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Are Most Polluted Regions Most Active in Energy Transition Processes? A Case Study of Polish Regions Acquiring EU Funds for Local Investments in Renewable Energy Sources

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Abstract: The primary aim of this study was to assess the investment activity of basic local government units in the development of renewable energy sources co-financed by EU funds depending on CO_2 emissions and other socio-economic conditions in terms of regions of Poland in the years 2007–2020. Empirical studies aimed at the verification of the research hypothesis that "the greatest investment activity in local projects co-financed from EU funds related to the development of renewable energy sources is observed for local government units in regions with highest CO_2 emissions". Empirical studies were conducted based on data from the Ministry of Investment and Economic Development in Poland, the Local Data Bank, and the National Centre for Emissions Management. Thus, the conducted analyses provide both cognitive and applicatory values for the establishment of an appropriate energy transition policy in individual regions of Poland, which may be implemented by local government authorities within the current financial framework. Data concerning CO_2 emissions at the regional level were estimated by applying the original disaggregation method as modified by the authors, which made it possible to fill the research gap resulting from the lack of data on emissions at the regional level. In order to show the regional diversification in investment activity of local government units in terms of renewable energy sources, its multi-faceted analysis was conducted by applying the Ward method. Clusters of regions with similar investment activity of local government units were described based on characteristics included in the typological classification (so-called active characteristics) and selected indexes showing CO_2 emission levels, as well as selected socio-economic indexes (so-called passive characteristics). Based on the empirical studies, the research hypothesis presented in this paper was negatively verified. Considering both multiannual financial frameworks, the EU financial support for the development of renewable energy sources was used primarily by local government units of a predominantly agricultural character, and less advanced in terms of their development but exhibiting conditions conducive to renewable energy development.

Keywords: energy consumption; CO_2 emission; renewable energy sources; energy transition; local investments; EU projects; regions; sustainable development

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1. Introduction

Issues related to the improvement of energy efficiency, air quality, and transition to cleaner, locally available renewable energy sources are becoming priorities for European countries. Upon signing the Kyoto Protocol in 1997 [1], the European Union (EU) and its member countries became obliged to introduce actions mitigating the negative consequences of climate change by implementing a variety of policies and measures aimed at the decarbonisation of the economy. Among other things, within the framework of the European Green Deal, Europe strives to be the first continent to adopt such actions, which by 2050 will be able to remove the amount of CO_2 emissions equivalent to what it generates.

This goal is ambitious, since at present, the EU ranks third among greenhouse gas emitters, immediately after China and the United States [2]. The European leaders in this respect include Germany, France, Italy and Poland. Regions of Poland, as well as other regions in Central Europe, continue to be highly dependent on fossil fuels, the combustion of which is the main source of greenhouse gas emissions [3–5]. In order to achieve the objectives imposed by the European community to reach climate neutrality by 2050, these regions need to transform their energy systems [6].

An important element of energy transition is connected with renewable energy technologies, which constitute a key alternative to fossil fuels in all applications and sectors of the economy, from transport to the generation of electricity and heat [7]. According to the Energy Law Act, renewable energy sources are "sources using in the energy generation processes the energy of wind, solar radiation, geothermal energy, the energy of sea waves, currents and tides, river gradient as well as the energy obtained from biomass, landfill gas and biogas produced in sewage disposal or treatment, or decomposition of stored plant and animal waste" [8]. Increased use of renewable energy sources may not only result in an obvious reduction in greenhouse gas emissions but also provide a variety of significant benefits, such as decreased local air pollution or improved energy security [9], which are essential in view of depleted natural resources and being a panacea to the EU energy crisis that is additionally exacerbated by the current military conflicts. The EU policy concerning renewable energy sources is clear. The European economy is to reduce carbon dioxide emissions, which is obviously connected with the development of renewable energy sources [10]. Actions aimed at reaching this goal, decreasing barriers to integration or promoting innovations, should play a crucial role in providing a low-emission future [7].

Energy transition focused on the development of renewable energy sources warrants considerable participation of local communities, as indicated, e.g., by the authors of the Poland Net-Zero 2050 report [7]. The transition to a low-emission and ultimately a climate-neutral economy will require coordinated actions in many areas. Local government units need to play a major role in this process, since they are closest to the local residents and know their needs best. To attain this goal, it is necessary to make investments supporting energy transition, particularly those implemented at the local level, which would accelerate the sustainable development of the region. An important role in the construction of installations generating green energy is served by local investments by basic local government units in Poland, i.e., communes, which for this purpose use financing from various EU fund schemes [11,12]. Have Polish regions utilised the potential for renewable energy development, i.e., the two latest financial frameworks, within the last 14 years?

In view of the above, the primary aim of this study is to assess the investment activity of basic local government units for the development of renewable energy sources co-financed from EU funds depending on CO_2 emissions, as well as other socio-economic conditions in individual regions of Poland in the years 2007–2020. Empirical studies were conducted to verify the following research hypothesis: "The greatest investment activity in local projects co-financed from EU funds related to the development of renewable energy sources is observed for local government units in regions with highest CO_2 emissions".

2. Towards Green Energy Transition

Economic development, apart from financial aspects or enrichment of a country or an entity, aims to improve the quality of life and ensure the prosperity of the population [13]. However, attaining an adequate level of economic development and thus a satisfactory standard of living is initially connected with dynamic industrialisation processes, as stated, e.g., in the Environmental Kuznets Curve (EKC) concept [14–16]. These processes determine the increase in anthropopressure and excessive consumption of natural resources [17]. As shown by investigations conducted by Cherniwchan [18], a 1% increase in industries' share of gross domestic product (GDP) increases emissions per capita by 12%. Additionally, globalisation, economic growth and prosperity promote consumerism [19,20], which accelerates the resource-intensive production of goods and services to a degree exceeding the

carrying capacity of the environment [21–23]. As was observed by Ivanova et al. [24] and Reisch et al. [25], the consumption of goods is responsible for approximately 60% of global greenhouse gas emissions, including 50–80% of the consumption of natural resources. Economic transformations and an improved standard of living are thus associated with a considerable deterioration in the condition of the natural environment [26]. Among other things, this results from problems in appraising environmental services and limitations of the market mechanism connected with the collection of fees for the use of natural resources [27–30]. The weakness of the market and a lack of actual costs determine the scale of negative externalities [31].

A particularly troublesome problem is related to the high energy consumption of present-day economies [32], resulting among other things from the intensification of industrial processes. Due to the persisting high share of conventional energy generation technologies involving the combustion of fossil fuels, the production of energy is accompanied by greenhouse gas emissions [3–5,16,33]. In 2018, as much as 85% of the total energy consumption was covered by coal, oil and natural gas [32], with energy production constituting the greatest source of greenhouse gas emissions [32,34]. As per the results of an Intergovernmental Panel of Climate Change (IPCC) report [35], in 2019, greenhouse gas emissions were 12% higher than in 2010 and 54% higher than in 1990, and such emissions in the years 2010–2019 were the highest in history. A high demand for electricity and the intensive production of energy using conventional sources contribute to growing greenhouse gas emissions and the deepening transboundary problem of global warming. As shown by research, global warming will be responsible for 10% to 40% of all externalities in the 21st century [36].

Climate change constitutes an intangible cost of using the environment, and it also poses a health hazard and a barrier to economic development, e.g., by reducing soil fertility or depleting natural resources [37–39]. The mitigation of climate change is thus a global priority [16,37]. In view of the fact that the production of electricity continues to be the greatest source of greenhouse gas emissions, many actions aimed at reducing anthropopressure focus on measures related to energy transition, i.e., changes in the structure of energy production and the replacement of non-renewable energy sources with renewable ones [40–42]. Energy transition is necessary both to protect the environment and to ensure energy security [41,43,44]. Power cuts and blackouts are becoming a real threat, due to either the depletion of natural resources, e.g., crude oil deposits [45], or ongoing military conflicts [46,47]. The reliability of the electricity supply is crucial for the proper functioning of the economy, transport and safety [48].

In view of the existing problems and threats, many countries have already taken actions towards energy transition and improving energy security. These countries include the European Union members, particularly France, as well as Canada, China [49], and the USA [45]. They are mainly highly developed, technologically advanced countries, as indicated by economic theory. Particularly in the short-term perspective, it may seem difficult to simultaneously maximise actions connected with environmental protection and economic growth [50]. Only a high level of economic development facilitates the allocation of capital in technology, innovations leading to a reduction of emissions thanks to a greater financial elasticity, and the growing public demand for a clean environment and security [14,51,52]. Additionally, resources are invested in scientific advances and the acquisition of know how [53]. For this reason, these transitions may be termed dematerialisation [54], i.e., the replacement of resources (e.g., coal), by knowledge on the measures to reduce energy consumption or to generate energy from renewable sources [55].

Examples of the applications of know how, innovations and technologies aiming at energy transition and the mitigation of climate change include the use of hydrogen as a fuel, the construction of wind farms and the application of such technologies as bioenergy with carbon dioxide capture and storage (Bioenergy with Carbon Capture and Storage (BECCS) [56], consisting in the capture of already-emitted carbon dioxide from the atmosphere through appropriately planned afforestation [57]. An equally important

issue for effective energy transition is to recognise problems already at the regional level. Mazzantii et al. [58] indicated that for the effectiveness of actions undertaken, it is crucial to identify regional problems as well as differentiate policies and actions considering the heterogeneity of regions.

The transition towards a low-emission economy thus requires coordinated actions in many areas. One of the key roles is already played by local government units [59]. These administrative bodies are closest to local populations and have in-depth knowledge of their needs. The dispersion of sites where energy is generated from renewable energy sources promotes an increased role of local government bodies, including basic units, i.e., communes. Energy from renewable energy sources is produced in a more decentralised manner compared to conventional sources. In the case of non-renewable energy sources such as coal, the site where energy is produced is typically located close to the site where these energy sources are extracted [12].

Local government bodies, particularly communes, take a special position on the energy market and renewable energy sources initiatives in view of numerous functions served in these spheres. The basic local government unit in Poland is an energy user (frequently a major energy consumer in their area), a local energy sector regulator, an investor and producer of energy, and an entity responsible for the planning and financing of the lighting of public spaces and roads located in the area it administers [60]. Additionally, these entities may conduct information campaigns and promote the use of renewable energy sources by local residents and businesses. Moreover, the position of the commune as a public institution acting to improve the standard of living for the local population predisposes it to take an activating stance in the development of energy-cooperative activities in the area it administers. In some European countries, particularly Denmark, Germany and the Netherlands, energy cooperatives play a considerable role in the production and commercialisation of renewable energy [61–63].

The greatest barrier ro the accomplishment of energy transition principles in local government units is connected with the shortage of funds for investments. However, as indicated by the authors of the Poland Net-Zero 2050 report [7], it is caused by a lack of qualified specialists, which could prove effective in energy planning and the acquisition of external funds for programmes meeting the EU energy transition priorities.

The greatest source of funds allocated to investments aimed at energy transition, including the development of renewable energy sources, is provided by the EU. Most of these EU funds (80%) are granted through programmes, which are managed independently by individual EU member countries. The European Commission may manage the other funds, e.g., by granting subsidies or public tenders [64]. Local government bodies, through Regional Operational Programmes (ROP), may acquire funds for investments and their own enterprises coming, e.g., from the European Regional Development Fund and the European Social Fund. These Regional Programmes aim primarily at increasing the competitiveness of regions (provinces; Polish: województwa), improving the standard of living and the quality of life for their inhabitants thanks to the utilisation of the development potential and elimination of development barriers. Within the framework of competitions organised by provincial Regional Operational Programmes, support is provided, e.g., for investments in the power sector, including the production of electricity from renewable energy sources [7].

Economic development and the growing demand for electricity, along with the simultaneous need to mitigate climate change, present countries and regions with ambitious challenges related to reaching climate neutrality. In view of the fact that processes connected with the production of energy from fossil fuels are the primary source of greenhouse gas emissions, actions aimed at the energy transition of any country are the most desirable and efficient. An increase in the share of renewable energy sources in the total energy production depends first of all on measures undertaken at lower levels, including local government entities.

3. Materials and Methods

Empirical studies concerning the investment activity of local government units in regions of Poland related to the development of renewable energy sources and co-financed from EU funds were conducted based on data from the Ministry of Development Funds and Regional Policy [65,66]. The subject of these investigations consisted of 2477 communes, i.e., basic administrative units in Poland. The data for this study were collected from the database of almost 76 thousand projects within the multiannual financial framework for 2007–2013 published by the Ministry and over 80 thousand projects implemented within the EU's financial framework for 2014–2020. The criteria applied for the purpose of this analysis required the selected projects to be those supporting the transition towards a low-emissions economy and those concerning renewable energy sources, i.e., solar, wind, biomass, hydropower, geothermal, etc. These are the so-called priorities in the years 2007–2013 and the Areas of EU action in the years 2014–2020. The analyses covered only 237 such enterprises within the first and 926 within the second of these financial frameworks, in which communes were beneficiaries. This study did not investigate projects implemented by other tiers of local government in view of the fact that they are executed in an area covering several communes or counties, making it problematic when allocating a financial amount or its part to a specific area and beneficiary. The other empirical data concerning the socio-economic situation of the investigated local government units were collected from the Local Data Bank of Statistics Poland (formerly known as the Central Statistical Office, GUS) [67]. The results are presented in Polish currency (the key data were converted to euros as per the weighted average exchange rate of the National Bank of Poland in 2020 [68]).

Data concerning CO_2 emissions in regions of Poland were estimated based on an original method of estimating emissions, combining the approach proposed by the National Centre for Emissions Management (NCEM), consisting of the disaggregation of data on emissions and modifications proposed by the author [69]. Using the data from Polish National Inventory Reports prepared by the National Centre for Emissions Management (NCEM) [70] for the Intergovernmental Panel on Climate Change (IPCC), as well as Common Reporting Format (CRF) data, the conducted calculations also included categories, which jointly accounted for approximately 98% of emissions, i.e., Energy and Industrial processes and the use of products. The categories were ascribed to respective point, linear and area emission sources. In the case of point sources, emissions were taken directly from the Statistics Poland data [67] as emissions from particularly noxious plants. For linear and area sources, the share of individual provinces (Polish: województwa) in the national emissions was established based on the adopted proportional values. For linear sources, the share was calculated as the sum of products of the number of cars, trucks and buses in the province, the length of trunk roads and other roads in provinces and corresponding weights adopted based on the exhaust emission classes of cars. In the case of area sources, the share of a given region in emissions was calculated as the sum of products of consumption of individual fuels and corresponding emission indexes (hard coal, natural gas, liquefied gas and fuel gas).

Analyses were conducted to assess investment activity of local government units in individual regions, related to the development of renewable energy sources and co-financed from EU funds in Poland in two multiannual financial frameworks (covering the years 2007–2013 and 2014–2020), as well as their relationship with the volume of CO_2 emissions resulting from energy consumption and the combustion of fossil fuels, and other socio-economic conditions. The investigations consisted of several stages. The collected empirical material was transformed by applying basic descriptive statistics methods (stages 1 and 2) and using the structural classification method, which here was the Ward method (stage 3). In the first stage, the analyses concerned the diagnosis of energy consumption and CO_2 emissions in regions of Poland, while in stage 2, the size and diversification of the Polish regions were investigated in terms of the number and value of support acquired by the communes from EU funds for the development of renewable energy sources. Next,

the analyses concerned the number and total value of completed projects, the percentage of the number and value of the acquired projects, and the percentage of local government units acquiring the investigated financial support. Moreover, quantitative relationships were indicated between the level of investment activity for renewable energy sources of the communes depending on the region and selected environmental and socio-economic characteristics of Polish regions. In order to verify whether the value of acquired EU subsidies and the number of projects within the first multiannual financial framework were reflected in the success in the second financial framework, the significance test was performed for dependent variables. This study was preceded by the verification of the normality of distribution. Based on the Shapiro–Wilk test, the hypothesis assuming the normal distribution was rejected, and in the further analyses, the non-parametric Wilcoxon test was used. It is used to compare two pairs of measurements (the financial frameworks for 2007–2013 and 2014–2020) in one cluster (the analysed local government units) if the assumptions of Student's *t*-test are not met or if the results are expressed in an ordinal or quantitative scale. The analysis using this test makes it possible to classify all the results in increasing order, i.e., ranking. This test verifies the equality of medians [71].

In the final stage (stage 3) of this study, the aim was to assess the diverse levels of investment activity of local government units related to renewable energy sources and co-financed from EU funds, as well as the relationship of this phenomenon with the level of CO_2 emissions and selected socio-economic characteristics of Polish regions. For this purpose, a multivariate analysis of the investigated phenomenon was conducted by applying the Ward method. The required calculations were performed using the Statistica software 13.3 package. The taxonomic analysis made it possible to assess the diversification of the regions in terms of investments in renewable energy sources co-financed from EU funds, described using a set of simple characteristics. This leads to the identification of clusters of these regions in terms of the similarity of the complex phenomenon investigated [72]. In the multivariate evaluation of investment activity of these regions in renewable energy sources (in the first step of the proposed procedure), six simple characteristics were considered, i.e., the value of completed projects per 10 thousand inhabitants (in thousands of PLN) (x_1) and per 100 km^2 area (in thousands of PLN) (x_2), the percentage of projects implemented by the local government units in the region out of its total number in Poland (%) (x_3), the percentage of the total value of the projects of the local government units in the region out of its total value in Poland (%) (x_4), and the percentage of local government units acquiring the investigated support in a given region within the financial frameworks for 2007–2013 and 2014–2020 (%) (x_5) (with x_4 being rejected at the further stages of analyses in view of the high degree of correlation with the other simple characteristics). In the second step, the values of simple characteristics were normalised by applying the classical standarisation procedure. In the third step, the Polish regions were classified using the Ward method. Hierarchical cluster analysis consists of linking the closest units until one cluster is obtained. The distance between units is estimated using the analysis of variance in order to minimise the sum of squares of deviations within the clusters. The agglomeration graph was analysed in order to determine the optimal number of classes. The distinguished typological classes were described using the so-called active characteristics, showing the level of investment activity of local government units in renewable energy sources, as well as passive characteristics, presenting socio-economic and environmental conditions for the investigated phenomenon, focusing on environmental conditions and CO_2 emissions.

4. Results of Empirical Studies

4.1. Consumption of Electricity and CO_2 Emissions Depending on the Regions of Poland

In accordance with global trends, the consumption of electricity is growing from year to year [30]. Analogous changes are also observed in all regions of Poland. In 2007, the greatest consumption of electricity was recorded in the Śląskie province, where it amounted to over 5000 kWh/person (Figure 1). This high energy consumption was connected with the industrial character of the region and a high concentration of power plants and heat- and

power-generating plants, which resulted from the location and extraction of coal deposits. The Opolskie and Mazowieckie provinces ranked next in terms of energy consumption. In the Opolskie province, this high energy consumption is connected with the high number of manufacturing plants in relation to the low population density in the region, while in the case of the Mazowieckie province, this resulted from the location of the capital city, which constitutes a growth pole. The lowest energy consumption was recorded for the Podlaskie, Podkarpackie and Warmińsko-mazurskie provinces, i.e., regions, which are not industrialised. In 2020, an analogous situation was observed, with the Opolskie, Śląskie and Mazowieckie being the regions with the greatest energy consumption, while those with the lowest energy consumption included the Podkarpackie, Warmińsko-mazurskie and Podlaskie provinces (Figure 1).

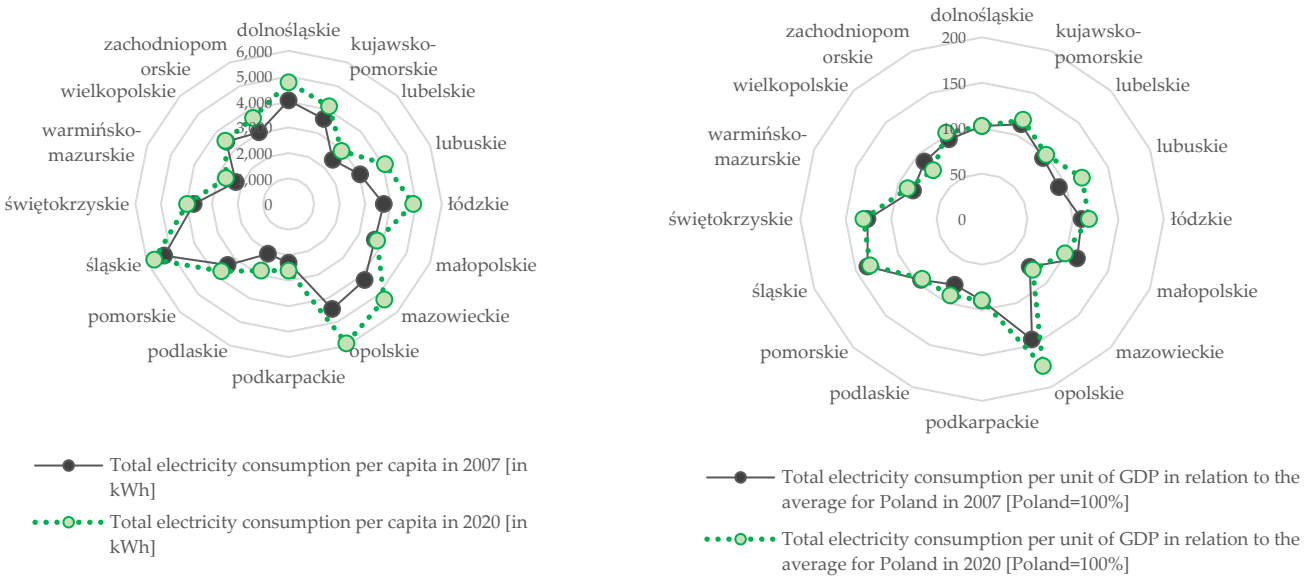

Figure 1. Regional diversification of electricity consumption in Poland in the years 2007 and 2020. Source: the author's study based on [67].

An analogous trend is observed for the total consumption of electricity per GDP in relation to the national mean (Figure 1). In most regions, consumption increased in the investigated period. A slight decrease is observed only for the Wielkopolskie, Śląskie, Pomorskie and Małopolskie provinces, which may indicate a reduction in energy intensity in the economy of this region, a positive phenomenon. In accordance with the Environmental Kuznets Curve, this may be explained by the composition effect, i.e., changes in the structure of the economy, as well as technological progress and the implementation of innovations.

Energy consumption and the related energy production constitute the main sources of greenhouse gas emissions. For this reason, the heavily industrialised regions are typically characterised by high emission levels. Apart from the degree of industrialisation and energy intensity of the economy in the region, the source of energy used also influences the level of emissions.

In the case of conventional power plants, anthropopressure is much greater than renewable energy sources. In accordance with legal regulations, both national and international, the share of renewable energy sources in the production of energy in Poland is expected to grow. By realising the objectives of green policies in the investigated period, we could observe an increase in the share of renewable energy in the total energy production in all regions of Poland. The greatest share of renewable energy sources and an increase in its share were recorded in the Podlaskie, Warmińsko-mazurskie, Zachodniopomorskie and Pomorskie provinces (Figure 2). These are the regions with a relatively low level of industrialisation, as a result of which the share of renewable energy in total energy production compared to the other regions is highest. The lowest share of renewable energy

sources out of the total energy production is found in the industrial regions, in which conventional energy production technology on the national scale is greatest. These were the Opolskie, Śląskie, Dolnośląskie, Łódzkie and Mazowieckie provinces.

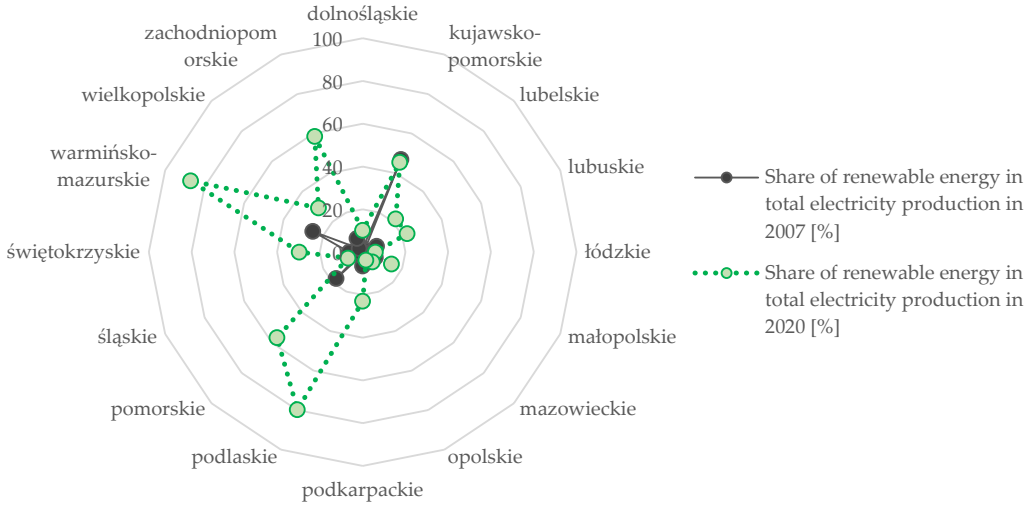

Figure 2. Regional diversification in the share of renewable energy in the total production of electricity in Poland in the years 2007 and 2020. Source: the author's study based on [67].

Considering the level of industrialisation and sources of electricity, it seems plausible to justify disproportions in greenhouse gas emissions in the different regions of Poland. The relatively high emission levels are found first of all in the industrial regions, with the predominant production of electricity from fossil fuels. The highest emissions per capita were recorded in the Opolskie and Łódzkie provinces, which resulted from the high number of manufacturing plants and a relatively low population density. In relation to the area of the region, the greatest emissions are found in the Śląskie province, where, due to the location of lignite deposits, the largest number of plants and industrial plants are situated (Figure 3).

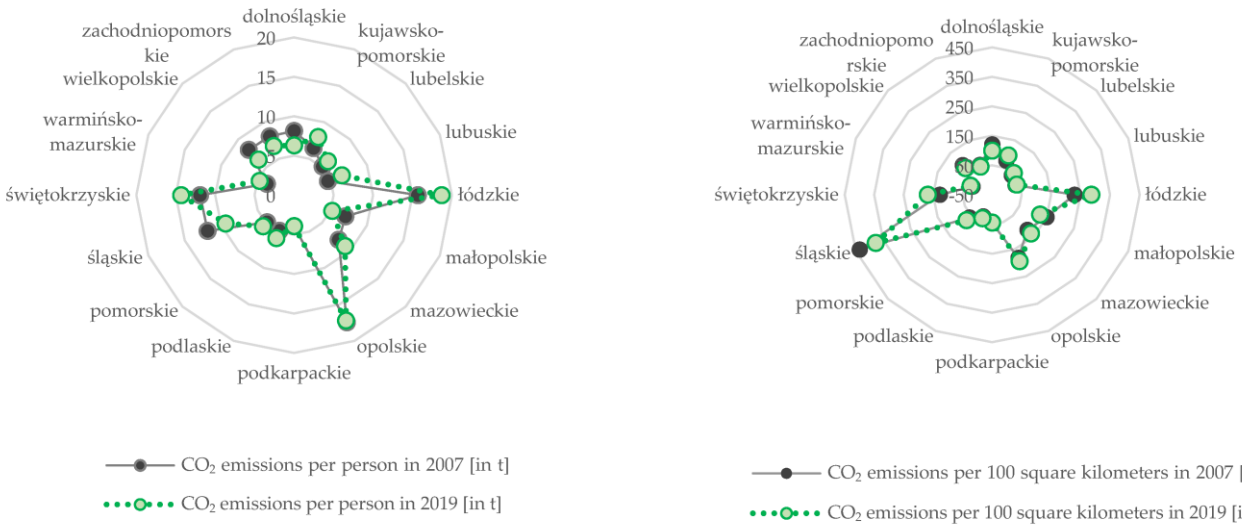

Figure 3. Regional diversification of CO_2 emissions in Poland in the years 2007 and 2019. Source: the author's calculations based on [67,70].

When analysing correlation coefficients between energy consumption, the share of renewable energy sources in the production of energy, and CO_2 emissions, it needs to be stated that energy consumption strongly determines the level of emissions in individual regions of Poland. Increased total consumption of electricity leads to a growth in CO_2

emissions (Table 1). This results from the still-dominant share of energy from conventional sources in the total production of energy. Despite the low correlation coefficients between the share of renewable energy sources in energy production and CO_2 emissions, it needs to be stated that the signs for the coefficients indicate a negative correlation, which means that with an increase in the share of renewable energy sources, the resulting emissions are reduced. A significant correlation between the level of CO_2 emissions per 100 km^2 and the share of renewable energy in the total production of electricity in the Polish regions was observed in 2020 (Table 1).

Table 1. Pearson's linear correlation coefficients between the level of CO_2 emissions and indexes illustrating the consumption of electricity and the share of renewable energy in total production of electricity depending on regions of Poland.

Parameter	Consumption of Electricity Per Capita (in kWh)		Total Consumption of Electricity Per GDP in Relation to the Mean for Poland (Poland = 100%)		Share of Renewable Energy in Total Production of Electricity (%)	
	2007	2020	2007	2020	2007	2020
CO_2 emissions per capita (in t)	0.70 *	0.66 *	0.75 *	0.71 *	−0.35	−0.46
CO_2 emissions per 100 km^2 (in kt)	0.83 *	0.77 *	0.70 *	0.55 *	−0.31	−0.59 *

Significance level: * $p = 0.05$. Source: the author's calculations based on [67,70].

Based on the results of these analyses, it may be stated that energy consumption is a significant determinant of changes in CO_2 emissions in individual regions of Poland. In view of the growing demand for energy and the high share of conventional energy-production systems, the adopted priorities should focus on actions leading to Poland's energy transition and a reduction in energy production using fossil fuels.

4.2. Local Investments in Renewable Energy Sources Co-Financed from EU Funds in Individual Regions of Poland

Support for investments in energy-sector infrastructure is in line with the assumptions of the EU cohesion policy. The adopted system of the thematic areas of this policy comprises the term "low-emission economy", referring to the reduction in carbon dioxide emissions. Europe is one of the largest greenhouse gas emitters [2], while the European Community presented an ambitious long-term goal of reaching climate neutrality by 2050. In order to attain this assumed goal, actions are being undertaken, aiming, among other things, at the development of renewable energy sources and increased consumption of renewable energy. In 2021, the final energy consumption originating from renewable sources in the EU amounted to slightly over 20% [73], whereas by 2030, the binding goal has been set for the final energy consumption in the EU to include a minimum of 32% to be generated from renewable sources. Moreover, a clause has been passed making it possible to increase this amount, as well as increase the goal concerning the 14% energy from renewable sources in transport [74].

Poland belongs to the group of countries with the lowest final share in the consumption of energy from renewable sources, which was below the EU average in 2021 [75]. Thus, reaching the strategic goal for renewable energy sources requires considerable funds to finance investments in this respect in Polish regions. The main sources of financing for energy projects are EU funds. For this reason, analyses were conducted to assess the scale of investments in renewable energy sources in regions of Poland, co-financed from EU funds, and its evolution in two EU multiannual financial frameworks, i.e., in the years 2007–2013 and 2014–2020. The adopted period of analysis was the time when Poland was an EU member country during two complete financial frameworks (see [76–78]), and its beneficiaries could use the huge EU assistance to make investments supporting energy transition towards climate neutrality [79,80]. Thus, characteristics were provided for the

acquired projects focused on energy from renewable sources co-financed from the EU budget and executed by communes, which are the basic local government units in Poland, depending on the region.

These analyses showed that in Poland, within the multiannual financial framework for 2007–2013, a total of 572 projects were executed, while in the next financial framework, for 2014–2020, it was as many as 2625 projects in renewable energy sources, for a total amount of PLN 3.4 billion and PLN 7.8 billion, respectively (EUR 0.8 billion and EUR 1.8 billion). In the years 2007–2013, projects in renewable energy sources accounted for 28.3% of the total amount of projects and 46.4% of the total amount of projects in a low-emission economy, whereas in the financial framework for 2014–2020, it was 31.1% and 11.0%, respectively. It needs to be stressed that greater support for the development of low-emission economy was accompanied by a lower share of total funds allocated to the development of renewable energy sources [65,66].

Local government units, including communes, are the most active beneficiaries of the acquired EU support for the development of renewable energy sources. In both investigated financial frameworks, they jointly completed 1163 projects in renewable energy sources, which constituted more than one-third of their total number. Generally, the completed projects amounted to PLN 4.3 billion (EUR 1.0 billion), which accounted for almost 40% of their total value. In the years 2007–2013, commune enterprises constituted over 40% of these investments, i.e., 23% of funds allocated for the development of renewable energy sources. In turn, in the next multiannual financial framework, the share of executed projects was slightly lower, whereas the value of commune projects related to renewable energy sources accounted for almost 50% of the value of all the projects.

What needs to be stressed here, in the analysed multiannual financial frameworks, is that the activity of communes in the acquisition of support for investments in renewable energy sources increased in both the number of investments (an almost 3-fold growth) and the total value of investments in renewable energy sources (an almost 3.5-fold increase). In the first of the investigated multiannual financial frameworks, the activity in the acquisition of EU support for investments in renewable energy sources was recorded for 7.4% of the communes in Poland, while in the next framework, it was recorded for over 27% of the communes in Poland (Table 2).

All local projects related to renewable energy sources are executed by communes within the framework of Regional Operational Programmes, i.e., programmes dedicated to meeting the needs of beneficiaries from a specific region. As was observed by Gradziuk, Gradziuk and Kawecka-Wyrzykowska [3,4], thanks to the fact that the operation of renewable energy sources is financed from Regional Operational Programmes (ROPs), they are adapted to local conditions (prioritizing socio-economic development, the natural environment, and resources). The county and provincial local governments also used national programmes, from which they could acquire even greater subsidies. In the case of support acquired by the investigated communes, we may observe their spatial diversification. In the multiannual financial framework for 2007–2013, in over half of Polish region no activity of basic local government units was observed in the acquisition of EU support for the development of renewable energy sources, while in the case of most other regions, this activity was relatively limited. The highest activity during the discussed period was observed in the case of communes from the Podlaskie (37.3%) and Lubelskie provinces (28.6%). In the multiannual financial framework for 2007–2013, investments in renewable energy sources were frequently neglected by Polish authorities and the general public, and in many regions, they were developed to a minimal degree only due to the EU requirements, with no apparent enthusiasm or commitment on the part of local authorities. Moreover, it needs to be stressed that it was the first financial framework in which Poland participated throughout its entire period. Additionally, at that time, funds were allocated to what then seemed to be more important, such as the development of transport infrastructure or agriculture [81,82].

Table 2. Characteristics of renewable energy projects co-financed from EU funds and executed by communes depending on the region within financial frameworks for 2007–2013 and 2014–2020.

List	2007–2013						2014–2020					
	Mean Value of Project (in Thousand PLN)	Number of Projects	Total Value of Projects (in Thousand PLN)	Investments in Renewable Energy Sources per 10 Thousand Inhabitants (in Thousand PLN)	Investments in Renewable Energy Sources per 100 km^2 (in Thousand PLN)	% Communes Acquiring Funds in the Region	Mean Value of Project (in Thousand PLN)	Number of Projects	Total Value of Projects (in Thousand PLN)	Investments in Renewable Energy Sources per 10 Thousand Inhabitants (in Thousand PLN)	Investments in Renewable Energy Sources per 100 km^2 (in Thousand PLN)	% of Communes Acquiring Funds
Dolnośląskie	0.0	0	0.0	0.0	0.0	0.0	3358.3	9	30,224.3	103.9	151.5	4.1
Kujawsko-Pomorskie	0.0	0	0.0	0.0	0.0	0.0	1075.9	69	74,236.1	365.4	413.1	34.7
Lubelskie	4105.4	93	381,802.9	1770.8	1519.8	28.6	3817.9	291	1,110,996.2	5401.3	4422.2	88.3
Lubuskie	0.0	0	0.0	0.0	0.0	0.0	545.0	3	1634.9	16.5	11.7	3.7
Łódzkie	9378.8	6	56,272.5	223.9	308.9	4.0	3237.8	64	207,221.6	857.8	1137.4	32.8
Małopolskie	1744.7	9	15,702.7	46.7	103.4	4.4	52,743.0	3	158,229.1	460.9	1042.1	1.6
Mazowieckie	3349.4	25	83,735.9	157.5	235.5	5.1	8846.0	32	283,070.8	513.0	796.1	10.2
Opolskie	1402.5	7	9,817.6	97.7	104.3	8.5	0.0	0	0.0	0.0	0.0	0.0
Podkarpackie	2852.7	18	51,348.5	241.2	287.7	10.6	8028.0	71	569,988.6	2719.2	3193.9	36.3
Podlaskie	2100.3	51	107,115.3	896.4	530.6	37.3	1039.5	123	127,864.6	1105.5	633.4	71.2
Pomorskie	2024.9	18	36,448.1	158.8	199.1	13.0	6960.6	18	125,290.6	531.3	683.8	14.6
Śląskie	4964.8	10	49,647.9	107.9	402.6	5.4	3555.7	144	512,015.6	1160.5	4151.6	50.3
Świętokrzyskie	0.0	0	0.0	0.0	0.0	0.0	4590.2	27	123,935.3	1033.2	1058.4	25.5
Warmińsko-mazurskie	0.0	0	0.0	0.0	0.0	0.0	677.7	38	25,751.3	185.8	106.5	28.2
Wielkopolskie	0.0	0	0.0	0.0	0.0	0.0	7195.8	23	165,502.9	471.9	554.9	10.2
Zachodniopomorskie	0.0	0	0.0	0.0	0.0	0.0	1638.5	11	18,023.5	108.5	78.7	5.3
Poland	3341.3	237	791,891.4	205.7	253.3	7.4	3816.4	926	3,533,985.4	927.8	1130.1	27.2

Source: The authors' study based on [65,66].

In the next multiannual financial framework for 2014–2020, huge potential opportunities appeared for Polish regions thanks to the EU funds and an even greater amount of money allocated to the support of investments. A marked almost four-fold increase was observed in the activity of local government units in the acquisition of projects investing in the development of green energy (Table 2). The Lubelskie province was a leader among the Polish regions in support from EU funds for energy transition, as it was the region with the highest increase in the percentage of communes acquiring such support (by almost 60 p.p.). Studies conducted by Gradziuk and Gradziuk [3] also confirmed the considerable success in the acquisition of EU funds by local government units of the Lubuskie province, particularly thanks to the implementation of enterprises aiming at the installation of solar collectors and photovoltaic panels. An increase in the scale of this investment activity was also observed in such regions as the Śląskie (by almost 45 p.p.), Kujawsko-Pomorskie (by almost 35 p.p.) and Podlaskie provinces (by almost 34 p.p.). The activity of local government units in the acquisition of projects investing in the development of green energy is highly correlated with the value of acquired funds both per 10 thousand inhabitants (r = 0.78) and per 100 km^2 area of the region (r = 0.71). This means that success in energy transition is provided by the activity of all governing bodies in each of the provinces.

When investigating the level of executed investments in renewable energy sources jointly in the two analysed multiannual financial frameworks, the largest funds were definitely spent by communes from three regions, i.e., the Lubelskie, Podkarpackie and Śląskie provinces (Table 2). It was communes from these provinces that were the leaders of the absorption of funds in both financial frameworks. On the one hand, this is connected with the significant role of experience in the acquisition of EU subsidies in the first of the financial frameworks (see [83,84]), while on the other hand, it results from the importance of environmental problems for local government authorities (Figure 4). The Wilcoxon test for dependent measurements showed that the experience gained by communes in the years 2007–2013 was manifested in their success in the acquisition of EU funds for the development of renewable energy sources in the next multiannual financial framework. This test confirmed the dependence between both the total values of the projects and the number of projects in both financial frameworks at the significance level p = 0.00 (Table 3). Obviously, in these regions, the value of these investments per 100 km^2 was also highest. Jointly, they constitute over $\frac{1}{2}$ of the value of all completed projects co-financed from EU funds in Poland. Moreover, a relatively high concentration was observed in the number of implemented enterprises in renewable energy sources in the same regions, which executed over 60% of the total number of these projects.

It may be surprising that in the Opolskie province, in the multiannual financial framework for 2014–2020, no commune acquired a project to make investments in green energy. Limited interest in such enterprises was also recorded in the Zachodniopomorskie and Pomorskie provinces, even though Zachodniopomorskie has excellent conditions for wind energy installations. The diversification in the investments depending on the region is extensive, as indicated by the indexes presented in Table 2 and Figure 4. In view of both the volume of investments in renewable energy sources per capita and per unit area, the most active local government units are those from the provinces in eastern Poland, while a slightly lesser activity was reported for those from central Poland, and the lowest investments in renewable energy sources were executed in western Poland.

Among the four distinguished areas of intervention, most Polish communes acquired subsidies for solar energy in both analysed multiannual financial frameworks (jointly 1101 projects, i.e., almost 95% of all projects), absorbing for this purpose almost PLN 4.2 billion (EUR 0.9 million), which constituted 96% of their total amount. It needs to be stressed that the number of these projects in the second multiannual financial framework increased by over four-fold. The other area of interest on the part of Polish communes focused on renewable hydropower, geothermal and other types of renewable sources. In each of these periods, 21 such enterprises were made each. Energy from biomass and wind energy were of interest for very few beneficiaries, among which projects related to

biomass were generally most capital-intensive in the years 2007–2013, while wind energy projects were most capital-intensive in the years 2014–2020. As indicated by [85], in Poland, a particularly important role may be played by solar energy and biomass. The utilisation of solar energy is connected with climatic conditions and insolation [85,86]. In turn, biomass may be directly combusted or converted to biogas [85,87]. It needs to be stressed that the European Union is also interested in the utilisation of renewable energy through an increased use of byproducts and organic waste. This is connected with the production of new-generation biofuels, which creates huge opportunities for the development of rural areas and agriculture, where over a half of the world's production is not suitable for human consumption [88].

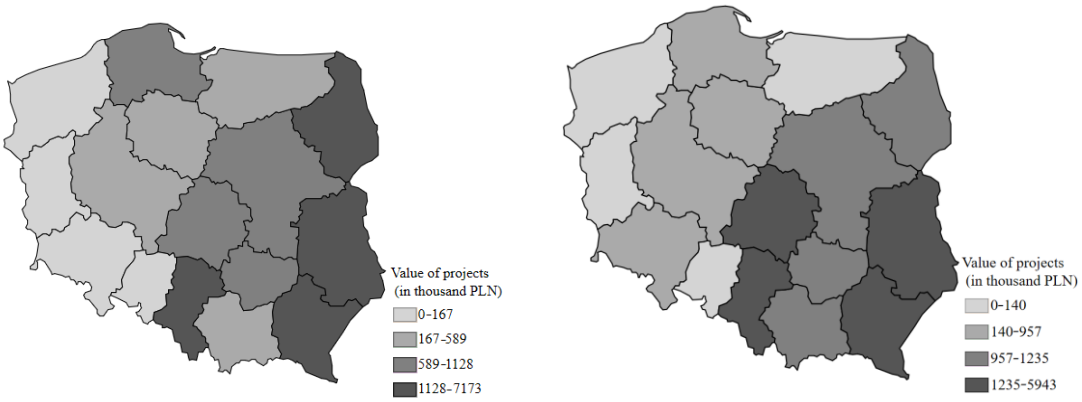

Figure 4. Renewable energy projects realised by communes co-financed from EU funds in Poland within multiannual financial frameworks for 2007–2013 and 2014–2020 depending on the region. Source: The authors' study based on [65,66].

Table 3. Results of the Wilcoxon test for dependent measurements for selected indexes illustrating the acquisition of EU funds for renewable energy sources by communes within multiannual financial frameworks for 2007–2013 and 2014–2020.

Pair of Variables	Test Result	*p*-Value
Number of renewable energy projects in 2007–2013 and number of renewable energy projects in 2014–2020	17.3434	0.00
Investments in renewable energy sources in 2007–2013 and investments in renewable energy sources in 2014–2020	16.7059	0.00

Source: the author's study based on [67].

In terms of the type of local government, when analysing both the number and value of investments in renewable energy sources, the greatest activity was observed for rural and rural–municipal local government units. Renewable energy enterprises should use the ecological potential of rural areas, which, as a consequence, may contribute to changes in land use and increased revenue for farmers. Thanks to renewable energy sources, the economies of rural and rural–municipal communes may be transformed [89,90].

In the years 2007–2013, out of five of the most active local government units, four came from the Lubelskie province and were rural in character and executed from 4 to 8 enterprises related to the development of renewable energy sources. In turn, in the years 2014–2020, the leading role was played first of all by rural local government units from the Lubelskie and Śląskie provinces, also including two towns with county rights, particularly Jastrzębie Zdrój, which implemented as many as nine such projects. However, when considering the number of individual units in the administrative system of Poland, it turns out that towns with county rights were the most effective beneficiaries. This is connected with the fact that towns have the largest needs for renewable energy sources, since within their boundaries, all the negative consequences of development tend to accumulate (see [91–93]). What is important is that the average investment in renewable energy sources amounts to PLN

3.3 million (EUR 0.7 million) in the first financial framework and PLN 5.3 million (EUR 1.2 million) in the second financial framework, but around a dozen Polish local government units spent from PLN 20 million (EUR 4.5 million) to as much as PLN 70 million (EUR 15.8 million). This means that they are capital-intensive enterprises, which only richer local government units may afford, and such entities are typically cities or towns with county rights [94–96].

4.3. Multivariate Analysis of Renewable Energy Investment Activity Co-Financed from EU Funds of Local Government Units and Its Environmental and Socio-Economic Conditions

In the next stage of the study, the Ward method was applied, and the analyses involved selected indexes illustrating the investment activity of communes related to renewable energy sources and co-financed from EU funds. On this basis, six typological classes of Polish regions were distinguished. These classes were characterised by a varied level of investment activity of local government units in the implementation of projects aimed at the development of renewable energy sources. The distinguished typological classes were described using active characteristics involved in the procedure of structural classification, as well as passive characteristics, reflecting the environmental and socio-economic conditions of these Polish regions.

Two classes, comprising a single element each, were formed by the Podlaskie (class I) and Lubelskie provinces (class III). The Lubelskie province is a leader in Poland in terms of local renewable energy investments co-financed from EU funds. In the two multiannual financial frameworks, it acquired projects amounting to almost PLN 7.2 million (EUR 1.6 million) per 10 thousand inhabitants, i.e., over PLN 5.9 million (EUR 1.3 million) per 100 km^2 of the region. As a consequence, this region also executed more than 1/3 of the total number and value of projects acquired by all local government units in Poland. We also need to stress here the high investment activity of local government units in that region, as almost 90% of them acquired at least one renewable energy project co-financed from EU funds at the national average of less than 25%. Leaders among the beneficiaries from that province included the communes of Piaski, Janów Lubelski and Niemce. Piaski, together with Bychawa and Biała Podlaska, completed the largest projects, amounting to as much as PLN 10 million (EUR 2.3 million), particularly concerning solar energy. The Lubelskie province is the region with the lowest level of development in Poland quantified by GDP per capita. It is an agricultural region with good soil and climatic conditions suitable for the development of agriculture, as well as the development of renewable energy sources. However, this region suffers from depopulation, since during the investigated period, it had the highest negative value of changes in the number of inhabitants per 1000 inhabitants (−36 people per 1000 inhabitants, while the national average was positive). Due to the low level of industrial development and its agricultural character, this region is characterised by a low level of CO_2 emissions per capita and per 1 km^2 of the region area (Table 4). The high investment activity in renewable energy in the region with a low level of development may be considered a positive phenomenon, influencing the growth in the dynamics of its development. The development of renewable energy sources is the issue not only of energy security and lower energy costs but also of the accelerated transformation of Poland, presenting numerous advantages for the economy and the population of a given region.

Table 4. Class diversification of Polish regions in terms of local investments in renewable energy sources co-financed by EU funds in the years 2007–2020 (average values in classes—medians).

List	Typological Class						Total
	I	II	III	IV	V	VI	
	Podlaskie	Podkarpackie, Śląskie	Lubelskie	Kujawsko-Pomorskie, Łódzkie, Pomorskie, Świętokrzyskie, Warmińsko-Mazurskie	Małopolskie, Mazowieckie, Wielkopolskie	Dolnośląskie, Lubuskie, Opolskie, Zachodniopomorskie	
Indexes illustrating renewable energy investment activity co-financed from EU funds in the years 2007–2020							
Investments in renewable energy sources per 10 thousand inhabitants (in thousand PLN)	2001.9	2114.4	7172.1	690.0	507.7	100.8	1133.5
Investments in renewable energy sources per 100 km^2 (in thousand PLN)	1164.0	4017.9	5942.0	882.8	1031.6	91.5	1383.4
Percentage of the number of projects realised in the region (%, total in Poland = 100%)	15.0	10.4	33.0	3.3	2.0	0.7	100
Percentage of total value of realised projects in the region (%, total in Poland = 100%)	5.4	13.7	34.5	2.9	4.0	0.3	100
Percentage of communes acquiring renewable energy projects co-financed from EU funds in the region (%)	79.7	47.6	89.7	28.2	10.2	4.7	29.9
Indexes illustrating the level, dynamics of changes and structure of CO_2 emissions							
CO_2 emissions in tonnes per capita (2019)	5.9	6.7	6.1	8.0	6.4	6.6	8.2
Dynamics of changes in CO_2 emissions in tonnes per capita in 2019 in relation to 2007 (in %)	20.6	−10.6	18.4	20.0	−21.5	−8.9	14.6
CO_2 emissions per 100 km^2 (in kt) (2019)	36.5	210.9	53.8	94.2	126.0	76.2	100.2
Dynamics of changes in CO_2 emissions per 100 km^2 in 2019 in relation to 2007 (w %)	22.7	−7.7	22.8	25.0	−15.2	−1.9	14.5
Share of the province in CO_2 emissions (%, 2019)	2.2	8.1	4.1	5.3	7.1	4.5	5.3
Change in the share of provinces in CO_2 emissions in 2019 in relation to 2007 (in p.p.)	0.4	−1.9	0.6	0.8	−1.6	−0.5	0.4
Indexes illustrating the socio-economic situation of regions in 2020 and its changes in relation to 2007							
GDP per capita in PLN	45,345.0	52,071.0	42,370.0	50,246.0	66,499.0	50,999.5	31,155.0
Dynamics of changes in GDP per capita in 2020 in relation to 2007 (in %)	196.2	190.6	194.7	187.8	200.4	187.4	196.5
Economic entities per 10 thousand inhabitants	947.0	1009.5	937.0	1032.0	1315.0	1289.5	967.0
Dynamics of changes in the number of enterprises in 2020 in relation to 2007	127.5	127.4	134.0	119.5	133.0	118.1	126.6
Population density (persons per 1 km^2)	57.3	237.6	81.9	113.0	155.2	87.1	121.8
Population density in developed and urbanised areas (persons per 1 km^2)	1471.0	2515.0	2054.0	2104.0	2566.0	1613.5	217.0
Change in population per 1000 inhabitants for 2007–2020 (total)	−19.3	−13.7	−36.2	−7.1	41.9	−2.0	3.6
Own income per person (in PLN)	2728.6	2891.2	2277.5	2793.4	3060.8	3151.7	3187.5
Dynamics of changes in own income per capita in 2020 in relation to 2007 (in %)	260.7	240.3	256.5	228.6	220.9	224.9	211.9
Share of own income in total income (in %)	42.6	45.2	37.3	44.4	48.6	50.1	48.8

Table 4. *Cont.*

List	Typological Class						Total
	I	II	III	IV	V	VI	
	Podlaskie	Podkarpackie, Śląskie	Lubelskie	Kujawsko-Pomorskie, Łódzkie, Pomorskie, Świętokrzyskie, Warmińsko-Mazurskie	Małopolskie, Mazowieckie, Wielkopolskie	Dolnośląskie, Lubuskie, Opolskie, Zachodniopo-morskie	
Share of developed and urbanised land (%)	3.9	9.2	4.0	5.4	6.0	5.5	5.6
Share of renewable energy in total production of electricity (%)	79.8	15.2	21.9	45.4	14.6	16.4	17.9
Change in the share of renewable energy in total production of electricity in 2020 in relation to 2007 (in p.p.)	78.0	11.5	20.7	23.3	8.1	12.0	14.5
Total consumption of electricity per capita (in kWh)	2824.7	4149.3	2936.5	3973.0	3750.4	4423.9	4235.3
Dynamics of changes in consumption of electricity in 2020 in relation to 2007 (2007 = 100%)	133.8	110.6	120.2	115.0	102.6	126.4	115.7
Total consumption of electricity per GDP in relation to national mean (Poland = 100%)	90.9	111.4	100.0	117.7	79.0	110.9	100.0
Cars per 1000 people	576.5	617.6	655.8	638.7	714.6	693.7	659.4
Share of agriculture and forestry in gross value added (%)	3.6	0.6	2.9	1.9	1.4	1.4	1.3
Share of industry and construction sector in gross value added (%)	14.9	17.3	13.6	16.6	14.4	17.8	15.4

Source: the authors' calculations based on [65–67,70].

The single-element class I was composed of the Podlaskie province. It is distinguished by high activity of local government units in the acquisition of projects in renewable energy sources co-financed by EU funds. Communes in that region during the two multiannual financial frameworks acquired investment projects for over PLN 2 million (EUR 0.5 million) per 10 thousand inhabitants, i.e., over 76% more than the national average. That region was also distinguished by a high activity of local government units in the acquisition of the investigated support (almost 80%, at the national average below 30%). Local government units in that region executed as much as 15% of the total number of projects, although in terms of their value, it was only 5.4% of the total value of completed renewable energy projects co-financed by EU funds in Poland. The Grajewo commune was the most successful in the absorption of the analysed support, as in the first financial framework, it obtained approximately PLN 15 million (EUR 3.4 million) for two enterprises, including almost PLN 14 million (EUR 3.2 million) for the project for energy generation from biomass. Grajewo, together with Ciechanowiec and Augustów, realised the most capital-intensive renewable energy investments. The Podlaskie province is a region of green energy in Poland, and it is characterised by low CO_2 emissions (the share of this region in CO_2 emissions is only 2.2%). During the two financial frameworks, the level of development of renewable energy sources in that region and the production of green energy changed to the greatest extent. In 2007, the share of renewable energy in the total production of electricity in the Podlaskie province was as low as 1.8%, while in 2020, it was already almost 80% (at the national average of 17.9%) (Table 4). Most investments were projects in the development of solar energy (almost 88% in terms of value and over 92% in terms of their number). Additionally, in the Podlaskie province compared to the other regions, a relatively large role was played by projects concerning the generation of energy from biomass (almost 1/3 of projects in terms of their value were executed in that region).

The lowest investment activity of local government units, co-financed from EU funds and related to the development of renewable energy sources, was observed in the last typological class IV. It comprised four regions—the Dolnośląskie, Lubuskie, Opolskie and the Zachodniopomorskie provinces. In this class, the lowest value of completed projects, both per 10 thousand inhabitants (PLN 100.8 thousand, i.e., EUR 22.7 thousand) and per 100 km^2 of the region (PLN 91.5 thousand), was considerably below the mean for all the local government units in Poland. Local government units from the analysed regions within the two financial frameworks executed very few projects, in terms of both their number and value. In those regions, a low activity of local government units was observed in the absorption of EU funds concerning the development of renewable energy sources (only every twentieth commune acquired a minimum of one such project within the two financial frameworks). Most regions constituting this class are distinguished by a low level of CO_2 emissions, except for the Opolskie province. Additionally, a typical characteristic of this class is related to the low average share of renewable energy in the total production of electricity. In terms of individual data for specific regions, we may see a very poor situation of the Opolskie province. In that region, the share of renewable energy in the production of electricity was as low as 4.1%, with the national average amounting to almost 18% (Table 4). This region has a very high potential for the development of renewable energy sources (e.g., thanks to the high share of agriculturally utilised area of over 60%). As reported by Juszczak and Maj [97], the potential of photovoltaics in Poland is not fully utilised, particularly in the southern regions, including the Opolskie province.

The two-element class, class II, was formed by two provinces, i.e., Podkarpackie and Śląskie. They are similar considering investment activity in the development of renewable energy sources, but they differ markedly in terms of their environmental and socio-economic conditions. Local government units in both regions actively acquired EU funds allocated to the development of green energy within two multiannual financial frameworks, reaching results exceeding the national average. The level of development and environmental problems in both investigated regions varied. The first of them, the Podkarpackie provinces, is situated in eastern Poland. It is distinguished by a markedly

lower level of urbanisation and a higher share of utilised agricultural area and forest cover. As a result, its demographic and economic potential was lower in relation to the other regions. The lower level of industrialisation is also indicated by the structure of CO_2 emission sources in the Podkarpackie province, in which CO_2 emissions from transport exceed the CO_2 emissions originating from particularly noxious plants. This does not mean that transport in that region is a well-developed branch of the regional economy. It rather indicates very low levels of pollution generated by economic entities. As a result, indexes show that the level of CO_2 emissions per capita in that region are the lowest in Poland. In turn, the greatest environmental problems in this respect are found in the Śląskie province, with the highest and definitely exceptional level of CO_2 emissions per unit area. This province is one of the most industrialised regions in Poland. The main sources of CO_2 emissions include particularly noxious plants located in this province. A very high population density and a high level of entrepreneurship are reflected in the affluence of these communes, but also in the high level of generated GDP. In the Silesia (Polish: Śląsk) region, we observe a high level of urbanisation, and cities in this province form one of the largest polycentric agglomerations in Europe. For this reason, in that area, the largest part of completed projects supporting the development of renewable energy sources in terms of value is accumulated. This province comprises local government units, which jointly, in both multiannual financial frameworks, acquired the greatest support among local government units throughout Poland. For this purpose, Zawiercie and Tarnowskie Góry spent PLN 70 million each (EUR 15.8 million), implementing only one project each. Both these projects were related to solar energy.

Class V comprised three regions—the Małopolskie, Mazowieckie and Wielkopolskie provinces. These regions were distinguished by the relatively low average investment activity of local government units concerning acquired EU funds allocated to the development of renewable energy sources (Table 4). On average, in the discussed class, only every tenth commune executed at least one such project, while in Poland, it was almost three communes out of ten. The low activity of local government units in the acquisition of the discussed projects resulted in a situation in which the funds acquired per person were almost 1/2 lower than the national average. In the group of these regions, in terms of environmental problems and CO_2 emissions, the Mazowieckie province was exceptional. It is the largest region in Poland, since it is more than five-fold larger in terms of the number of inhabitants compared to the Opolskie province, and at the same time, it is the region with the highest level of development. In the case of the Mazowieckie province, an important role in the implementation of projects co-financed from EU funds is played by the capital of this region and of Poland, Warszawa. It is distinguished by a high demographic and economic potential in relation to the other regional centres, and in the case of Warszawa, the population is increasing annually (the other regional centres suffer from suburbanisation), which exacerbates environmental problems. Despite the many investments, both those related to renewable energy sources and low-emission economy [98], the air quality in the capital of the Mazowieckie region is still unsatisfactory. On average, on every fourth day, the concentration of hazardous PM2.5 particulates exceeds the standards recommended by the WHO [99].

The most numerous class V comprised five regions, i.e., the Kujawsko-pomorskie, Łódzkie, Pomorskie, Świętokrzyskie and Warmińsko-mazurskie provinces. First of all, these regions are similar in terms of the activity of local government units in the acquisition of EU projects for the development of renewable energy sources. In that class, on average, at least every fourth commune acquired and executed a minimum of one such project in the two analysed multiannual financial frameworks. However, they differ in the volume of investments, e.g., per capita. A lower level of EU funds was allocated to the development of renewable energy sources acquired by communes in the regions of northern Poland, i.e., the Warmińsko-mazurskie, Kujawsko-pomorskie and Pomorskie provinces, in relation to two other regions located in central Poland. However, those regions are distinguished by the relatively low level of CO_2 emissions (below the national average), although it increased in the investigated period. Those regions are exceptional in view of the high share of renewable

energy in the total production of electricity, especially the Warmińsko-mazurskie province (87%). Communes in those regions mainly executed investment projects related to solar energy, although in the Warmińsko-mazurskie province, a significant role is also played by investments connected with the generation of energy from biomass (local government units in this region implemented more than 1/3 of the total number and value of projects for the generation of energy from biomass in Poland within the investigated multiannual financial frameworks). In turn, the Łódzkie and Świętokrzyskie provinces are leaders among regions with the highest CO_2 emissions per person, which increased over the analysed years, and the investment activity of local government units from those regions is not exceptional on the national scale (being close to the average values). It is particularly disturbing in the case of the Łódzkie province, which is responsible for a very high share of CO_2 emissions (14.6%). The conducted analyses showed a lack of statistically significant correlations between indexes illustrating the investment activity of local government units in the development of renewable energy sources and indexes characterising the level of CO_2 emissions. This means that EU support for the development of renewable energy sources was not necessarily used by local government units from the most polluted regions. A positive, statistically significant correlation was observed between the percentage of communes acquiring EU support for the development of renewable energy sources and the share of agriculture and forestry in gross value added, as well as a negative, statistically significant correlation between the percentage of communes acquiring this support and the share of their own income out of total income, as well as the number of economic entities per 10 thousand inhabitants. As a result, based on the results of the conducted multivariate assessment of investment activity in renewable energy sources co-financed from EU funds and correlations between the discussed investment activity and environmental and socio-economic conditions, the research hypothesis presented in this paper was negatively verified. This hypothesis assumed the following: "The greatest investment activity connected with local projects co-financed from EU funds, related with the development of renewable energy sources, is found for local government units located in regions with highest CO_2 emissions". In view of both multiannual financial frameworks, the EU support for the development of renewable energy sources was used by local government units from regions with a predominantly agricultural character, with a lower level of development, but which were predisposed to do so thanks to conditions conducive to the development of renewable energy sources.

5. Discussion and Practical Implications

The energy policy of the European Union is gradually implementing actions related to renewable energy sources. The rate of transformation varies, it may be criticised, and it results from the available resources, particularly coal and the level of development [100,101]. An advantage of the use of renewable energy sources is connected with the transition to energy self sufficiency in the future, particularly independence from energy supplies from politically unstable countries [101,102]. At present, attempts to mitigate climate change seem slow and insufficient, leading to protests of environmentalists and activists worldwide [103].

Interest in studying energy transition, particularly concerning the development of renewable energy sources at the local level, has recently been expressed by many researchers not only in Poland (see [104–106]) but also worldwide [107–111]. The role of the local government tier in the support of this transformation and mitigation of climate change is obvious (e.g., [112,113]). Many researchers (e.g., [107,114]) have stressed the fact that local government units play a considerable role in energy transition. As observed by [111], local government units such as communes should cooperate with other local tiers and the government agencies, or even global institutions, that each have a specific function in relation to climate and energy. The need to cooperate stems from the fact that the approach of regulating such actions by the highest government tiers does not necessarily ensure optimal actions towards such transformation [115–117].

Despite the fact that the European Union allocates considerable funds for this purpose, not all local government units may use this support. Thus, the question remains of why

some local government units take full advantage of this opportunity while others do not. What are the factors for or barriers to the opportunity to use the EU support? Firstly, the costs of investments in renewable energy sources are high [118,119]. Additionally, the profitability of these enterprises is affected by legal regulations, changes to which may make prospective beneficiaries less certain of their efficiency or return on their investments [120]. As was shown by the studies of Rekowska and Ozimek [104], in the opinion of most representatives of local government units, the implementation of renewable energy technologies is one of the goals of their local development strategies, but they do not consider these investments to be urgent. This diminishing of the role of actions for renewable energy is characteristic of not only Polish local government units (see [121]). In the opinion of Rekowska and Ozimek [104], it also results from the limitations connected with the financial situation with the simultaneous requirement to finance a part of the tasks, the so-called obligatory tasks. Studies conducted by Klepacki and co-workers [106] show that investments in renewable energy sources made by local government units are correlated with acquired EU funds—without the support from EU funds, investing in renewable energy in local government units is not possible. Thus, it may be stated that the financial situation of local government units is a significant determinant in this respect. Financial and legal barriers are also indicated in studies on the development of renewable energy sources in Sweden [105,122]. A different opinion was expressed by Lackowska and Swianiewicz [123], who stated that it is not affluence that determines whether or not we do something, although it may determine the scale of our activity. The awareness (conviction) and skills and competencies related to the size of the local government unit are decisive. Kata et al. [105] also indicated a significant role of local government units as entities stimulating such investments among their inhabitants. Communes support renewable energy enterprises in their participatory budgeting, mainly through so-called umbrella projects. The effectiveness of such measures is dependent on the efficiency of project execution and the quality of information concerning the conditions for participation in the project and the benefits of renewable energy sources. Zahran et al. [124] were of the opinion that involvement in investments broadly understood as mitigating climate change, apart from the attitude of the local residents to green initiatives, is also determined by the geographical location of local government units and the potential risk of natural disasters. As indicated by research results from Gradziuk and Gradziuk [85], local inhabitants are interested in investments in renewable energy sources, with as many as 75% declaring willingness to participate in such investments. Apart from the above-mentioned factors, natural conditions and technological capacity are also important for the development of renewable energy sources [125]. A considerable role is also played by qualifications of the commune administration bodies [126].

It needs to be stressed that in Poland, local government units applying for financial support for enterprises related to energy efficiency and renewable energy sources within the framework of Regional Operational Programmes for 2014–2020 are obliged to submit their applications together with their Low-emission Economy Plan, which has to be positively verified by an energy consultant employed by the Provincial Fund for Environmental Protection and Water Management, a branch of the National Fund in Warszawa. These low-emission economic plans need to cover the entire area of a given commune and comprise measures promoting a low-emission economy and sustainable resource management, including improved energy efficiency and the utilisation of the local renewable energy potential. The scope of these plans obligatorily includes these sectors of the economy, in which the local authorities may influence energy consumption, i.e., public buildings and council housing and technical infrastructure including street lighting, district heating and transport. The function of the Low-emission Economy Plans is also to improve air quality in areas for which, in accordance with the Act on the Environmental Protection Law, air-protection programmes and short-term action plans have been developed in view of the persisting exceedance of permissible and target air pollution levels (including, e.g., PM 10, PM 2.5, SO_2, NOx. benzo-α-pyrene) [127].

This study provides a considerable contribution to further discussions and in-depth analyses. Among other things, this is connected with the fact that the EU will continue to allocate funds to renewable energy and the demand for such investments will likely increase (in view of growing energy prices and progressing climate change). It needs to be stressed that the demand generated by local government entities themselves may be limited due to their changing financial resources, which result not only from the determinants attributable to these local government units, but also exogenous ones beyond their control, such as changes in the tax system and the geopolitical situation. Thus, it seems advisable to focus also on the importance of the institutional factor for the implementation of such enterprises.

6. Conclusions

Recent years have been a period of turbulence in the political, economic, social and climate spheres experienced worldwide, not only in the EU or Poland specifically. The war in Ukraine has considerably increased the pressing need to find alternatives to fossil fuel sources. Imposed sanctions and geopolitical disturbances increase risks and result in a marked growth in hydrocarbon fuel prices, in this way leading to inflation. In turn, growing energy and food prices are manifested in energy poverty and malnutrition. This produces pressure to search for alternative energy sources. In the coming years, energy (its availability, (un)sustainability and affordability) will thus be a factor determining the competitive advantage of both whole countries and individual regions. Currently, the green transformation, including renewable energy sources and energy storage, is an area where funds for investments are allocated—both private and public and those coming from EU programmes. In view of the above, did the Polish regions fully utilise the potential for the development of renewable energy sources in their area during the last 14 years, i.e., the two recent financial frameworks? The aim of the empirical analyses presented in this paper was to assess the investment activity of local government units related to the development of renewable energy sources co-financed from EU funds in relation to CO_2 emissions and other socio-economic conditions depending on the region in Poland in the years 2007–2020.

At present, a major environmental problem is connected with the reduction in greenhouse gas emissions, including CO_2, whose share in the emissions is the greatest. As per the results from the greenhouse gas inventory reports for Poland, despite the national and international regulations, the level of these emissions in Poland has not decreased since the year 2000. This indicates the ineffectiveness of undertaken actions, which, among other things, results from the implementation of the national policy at the lower tiers of government administration. The lack of changes at the national level is a consequence of unsuitable and insufficient measures introduced at the regional and local levels. As shown by the estimated emissions in the individual regions of Poland, the emissions were reduced in only four provinces. This is connected with the still unsatisfactory standard of economic development in most regions and the decisions to satisfy other social needs, as well as the considerable availability and affordability of fossil fuels and the insufficient infrastructure for the production and distribution of renewable energy.

The role of local government units in supporting initiatives aimed at environmental protection is becoming increasingly important, particularly in the implementation of investments in renewable energy sources. This results from the fact that these administrative bodies have increasing public funds to satisfy the needs of local communities and the fact that a growing section of the public is interested in these issues. One of the sources of financing for enterprises related to renewable energy sources is provided by EU subsidies. The most active beneficiaries in the acquisition of EU support for the development of renewable energy sources include local government units, including communes, among which rural and rural–municipal local government units were most active. Lubelskie province is a leader in this respect among the Polish regions. In both multiannual financial frameworks analysed, the investigated entities completed 1163 projects altogether in renewable energy sources, which constituted more than 1/3 of their total number. What needs to be stressed is that, in the investigated multiannual financial frameworks, the activity of communes

connected with the acquisition of this support for investments in renewable energy sources increased. This is evident in terms of both the number of investment projects (an almost 3-fold increase) and the total value of investments in renewable energy sources (an almost 3.5-fold increase). The Wilcoxon test for dependent samples confirmed that the experience gained by the communes in the years 2007–2013 was reflected in their success in acquiring EU funds for renewable energy sources in the next financial framework.

The activity of local government units connected with the acquisition of investment projects for the development of green energy is highly correlated with the volume of acquired funds both per 10 thousand inhabitants and per 100 km^2 of the region's area. This means that success in energy transition is determined by the activity of all entities governing within individual provinces.

Among the four distinguished areas of intervention, most Polish communes acquired subsidies for solar energy within both investigated multiannual financial frameworks. The second area of interest for the Polish communes was related to hydropower, geothermal energy and other renewable energy sources. Energy from biomass and wind energy was pursued by very few beneficiaries, with projects related to biomass being on average the most capital-intensive.

Based on the results of the multi-faceted assessment of investment activity of local government units related to renewable energy sources and co-financed by EU funds, as well as correlations between such investment activity and environmental and socio-economic conditions, the research hypothesis presented in this paper was rejected. This hypothesis assumed the following: "The greatest investment activity in local projects co-financed from EU funds related to the development of renewable energy sources is observed for local government units in regions with highest CO_2 emissions". In both investigated multiannual financial frameworks, the EU support for the development of renewable energy sources was used first of all by local government units from regions that are predominantly agricultural in character, characterised by a lower level of development but equipped with the potential to develop renewable energy sources.

In view of the above, local government bodies need to intensify their actions focused on investments in renewable energy sources. For example, they should not restrict their activity solely to individual projects executed by the local government units but financially support or at least provide consultancy and promote such investments among their inhabitants or local entrepreneurs. What is important is that these actions need to be coordinated not only locally but also regionally at each tier of the local government system. In view of the importance of the problem and capital intensity of such investments, further financial support from the European Union or national governments is required.

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Abbreviations

The following abbreviations are used in this manuscript:

BECCS	Bioenergy with Carbon Capture and Storage
CO_2	Carbon Dioxide
CRF	Common Reporting Format
GDP	Gross domestic product
EKC	Environmental Kuznets Curve
EU	European Union
IPCC	Intergovernmental Panel on Climate Change
km^2	Square kilometer
kt	Thousands of tons
NCEM	National Centre for Emissions Management
NOx	Nitrogen Oxide
PLN	Polish zloty
PM	Particulate matter
ROP	Regional Operational Programmes
SO_2	Sulphur dioxide
t	Ton

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