time have a high potential in terms of energy generation, can result in a reduction in its price. At the same time, technological progress improves efficiency, both in terms of energy production and its transmission, as well as in terms of consumption. Lower energy prices and consumption will have an obvious impact on the level of income, especially disposable income. The above processes can take place naturally, but appropriate government actions based on a properly designed energy policy can significantly accelerate their pace. However, this policy must take into account the socio-economic nature of the area/country, its level of infrastructure, and, above all, its potential in terms of energy generation. It should also include promotional and educational activities and, most importantly, be stable and conducted in a rational manner.

The authors intend to continue research in this area, focusing primarily on the countries that joined the EU in 2004 and later, to see whether in the following years—as the socio-economic growth of these countries increases—the use of energy from renewable sources will contribute to reducing energy poverty. Additionally, in these future studies, in addition to indicators related to renewable energy and energy poverty, indicators characterizing the socio-economic situation of these countries will be used.

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