

Article

The Role of Large Cities in the Development of Low-Carbon Economy—The Example of Poland

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Abstract: The main objective of the article is to evaluate the investment activity of large cities in Poland in the area of developing a low-carbon economy in 2014–2020, co-financed by European Union funds. This article poses several research questions, namely: Do large cities with environmental problems actively obtain EU funding to develop a low-carbon economy? What are the main socio-economic and environmental determinants of the level of the EU funding absorption among large cities in the research area? The empirical research was conducted on the basis of the data from the Ministry of Investment and Economic Development in Poland, which is responsible for the implementation of cohesion policy funds and from the Local Data Bank of Statistics Poland. Under the 2014–2020 perspective, 223 such projects have been implemented for a total of PLN 21 billion (EUR 4.74 billion). The projects focused on: transportation, electricity, gaseous fuels, steam, hot water and air for air conditioning systems, and environmental and climate change activities. In terms of both the number and the value of EU funds spent, great variation has been observed. Analysis of the correlation relationships showed a highly positive correlation between selected indicators of investment activity in the field of low-carbon economy co-financed by EU funds (especially taking into account the value of investments per area) and socio-economic indicators of Polish metropolises. Metropolises with high demographic, economic, and financial potential have proven to be more effective beneficiaries. Interestingly, no correlation was found between investment activity in the low-carbon economy and the level of environment pollution in large cities. This means that, unfortunately, pro-environmental activities depend on the state of finances of the cities, and not necessarily on the actual needs, even taking into account the fact that the EU covers a large proportion of the costs.

Keywords: low-carbon economy; renewable energy sources; sustainable development; local investment; cities; metropolises; EU funds; Poland



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1. Introduction

Interest in the problems of urban area development, including the so-called, smart cities, have been growing for several years [1–4]. As a result, a number of the following literature concepts have been formulated: “sustainable cities”; “green cities”; “digital cities”; “smart cities”; “intelligent cities”; “information cities”; “knowledge cities”; “resilient cities”; “eco cities”; “low carbon cities”; “liveable cities”; and even combinations, such as “low carbon eco cities” and “ubiquitous eco cities” [5]. Based on 191 publications [4], the following four major challenges for city research have been outlined: fragment analysis, a bigger focus on the benefits of smart cities and smaller on the drawbacks, the need to build new theories of smart city research, and the lack of empirical testing of the conceptual frameworks developed in smart city research. As a result, there is a significant cognitive gap.

Cities are the primary drivers of socio-economic changes. Today, more than 70% of Europe's population lives in urban areas, and this percentage is expected to rise to more

than 80% by 2050. About 60% of the Polish population live in urban areas, whereas nearly 20% of them live in metropolises [6,7]. This means that various kinds of environmental problems related to water, energy, waste or wastewater management accumulate in cities. Large cities, including those classified as metropolises (in Poland these are: Białystok, Bydgoszcz, Gdańsk, Katowice, Kraków, Lublin, Łódź, Poznań, Rzeszów, Szczecin, Warsaw and Wrocław), are the main centers of economic activity and are characterized by intense traffic. According to the Report on Polish Cities—Low Carbon and Energy Efficiency [8], the share of the transport sector in emissions in metropolises is nearly 39%. In other urban areas, the share is lower, and it is around 20% in local centers.

Many cities, the so-called smart cities, in Poland, Europe, and across the globe, make use of modern technologies in order to make the lives of their inhabitants more comfortable and healthier, and to protect the environment as much as possible. Many initiatives are being undertaken to modernize urban infrastructure and services to create better environmental, social, and economic conditions and to increase the attractiveness and competitiveness of cities [9–12].

One of the main priorities related to human development, which entails a growing demand for increasingly limited natural resources and contributes to the deterioration of the environment, is the need to create sustainable development and promote a resource-efficient, more eco-friendly and competitive economy. This challenge is reflected in the European Union's climate and energy package. Key targets adopted for 2030 include reducing greenhouse gas emissions by at least 40% (compared with 1990), improving the share of renewable energy in total energy consumption to at least 32%, and improving energy efficiency by at least 32.5% [13].

Investment expenditure is essential in driving local development. In Poland, local development is the responsibility of municipalities and urban districts, the basic local government units. Their activity includes key and the most cost-intensive investments, in particular, those related to the technical and social infrastructure, orderly development and environmental protection (Article 7 of the Municipality-level Local Government Act of 8 March 1990) [14]. The investment policy implemented by big cities affects their competitiveness, especially in residential and economic terms [15–17].

An important role in building a low-carbon economy is played by local investment projects implemented by Polish local governments and financed from EU structural funds. These funds aim to create workplaces and a sustainable and healthy European economy and environment. Among the EU-funded activities from which cities can benefit are promoting the generation and distribution of renewable energy, increasing energy efficiency in businesses, supporting intelligent energy management in public buildings and in the housing sector, and research and innovation in low-carbon technologies. There are also activities to put low-carbon economic strategies into place in cities of all sizes, including the promotion of sustainable forms of urban transport and smart energy networks [18].

The main objective of this article is to evaluate the investment activity of large cities in Poland in low-carbon economic development co-financed by European Union funds from 2014 to 2020. The article poses several research questions, namely: Do large cities with environmental problems actively obtain EU funding to develop a low-carbon economy? What are the main socio-economic and environmental determinants of the level of the EU funding absorption among large cities in the research area?

2. Review of the Literature

2.1. Concept of Low-Carbon Economy Development

The European Union is taking steps to make Europe the first climate-neutral continent by 2050. One tool to achieve this is the European Green Deal, the idea of which is to achieve zero greenhouse gas emissions by 2050 and to modernize the EU economy [19,20]. Above all, the EU economy will be resource-efficient and competitive, with economic growth not increasing resource consumption. To achieve climate neutrality, net greenhouse gas emissions in Europe are to be reduced to 55% by 2030 compared with 1990 [21]. To pursue

this goal, the European Commission adopted a package of legislative proposals to adjust EU climate, energy, transport and tax policies on 14 July 2021. The proposals are intended to assist and facilitate the transition to a low-carbon economy in all EU member states [19].

The green transformation is not only designed to reduce CO₂ emissions, but is also expected to play a significant role in economic growth and creating new jobs. The project is expected to reduce the dependence on external energy sources, reduce energy poverty and, most importantly, improve the health and well-being of people.

The goal of the European Commission is to reduce emissions from passenger cars by 55% and commercial vehicles by 50% by 2030, and to achieve zero emissions of new passenger cars by 2035. This is to be facilitated by developing the market of zero- and low-emission vehicles, as well as the infrastructure necessary to charge such vehicles. From 2026, charges for polluting the environment will be levied, which should translate into the use of cleaner fuels and investment in new, low-carbon technologies. The charges would also apply to aviation, which has been exempted from them thus far despite the highest greenhouse gas emissions among all means of transport. The maritime transport sector will also be charged, and goals will be set for the major ports which will supply ships with shore-side electricity, reducing the use of polluting fuels that also adversely affect local air quality [19].

The legislative proposals adopted by the EC not only concern energy and transport, but construction and renovation as well [22]. By 2030, 35 million buildings are expected to be renovated and adapted to the low-carbon economy, and these actions will create new jobs and demand for local workforce.

Reducing greenhouse gas emissions by at least 55% by 2030 will not be possible without increasing the share of renewable energy sources, as well as higher energy efficiency, which is why the European Commission is proposing to increase the share of renewable energy sources to 40% by 2030. EU citizens will make a major contribution to reducing CO₂ emissions, saving energy and increasing the share of renewable energy sources by renovating their homes and residential and public buildings. The New Community Climate Fund was established to support these goals. The fund will help meet the goals proposed by the Commission [19]:

- Committing member states to renovate at least 3% of the total area of all public buildings annually;
- Setting renewable energy use in buildings to 49% by 2030;
- Committing member states to increase the use of renewable energy for heating and cooling buildings by 1.1% annually by 2030.

One of the aims of the European Green Deal is to restore natural environments and bring back biodiversity to Europe. By restoring forests, soils, wetlands, and peatlands, carbon absorption and oxygen production will increase, which directly affects the reduction in greenhouse gas emissions.

As a part of the Green Deal, the EU is implementing a number of different low-carbon economy programs on climate, energy, agriculture, industry, environment and oceans, transport, finance and regional development, and research and innovation. Each of these programs aims for greenhouse gas reductions and sustainable regional development. Taking into account the European Green Deal, a key issue for the EU is to improve energy supply security. Since its initiation, the European Community has pursued a policy on coal production and energy use (European Coal and Steel Community), and with time, the Energy Charter Treaty was introduced [23]. Subsequently, the EU established the Energy Community to expand the energy market for community members [24,25]. One of the important functions of the Energy Community is to guarantee energy supply security in the EU. Energy security ensures the comprehensive economic development of member states while maintaining or improving the quality of life of the population [26]. Energy security can be divided into two key aspects. On the one hand, it refers to providing the public with access to energy sources that will meet its needs. On the other hand, significant

factors include the condition and capacity of the infrastructure, its efficiency and the level of security of mining and industrial systems [27,28].

Due to the importance of the problems of the Green Deal and low-carbon economy, they have been popular subjects among researchers [19,21,29–52]. Most of the studies refer to a low-carbon economy considering cities from around the world. Zones with limited greenhouse gas emissions have been introduced. The best example is Copenhagen, which has set a goal of becoming carbon-neutral by 2025. In Copenhagen, the target is being met in four key areas: energy production and consumption, mobility, and city government initiatives [53].

2.2. Low-Carbon Economy in Cities

In the 19th century, Ratzel, the German geographer, formulated one of the first definitions of a city, in which he addressed its three key dimensions: social, geographic, and communication. He considered a city to be a sustained population and housing density located at the center of transport routes [54]. As highlighted by Brol et al. [55], a city is a unit that has been granted proper rights by the government. Both Zuziak [56] and Runge [57] distinguish other criteria for cities such as the functions performed by a given unit and the population. On the other hand, the Act of 29 August 2003, on the official names of places and physiographical objects, describes a city as a settlement unit with municipal rights. Additionally, it is characterized by a compact design and non-agricultural functions [58–60].

The modern world, as well as the development and shape of cities, are shaped by globalization processes [61]. Globalization processes in reference to cities are the following [62]:

- The formulation of a global city;
- The unification of lifestyles and homogenization of urban structures;
- The turn to the idea of the city-state.

The aforementioned features of globalization reflect the process of metropolisation. The process of metropolisation has been recognized as a key in socio-economic development by many researchers, such as Taylor [63], Jałowicki [64] and Harańczyk [65]. A metropolis is a large city, a so-called “management center” [66], with a well-developed infrastructure. Due to the lack of a clear definition of the term “metropolis”, it is used interchangeably with the terms such as: “mega city”, “international city” and “global city” [67–69].

All researchers agree that the city has a unique role in the history of society and humanity [70]. The functioning of cities is identified in line civilization, or is an essential element of civilization [70]. It is cities which can be called the “engine of the development” of the local markets. Nowadays, an increasing emphasis is being put on sustainability. Its basis is the same treatment of environmental, social and economic issues. Moreover, metropolises have changed the perception of the environment, which has translated into the development of modern concepts. One such concept is smart cities, which have evolved into sustainable smart cities. This concept involves minimizing the impact of infrastructure and the urban economy on the environment [71]. Environmental problems are an inevitable part of cities, which can include [72]:

- Waste management (recycling, waste segregation);
- Water and water supply management (water quality);
- Drains and sanitation (wastewater management);
- Rainwater (stormwater drainage network);
- Air pollution (air quality, noise).

Public debates are increasingly directed toward climate change. Extreme weather events are much more common, and they show that the state of the environment directly affects people’s lives. Researchers stress that climate change is a real problem that must be addressed.

Large cities/metropolises are the largest emitters of greenhouse gases. Although they occupy only 0.5% of the planet’s area, they emit about 80% of the total carbon dioxide [73]. One way to reduce CO₂ emissions in cities is through the Green Transformation, which

is designed to help protect the environment, increasing the area of green spaces and biodiversity. This process will improve the quality of public spaces and build the resilience of cities to climate events, as well as reduce the use of fossil fuels [74]. As a part of the Green Transformation, metropolises pledge to: improve air and water quality; green up, i.e., cover city spaces with trees; and achieve climate neutrality [73].

Another example of the environmental actions of cities is the implementation of a low-carbon economy. This is a multidimensional process which includes, but is not limited to: energy supply sources, waste and wastewater management, public transportation, lighting of public places, and the operation of public facilities. Cities must work closely with residents and businesses to achieve success, as low-carbon development is made possible by supporting sustainable consumption and production. Table 1 presents three categories of cities' actions for developing a low-carbon economy in terms of investment, non-investment, and supporting activities. The former (unlike non-investment activities) are investments which can contribute to reducing greenhouse gas and CO₂ emissions in the future. This is supported by information measures taken to change residents' awareness of a low-carbon economy. Today, cities are primarily focused on investment and supporting activities; examples include the construction of renewable energy sources and green economy information campaigns.

Table 1. City's activities for a low-carbon economy.

Investment	Non-Investment	Supporting
Development of a system for recording emissions	Emission Inventories	Establishing low-carbon economy standards and procedures and introduce them into public procurement
Building Modernization		
Modernization or building the lighting for public areas	Introduction of transport strategies	
Transport		Employee training
Electricity production		
Waste management	Urban planning—spatial planning	Promotion of activities on low-carbon economy within the local community
Water and drain management		
Purchase of office equipment		

Source: Own study based on [75].

The transition to a low-carbon economy can be carried out using the Deming Plan–Do–Study–Act (PDSA) cycle, which involves four stages [75]:

- Stage 1: Planning—analyzing the current situation and the potential effects of change;
- Stage 2: Implementation—implementing the changes;
- Stage 3: Investigation—analyzing the results and examining the effectiveness;
- Stage 4: Action—implementing the processes that produced the most desired results.

One of the most ambitious low-carbon economy plans is carbon-neutrality. This is the strive for a zero-carbon footprint, which is achievable by suspending technologies that generate high levels of greenhouse gases in favor of low-carbon solutions. In other cases, however, compensatory activities that result in the removal of CO₂ from the atmosphere should be applied. In 2008, Copenhagen was one of the first cities to express its aspiration to be the world's first carbon-neutral capital. At the time, it set a goal of achieving carbon neutrality by 2025. It proves that cities/metropolises notice the problem of greenhouse gas emissions and try to introduce appropriate solutions [75]. Moreover, the Sino-Singapore Tianjin Eco-city (SSTEC) and Shenzhen International Low-Carbon City (ILCC) are considered low-carbon cities [76].

According to the Report on Polish Cities [7], most Polish metropolises have low-carbon economy plans. However, the introduction of such plans is a time-consuming process, because a low-carbon strategy should be implemented in various areas of a city. Cities' activities in transportation, energy management, and buildings are important in reducing greenhouse gases [75]. Consequently, these activities need to be linked to an

appropriate influence on the production and consumption behavior of society. Actions targeting urban CO₂ emissions are mainly determined by increasing the share of renewable energy sources and reducing the burning of fossil fuels. In metropolitan areas, energy management strategies are created by relevant sectors. The authorities can choose how to provide heat, the main energy carriers and energy efficiency in the city. Cities' activities in developing a low-carbon economy can be divided into [75]:

- Using renewable energy sources in the urban areas from:
 - Unlimited sources, such as solar radiation, wind, geothermal water, land water, seas and oceans;
 - Limited sources, e.g., of plant or animal origin;
- Implementing and developing sustainable solutions in urban areas for:
 - Caring for the community's quality of life;
 - Complying with environmental protection requirements;
 - Respecting employment standards;
 - Reducing facility operating and construction costs (e.g., near-zero energy buildings);
- Creating limited emission zones in cities (e.g., entry into the zone is only possible with a vehicle that meets the emission standards);
- Transportation activities:
 - Initiatives promoting public transport, walking and cycling;
 - Promoting public cars or non-commercial car rental;
 - Arranging joint commuting;
 - Setting car bans or charging fees to enter various city zones;
 - Installing free car chargers for electric cars;
- Shaping desired producer and consumer behavior by:
 - Using direct coercion tools (e.g., norms and standards, prohibitions);
 - Using economic instruments (e.g., tax reliefs, fees);
 - Green public procurement;
 - Conducting educational activities for residents and businesses (e.g., training, courses, seminars, workshops on renewable energy sources, energy efficiency, CO₂ reduction);
- Connecting all utility and residential buildings to district heating networks, which will contribute to the elimination of local boilerhouses and household furnaces.

In summary, the total impact of cities in this respect should concern: reducing the emissions of CO₂ and other greenhouse gases, increasing demand for renewable energy sources, and leading to the expansion of markets for energy-efficient products. Thus, most importantly, cities will create living conditions in a more eco-friendly area.

3. Materials and Methods

The subjective scope of this research consisted of 12 cities with county rights which are the capitals of voivodeships and are considered metropolises in Poland. In the literature, the term "metropolis" usually refers to a large city (with more than 100,000 inhabitants). Much more often, however, the identification of metropolises is based on functional criteria, i.e., on the city's range of influence and higher-level functions performed for the benefit of the surrounding regions—the so-called metropolitan areas [77]. In this sense, there are 12 metropolises (the largest cities with county rights) in Poland, which were the subject of this study, i.e., Białystok, Bydgoszcz, Gdańsk, Katowice, Kraków, Lublin, Łódź, Poznań, Rzeszów, Szczecin, Warsaw and Wrocław [7,78].

In Poland, the Ministry of Investment and Economic Development is responsible for the implementation of cohesion policy funds. For the purpose of the study, 8445 projects fulfilling Priority Axis 4 under the 2014–2020 EU policy entitled "Supporting the shift towards a low-carbon economy in all sectors" were identified within the Ministry's pub-

lished database of more than 80,000 projects implemented. A total of 223 of them were identified as projects from which Polish metropolises, namely, 12 local governments and their subordinate units, benefited [79]. Other empirical data on the socio-economic situation and environmental protection of the studied municipalities were obtained from the Local Data Bank of Statistics Poland [6]. 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 [80]).

Research on the evaluation of investment activity of the metropolises in terms of obtaining EU funds for a low-carbon economy within the 2014–2020 financial perspective consisted of three stages (Figure 1). The collected empirical data were processed using basic methods of descriptive statistics (1st and 3rd stages of the research) and taxonomic methods (Ward's method) using Statistica (2nd stage of the research). The first stage of the research discussed the variation in the amount and quality of support obtained by Polish metropolises from EU funds for low-carbon economy purposes (1st stage of the research). To assess the diversity of the scale of investment activity of the metropolises in the low-carbon economy co-financed by EU funds, the second stage of research involved a multidimensional analysis of the studied phenomenon using Ward's method. Taxonomic analysis allows us to assess the diversity of the studied elements (e.g., cities), described by a set of simple characteristics. It leads to the determination of the clusters of these objects in terms of development similarity, as well as to the acquisition of homogeneous classes of elements due to the properties that characterize them [81]. With this in mind, the multidimensional analysis of the investment activity of metropolises which is co-financed by EU funds was carried out in the following stages:

- Stage 1. Selecting simple characteristics depicting metropolitan low-carbon investment activity based on substantive and statistical premises. The research took into account four sub-indices of the level of investment activity of the examined large cities in 2014–2020, including the value of implemented projects in PLN million per 10,000 inhabitants, the value of implemented projects in PLN million per km², the percentage of total projects implemented by metropolises (%) and the percentage of value of implemented projects by metropolises (%). Due to the low degree of correlation of the studied simple characteristics among themselves and the high variability of their values, all of them were considered in further analysis;
- Stage 2. Performing the standardization of simple characteristic values using classic standardization;
- Stage 3. Performing metropolitan classification using Ward's method. Hierarchical cluster analysis involves combining the closest units to each other until a single cluster is obtained. To estimate the distance between the units, the analysis of variance was implemented, which aims to minimize the sum of the squares of deviations within the clusters [82]. The agglomeration flow chart was analyzed to determine the number of classes. The distinguished typological classes were described by the characteristics taken into account in the typological classification (the so-called active characteristics), as well as selected environmental and socio-economic characteristics (the so-called passive characteristics).

In turn, the third stage of this study consisted of identifying the main socio-economic and environmental conditions for the absorption level of Union aid allocated to low-carbon economy projects in big cities. The Pearson's linear correlation coefficient was used for that purpose. An examination was carried out on quantitative relationships between the value of low-carbon economy projects implemented per capita and per area (on one side) and selected socio-economic and environmental indicators of Polish metropolises (on the other) [15,83–88].

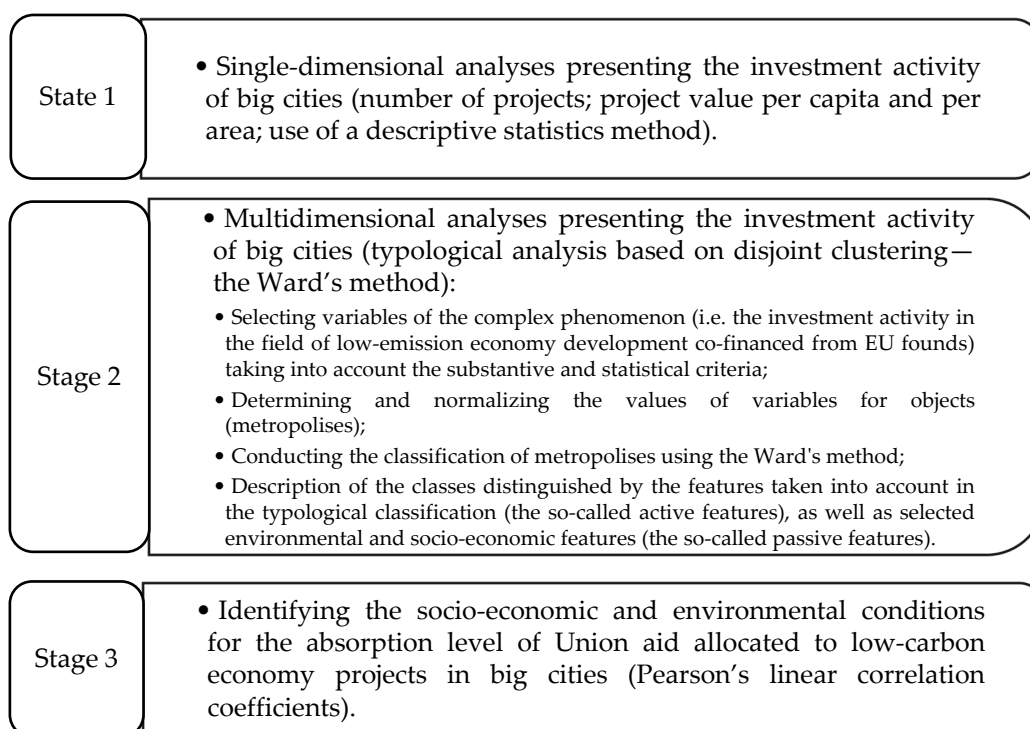


Figure 1. Procedure for evaluating the levels of investment in the low-carbon economy, co-financed with EU funds, in Polish metropolises. Source: Own study.

4. Results—Investment Activity of Large Cities in Poland in the Field of Low-Emission Economy Development Co-Financed by EU Funds

Making investments in the low-carbon economy requires significant capital. EU funds make such projects possible with cities’ limited resources. This is important because Polish cities are, on the one hand, characterized by a high income potential and financial autonomy [89], but on the other hand, have large infrastructure needs and significant debt levels [90]. Overall, 67% of municipalities benefited from EU funds for the studied purpose under the 2014–2020 perspective. Urban municipalities with powiat statuses, in comparison with other types of administrative units (rural and urban–rural), are characterized by several times more and dozens of times greater value of implemented projects. Of these, it is the large cities, which are the subject of the study, which are the largest group of beneficiaries, and each of those analyzed benefited from this support. In total, the surveyed entities had implemented 223 projects in the field of developing the low-carbon economy with a total value of PLN 21 billion (EUR 4.74 billion). On average, each local government implemented 14 such investments, with a value of PLN 1.3 billion (EUR 0.27 billion). The leaders in this respect were Kraków, Katowice and Szczecin. Although those cities implemented the most such projects, Warsaw, implementing the fewest of them, obtained as much as 40% of the funds. Therefore, the amount of the total value of the projects, both in terms of the number of inhabitants and the area for Warsaw, diverged significantly from the results of other examined local governments. The lowest investment activity was observed in Wrocław, Katowice and Gdańsk.

Cities’ low-carbon activities focused on the following economic areas: transport (34%), electricity, gaseous fuels, steam, hot water and air for air conditioning systems (24%), and environment and climate change activities (19%) (Figure 2). Considering the detailed area of support, most activities concerned transport infrastructure and renovation of public infrastructure. The vast majority (69%) of them were implemented under Regional Operational Programmes, i.e., programs dedicated to local governments of a given region. Due to the fact that renewable energy sources investments are characterized by significant capital absorption, the beneficiaries also benefited from the nationwide Operational Programme of

Infrastructure and Environment (59 projects). In addition, the cities with powiat statuses located in Eastern Poland (Lublin, Białystok and Rzeszów) were able to implement their activities using funds targeted only at those regions (10 projects). Accordingly, the activities were financed by both the European Regional Development Fund (74%) and the Cohesion Fund (26%). The vast majority of these projects were not completed (64%) (Table 2).

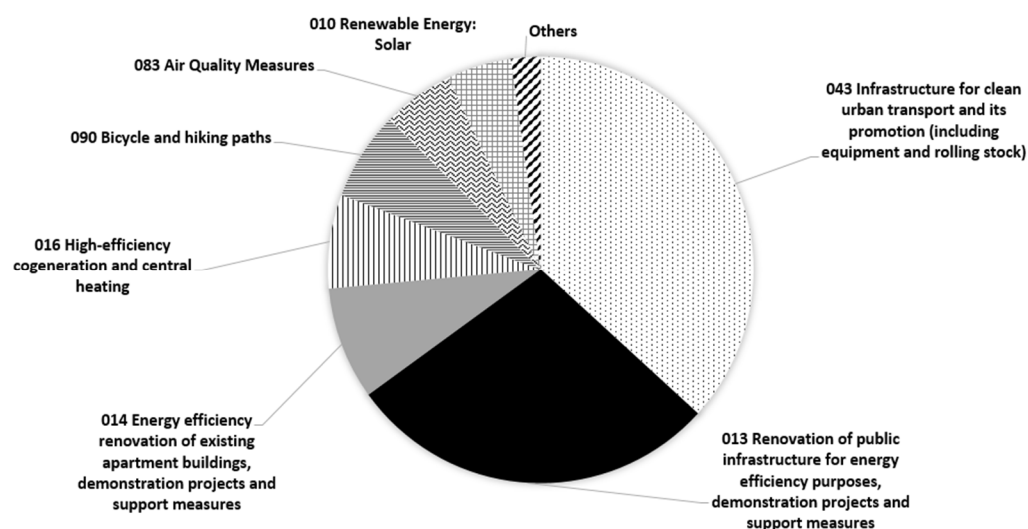


Figure 2. Support area for 2014–2020 projects implemented by the metropolises in the field of low-carbon economy in Poland. Source: Own compilation based on data from the Polish Ministry of Development and Economic Investment [79].

Table 2. Investment activity of metropolises in obtaining EU funds for the low-carbon economy in Poland in the 2014–2020 Financial Perspective.

Specification	Number of Projects	Value of Projects in Million PLN	Value of Projects in Million PLN per	Value of Projects in Million PLN per 1 km ²	Percentage of Total Projects Implemented (%)	Percentage of the Value (%)
Białystok	10	685.7	23.1	6.7	4.5	3.2
Bydgoszcz	21	713.6	20.7	4.1	9.4	3.4
Gdańsk	18	1187.3	25.2	4.5	8.1	5.6
Katowice	27	683.0	23.5	4.1	12.1	3.2
Kraków	42	2138.7	27.4	6.5	18.8	10.1
Lublin	14	1185.5	35.0	8.0	6.3	5.6
Łódź	10	1093.8	16.3	3.7	4.5	5.2
Poznań	15	1781.8	33.5	6.8	6.7	8.4
Rzeszów	15	691.2	35.1	5.5	6.7	3.3
Szczecin	24	1209.5	30.4	4.0	10.8	5.7
Warsaw	9	8547.5	47.6	16.5	4.0	40.4

Source: Own compilation based on data from the Polish Ministry of Development and Economic Investment [79].

In the second stage of the research, the diversity of investment activity of the metropolises in Poland in the field of the low-carbon economy was presented as distinguished (by Ward's method) typological classes. The typological research, conducted by the method of disjunctive classification, distinguished four typological classes of Polish metropolises, characterized by different levels of investment activity in the field of low-carbon economy co-financed by EU funds. The distinguished typological classes were described by the characteristics considered in the typological classification (the so-called active characteristics), as well as selected environmental and socio-economic characteristics (the so-called passive characteristics).

The first typological class consisted of Warsaw—the capital city of Poland. Among the other groups of cities, Warsaw was characterized by the highest value of completed projects per 10,000 population and per km², as well as the highest percentage of completed projects among all metropolises; however, at the same time, by the lowest percentage of completed projects among the examined large cities. These concerned infrastructure for clean urban transport, the construction of bicycle paths and the thermal modernization of public buildings. Warsaw stands out because of its high demographic and economic potential compared with other metropolises. Although many Polish cities are affected by the phenomenon of suburbanization, in the case of Warsaw, its population grows every year, causing increasing environmental problems. This also results in the high level of particulate pollutants (10,474.9 t/year/km²). As the capital city, it is an attractive place to live, for both Polish and foreign nationals.

The second typological class consisted of Kraków which, similarly to Warsaw, is distinguished by a high demographic potential, i.e., high population density and positive net migration, as well as a higher number of enterprises per 10,000 population compared with the average number of enterprises for all the metropolises. The quality of life capital in Kraków is still relatively low. One of the most important reasons is very poor air quality and high traffic nuisance [7]. In terms of investment activity in the area of low-carbon economy, Kraków was distinguished by the highest percentage of all investments completed by the metropolises (almost 19%) (Table 3). Kraków implemented projects in as many as five areas: infrastructure for clean urban transport, the renovation of public infrastructure, air quality measures and renewable solar energy, as well as highly efficient co-generation and central heating.

The third typological class consisted of three cities, i.e., Lublin, Poznań and Rzeszów. In comparison with the remaining cities (except for the first class), those cities were characterized by very high values of implemented low-carbon economy projects per 10,000 population, but also a relatively low percentage of the total number of completed projects by the metropolises. These cities are distinguished by a slightly lower demographic and economic potential in relation to the average for all metropolitan areas, and as a result, lower levels of particulate pollutants (Table 3).

The fourth and the last typological class consisted of the remaining 7 of the 12 Polish metropolises, i.e., Szczecin, Bydgoszcz, Gdańsk, Katowice, Łódź, Wrocław and Białystok. These cities had the lowest average values for up to three of the four indicators of low-carbon investment activity. These cities were characterized by the lowest average value of projects in million PLN per 10,000 population and per 1 km². In those cities, we observed a negative net migration (except for Gdańsk and Wrocław) and a lower economic potential in relation to the average for all metropolises, quantified by the size of GDP in relation to the average GDP for Poland (except for Katowice, Gdańsk and Wrocław). Low investment activity in those cities in the field of low-carbon economy could be a result of relatively low levels of particulate pollutants in those cities, except for Gdańsk, where the level of particulate pollutants is the highest (12,337.0 t/year/km²).

The research showed the existence of correlations between the value of implemented projects in the field of low-emission economy co-financed by EU funds per 10,000 population and per km² in million PLN, and the selected socio-economic and environmental characteristics of Polish metropolises (Table 4). Significant and positive correlations were observed mainly between the value of low-carbon economy projects per km² in million PLN and the GDP per capita in relation to the average GDP for Poland (in %), population density, the number of enterprises per 10,000 of the working age population and the amount of own income per capita. On the other hand, a weaker and statistically insignificant correlation was observed between the level of particulate pollutants in t/year/km² and the value of low-carbon economy projects per 10,000 population and per 1 km² in million PLN. This means that higher investment activity in the development of a low-carbon economy does not necessarily characterize large cities with the greatest environmental problems, i.e., air

pollution, but those with high economic and demographic potential and, as a result, with a high level of the so-called “own income potential”.

Table 3. Inter-group variation of metropolitan investment activity in the low-carbon economy co-financed by EU funds in Poland in the 2014–2020 Financial Perspective.

Specification	Typological Class				Metropolises in Total
	I	II	III	IV	
	Warsaw	Kraków	Lublin, Poznań Rzeszów	Szczecin, Bydgoszcz, Gdańsk, Katowice, Łódź, Wrocław, Białystok	
Investment activity in the low-carbon economy (2014–2020)					
Value of projects in million PLN per 10,000 population	47.6	27.4	35.0	23.1	26.3
Value of projects in million PLN per 1 km ²	16.5	6.5	6.8	4.1	5.0
Percentage of total projects implemented by the metropolises (%)	4.0	18.8	6.7	8.1	7.4
Percentage of the value of implemented projects (%)	40.4	10.1	5.6	5.2	5.6
Socio-economic and environmental characteristics (2020 data)					
Particulate pollutants in t/year/km ²	10,474.9	7316.7	6148.6	5430.7	6335.0
Population per 1 km ²	3469.0	2386.0	2031.0	1955.0	2111.5
Cumulative net migration per 1000 population (2014–2020)	28.5	25.3	−4.6	−4.7	−1.5
Entities by size class per 10,000 working-age population	4658.3	3343.4	2633.4	2954.9	3013.4
GDP per capita in relation to the average GDP for Poland (in %) *	293.0	166.0	115.0	123.0	134.0
Own income per capita in PLN	7030.0	4877.1	3718.6	4336.8	4607.0
Expenditures per capita in PLN	1274.0	1075.0	1287.0	1211.0	1242.5
Resources obtained from the EU per capita in PLN	2687.8	1271.6	3608.8	2105.0	2251.4

* 2018 data. Source: Own compilation based on data from the Polish Ministry of Development and Economic Investment [79].

Table 4. Pearson’s linear correlation coefficients between the value of implemented projects co-financed by EU funds per 10,000 population and per km² in million PLN and environmental and socio-economic indicators of metropolises in Poland in the 2014–2020 Financial Perspective.

Specification	Value of Projects in Million PLN per 10,000 Population	Value of Projects in Million PLN per 1 km ²
Particulate pollutants in t/year/km ²	0.283	0.474
Population per 1 km ²	0.324	0.784 *
Cumulative net migration per 1000 population (2014–2020)	0.425	0.378
Number of enterprises per 10,000 working-age population	0.601 *	0.644 *
GDP per capita in relation to the average GDP for Poland (in %)	0.604 *	0.790 *
Own income per capita in PLN	0.464	0.628 *
Expenditures per capita in PLN	0.017	−0.247
Resources obtained from the EU per capita in PLN	0.310	0.164

* Statistically significant correlations at the level of $\alpha = 0.05$. Source: Own compilation based on data from the Polish Ministry of Development and Economic Investment [79].

According to studies carried out by authors such as Kozera [15], the development level of big cities has an effect on their income potential and financial self-sufficiency. By

implementing their budget economy—which reflects the extent of their tasks and functions—cities have a tremendous impact on both socio-economic and environmental aspects. In Poland, the investment activity of cities and other local government units is driven by many different conditions. Some of them can be impacted by the cities, whereas others are beyond their direct control. The investment activity of a city is the consequence of multiple factors, including its financial situation. Metropolises, i.e., the biggest cities, demonstrate a higher demographic and economic potential, and therefore have a greater income potential than smaller urban units. Consequently, it becomes harder for less wealthy regions to catch up with wealthier regions [91].

5. Discussion

In order to access EU funds, local government units must provide their own financial contribution which, in many cases, means relying on repayable sources of financing. The biggest Polish cities, acting as urban districts, spend large amounts of money to develop their social and technical infrastructure due to their dual nature and differences in the extent of their needs. That infrastructure is used not only by the local community, but also by residents of metropolitan areas. Consequently, due to the implementation of numerous investments, metropolises see their debt grow faster than other local government units [90]. Finally, financial and other (economic, institutional and transitional) barriers slow down the innovations related to green technologies [92–95]. As Zhan et al. [76] point out, investing in a low-carbon economy is very expensive, and even wealthy cities have to rely on external funding, i.e., municipal bond issue and government grants, to do so. In contrast, Sun et al. [96] believe that the private sector should be involved. Richet and Sullivan et al. claim that public–private partnerships and bonds are two effective means for the private sector to participate in the development of climate-related projects. It is also important to note that many local governments do not prioritize low-carbon investments. This may be mainly due to the infrastructure gaps in Poland in other areas, such as transport [97,98]. In addition, Sarker et al. [99] postulate the introduction of a low-carbon monitoring system. All parties (residents, businesses and authorities) should be stimulated to ensure the sustainable development of low-carbon cities. We need to remember that only joint action can prevent environmental degradation.

The following banks were established to overcome the barriers to financing low-carbon energy projects: the Clean Energy Finance Corporation (CEFC) in Australia, Kreditanstalt fuer Wiederaufbau (KfW) in Germany and the Green Investment Bank (GIB) in the UK. They finance low-carbon investments, although are a drop in the ocean of capital which economies need to eliminate greenhouse gas emissions [100]. According to Polzin [101], there must be an eightfold increase in investments in energy efficiency by 2035. However, compared with other entities of the Polish local government sector, big cities (especially those acting as regional centers) play an important role in building a low-carbon economy. Additionally, Polish cities face the dilemma of whether a low-carbon policy can be a development policy for them. The essence of technical progress is a strict environmental impact. Hence, today, Polish cities have adopted a development policy which, on the one hand, is based on investments, but on the other, strengthens the residents' awareness of sustainable development. The same measures are being put in place in most cities around the world.

6. Practical Implications

Most Polish cities, including all Polish metropolises, have plans in place to shift to a low-carbon economy. Otherwise, local government units would be ineligible for EU funds used in co-financing low-emission and energy-efficiency measures. The low-emission strategies, developed as per the general policy followed by urban authorities, can be a strong development driver for big cities, and are likely to trigger changes resulting in improvements to living conditions for urban residents. Although the relevant plans in place in the biggest cities are the most ambitious, the metropolises strongly differ in how

they invest in a low-carbon economy co-financed by the EU. Hence, it seems that not all big Polish cities fully implement the approved low-carbon economy plans. Additionally, some of them fail to seize the financial opportunities for building a low-carbon economy provided by funds derived from the EU budget. Nowadays, it is the quality of living which has become a factor for the competitiveness of cities. Therefore, the sustainable development vision formulated in the urban policy should take into account the extreme vulnerability of cities to the effects of climate change. Consequently, in their development vision, many cities need to shift their priority from economic development to ensuring a high quality of living for the residents and to guaranteeing social and environmental justice [102].

The above studies may provide some guidance for local governments and public aid managers in Poland, especially in the implementation of EU support. The studies cited here highlight the fact that regardless of the need for developing a low-carbon economy, the highly capital-intensive nature of investments focusing on it remains an important issue. This problem is significant even in the case of EU projects, of which, as a general rule, a notable share is co-financed by the European Union. If the problem is to provide funds for the so-called own contribution, then how are Polish cities supposed to finance such investments in full? Therefore, it seems reasonable to maintain funding for these types of investments under both national and regional EU programs. In turn, to provide cities with an easier way to find capital for their own contribution, the support in the form of a pre-financing loan from Bank Gospodarstwa Krajowego should be maintained. Pre-financing is intended to provide the financial resources necessary for the implementation of projects co-financed by the European Union. An entity implementing such a project requires interim financing for a portion of the expenses, and only then (after the payment application is approved) receives funding. This means that EU funding is transferred by way of reimbursement, i.e., a return of part of the expenses already incurred.

7. Summary

Increasing the demographic potential of cities has both positive and negative effects. On the one hand, cities are stimulators of development, generating a significant share of GDP and huge incomes. On the other hand, they are also areas of the accumulation of problems, including environmental concern. This is a particularly important issue in an era of depleting natural resources with an increasing demand for energy. As a result, concepts that reduce negative environmental impacts are being implemented. One of them is the EU Green Deal.

Polish metropolises implementing activities in the field of low-emission economy may benefit from EU support. Under the 2014–2020 perspective, 223 such projects have been implemented, at a total cost of PLN 21 billion (EUR 4.74 billion). The projects focused on: transportation, electricity, gaseous fuels, steam, hot water and air for air conditioning systems, and environmental and climate change activities. In terms of both the number and the value of EU fund absorption, great variation has been observed. Warsaw, as the largest metropolis in Poland, has implemented the fewest such projects, but they were of the highest value. On the other hand, Kraków, a city with big problems with particulate pollutant emissions, has undertaken the most such actions. While taking into account activities in the implementation of EU projects in the field of the low-carbon economy in other Polish metropolises, the metropolises formed two separate groups. These were characterized by a lower percentage of the value of projects implemented by the metropolises, although Lublin, Poznań and Rzeszów, in terms of the value of projects per capita or area, were characterized by more favorable results than Szczecin, Bydgoszcz, Gdańsk, Katowice, Łódź, Wrocław and Białystok.

The analysis of correlation relationships showed a strong positive correlation between the selected indicators of investment activity in the field of the low-carbon economy co-financed by EU funds (especially taking into account the value of investments per area) and socio-economic indicators of Polish metropolises. Metropolises with high demographic,

economic and financial potential have proven to be more effective beneficiaries. Interestingly, no correlation was found between investment activity in the low-carbon economy and the level of environment pollution in large cities. This means that, unfortunately, pro-environmental activities depend on the state of finances of the cities, and not necessarily on the actual needs, even taking into account the fact that the EU covers a large part of the costs.

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