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Smart Energy in a Smart City: Utopia or Reality? Evidence from Poland

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Abstract: The main principles of the smart city concept rely on modern, environmentally friendly technologies. One manifestation of the smart city concept is investments in renewable energy sources (RES), which are currently a popular direction in urban transformation. It makes sense, therefore, to analyse how Polish cities are coping with this challenge and whether they are including the implementation of RES facilities in their development strategies. The aim of the article is to analyze and assess the level at which renewable energy facilities are being implemented or developed in the urban space of cities in Poland as a pillar of the implementation of the smart city concept. This goal is realized on two levels: the theoretical (analysis of strategic documents) and the practical (analysis of the capacity of RES installations, questionnaire studies). The study shows that renewable energy installations are an important part of the development strategies of Polish cities, and especially of those that aspire to be termed "smart cities". Moreover, it is shown that the predominant RES facilities are those based on solar energy.

Keywords: smart city; renewable energy; distributed generation; urban policy; Poland

1. Introduction

Eliminating unfavourable aspects of urban management and urban living, showing a city makes energy savings and providing it with a good metabolism—these are all markers of the implementation of the smart city concept [1–6]. The smart city concept combines several elements, including: innovative use of technology, efficient transportation, sustainable energy consumption, and a clean environment [7–10]. All these components are intended to improve residents' quality of life, but also to positively affect the environment. Technological progress and socio-economic development—which are clearly visible in large urban centres in particular—increase energy demand. Modern cities are therefore currently faced with the challenge of securing energy supplies, on which are founded not only the functioning of the economy as a whole, but also residents' quality of life. The key to solving emerging problems is the concept of the "smart city", which, based on data and technology, supports economic development and improves quality of life while promoting sustainable development in cities [11].

The smart city is a complex concept with various definitions [2,9,12]. The idea features two main threads. The first is related to the use of Information and Communication Technologies (ICT) and modern urban technologies—these are mainly technical solutions [13–16]. The second is related to the role of human capital in the development of a smart city [17,18]. Furthermore, the smart city can be taken as a concept for urban development within specific fields of activity. These are usually assumed to be: the economy, residents, development management, mobility, the environment, energy, and quality of life [19]. One can analyse individual fields of activity or a specific aspect of the complex concept, but only a holistic approach creates a smart city [20].

Energy infrastructure stands out as one of the key elements of a smart city, especially because its state and structure determine whether sustainable development principles will be implemented and residents will be provided a high quality of life in a clean urban environment. Cities are increasingly important players in implementing renewable energy based on endogenous resources [21]. According to the premises of the smart city, the energy system must be wholly integrated into the local context [22]. In addition to energy demand, the potential for energy generation based on endogenous resources—locally occurring renewable energy sources (RES)—should be taken into account, with the ultimate aim of achieving independence from external fossil fuel supplies [23].

The development of RES in cities and regions is a research subject in many countries. Examples of research on RES in cities of the region are presented in Table 1.

Table 1. Research on renewable energy sources in cities and regions (selected).

Region	References
Europe	Eicker (2012) [24]; Gerpott and Paukert (2013) [25]; Gabillet (2015 [26]); Kılkış (2016) [27]; Petersen (2016) [28]; Kazak, et al. (2017) [29]; Ahas, et al. (2019) [30]; Bahers, et al. (2020) [31].
North America	Hammer (2008) [32]; Denis and Parker (2009) [33]; Moscovici et al. (2015) [34]; Bagheri et al. (2018) [35]; DeRolph et al. (2019) [36]; Hess and Gentry (2019) [37]; Kouhestani et al. (2019) [38].
Central and South America	Ramírez et al. (2000) [39]; Huacuz (2005) [40]; De Araújo et al. (2008) [41]; Fonseca and Schlueter (2013) [42]; Cedeno et al. (2017) [43]; Pérez-Denicia et al. (2017) [44]; Lino and Ismail (2018) [45].
Africa	Bugaje (2006) [46]; Cloutier and Rowley (2011) [47]; Zawilska and Brooks (2011) [48]; Gumbo (2014) [49]; Akuru et al. (2017) [50]; Bouhal el at. (2018) [51].
Asia	Jebaraj and Iniyan (2006) [52]; Bilgen el al. (2008) [53]; Cheng and Hu (2010) [54]; Farooq and Kumar (2013) [55]; Schroeder and Chapman (2014) [56]; Madakam and Ramaswamy (2016) [57]; Noorollahi et al. (2017) [58]; Yuan et al. (2018) [59]; Awan (2019) [60]; Fraser (2019) [61]; Meng et al. (2019) [62].
Australia	Mithraratne (2009) [63]; Martin and Rice (2012) [64]; White et al. (2013) [65]; Dowling et al. (2014) [66]; Imteaz and Ahsan (2018) [67]; Li et al. (2020) [68].

Source: own study.

In Poland, as in many countries, RES is being researched. Most analyses mainly involve selected case studies [69] (Table 1). However, there are no studies that, first, attempt to systematize the current state of knowledge regarding renewable energy in cities as a component of the smart city, or, second, holistically approach RES installations (small and large) to make comparisons between cities aspiring to be smart cities. This study attempts to fill precisely this gap in the current state of scientific knowledge.

Energy planning that leads to "smart" urban solutions requires that energy design be integrated with spatial and urban planning [70–73]. Planning and implementing smart city energy systems is not easy, as it involves a wide range of stakeholders—from municipal administration, through developers and energy suppliers, to current and future residents [74–77]. In addition to requiring that a synergy of trans-sectoral interests be achieved [78], the process of energy transition also appears to exhibit huge spatial inequalities [79]. In Europe, the region in need of special support for energy transformation is the central European countries (CECs), including Poland. This situation has its roots in the historical, political, and economic past. In the post-socialist countries (because it is these that we are talking about), the modernization of the energy sector is different than in the countries of western Europe. The main barriers to the transition from fossil energy to renewable sources are, on the one hand: the monoculture of conventional raw materials (i.e., of coal in Poland); the dependence on fuel imports;

and the predominantly outdated energy infrastructure; and on the other hand: the growing demand for energy conditioned by the region's socio-economic development [80].

In Polish cities, the production of electricity from RES sent to the power grid is relatively insignificant in total energy generation electricity. This situation is conditioned by three main factors. Firstly, urban areas are not inherently conducive to new large-scale energy investments, on account of their extremely limited access to free space that would class as potential locations for RES power plants. Secondly, large-scale renewable energy installations require significant financial outlays stemming from, among other things, high urban land prices and the need for complicated bureaucratic procedures. Thirdly, developing large RES installations entails significant environmental costs [81,82].

RES has the potential to be made more widespread in smart cities through the development of distributed generation (DG), which involves energy generation based on small-scale decentralized technologies that meet mainly local needs [82,83]. In accordance with the act on renewable energy sources of 20 February 2015 [84] in Poland, a small installation does not exceed 500 kW, and a micro-installation does not exceed 50 kW. Such RES installations are used both in multi-family and single-family residential buildings, as well as in autonomous power supply systems (off-grid.) Setting up micro-installations does not involve so many bureaucratic procedures, nor a license, and does not require a large space—a rare commodity in urban areas. Meanwhile, it can power various devices: street lamps, road signs, vehicles, parking meters, and such.

The aim of the article is to analyse and evaluate the level of implementation and growth of RES facilities within the urban space of cities in Poland as a pillar of the implementation of the smart city concept. The study was carried out on two levels: (1) the theoretical, involving analysis of strategic documents of Poland's largest cities, and (2) the practical/applied, involving analysis of the number and total capacity of RES installations operating in those cities, including the DG system. This study was complemented by an empirical analysis aimed at verifying the level of RES development at the local scale.

2. Material and Methods

Due to the multifaceted nature of the research, the authors decided to implement a multistage research procedure. To achieve the research objective, the following methods were employed:

- quantitative analyses,
- desk research on cities' strategic documents,
- a PAPI (paper and pen personal interview) survey as a case study of Bydgoszcz.

The research methods were complemented by a city walk and exploration of Bydgoszcz, with the aim of identifying renewable energy sources within the urban space and determining how they related to the concept of the "smart city" (Figure 1).

The authors began the research with a quantitative analysis of the structure of RES installations and with an analysis of the capacity of RES installations in Poland's 20 largest cities. This had a particular emphasis on micro-installations and was based on data from the Energy Regulatory Office (ERO) [85] concerning electricity producers, including small renewable energy installations. The authors decided to conduct a quantitative analysis in the 20 most populous cities in Poland, which have a high degree of socio-economic development related to the presence of renewable energy installations within the urban space (i.e., Warsaw, Kraków, Łódź, Wrocław, Poznań, Gdańsk, Szczecin, Bydgoszcz, Lublin, Białystok, Katowice, Gdynia, Częstochowa, Radom, Toruń, Sosnowiec, Rzeszów, Kielce, Gliwice, Zabrze). This stage formed the quantitative background to the research and an introduction to later considerations.

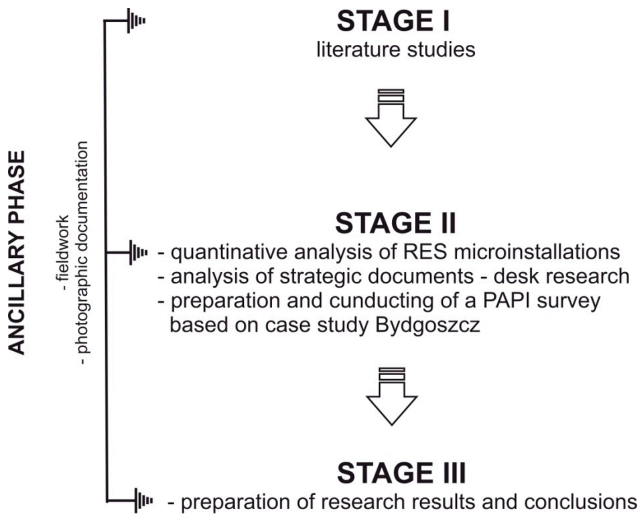


Figure 1. General research procedure framework. Source: own study.

In the next step in the research procedure, the authors used basic desk research based on existing (i.e., secondary) data [86]. It consisted in an analysis of the content of strategic documents (the Long-term National Development Strategy, the Strategy for Responsible Development [87], the Urban Development Strategy [88–107] and Low-Emission Economy Plans [108–126]) for the 20 largest cities in Poland, in terms of the smart city concept, with particular emphasis on provisions regarding the implementation of RES in the urban space. It was also investigated which of the analysed cities has a separate smart development strategy, and these documents were also examined. The authors based their analysis on documents in Polish available from the official websites of the cities selected for analysis. In total, 5480 records were analysed for entries related to RES in the context of the smart city.

The study's research period covered:

- the year 2019, for quantitative data relating to the installation of RES in cities;
- 2007–2020 for the analysis of strategic documents.

The article also uses the results of a survey that was conducted in Bydgoszcz (Kujawsko-Pomorskie voivodeship). The Bydgoszcz case study is a valuable testing ground for issues relating to a large post-communist (and post-industrial) city's energy transition towards becoming a smart city. The activities undertaken in Bydgoszcz constitute a starting point for addressing the challenges in effecting a smart city energy transition in cities marred by a past experience of being subject to a centrally planned economy. The scale of the selected case study is also crucial here, because, as contemporary research shows [78], energy transition is an extremely complex process, so research in this field should relate primarily to the local level, which in this case is the city. The authors used the PAPI survey method [127,128]. This method allows a questionnaire to include many research questions that are high in difficulty and complexity. The questionnaire form was based on closed questions using a dichotomous, nominal, and modified Likert scale [129]. In total, 475 questionnaires were collected, in accordance with the principle that the obtained sample should reflect the demographic and social structure of the city under study. The study results were digitized and analysed using IBM SPSS software. Another advantage is the high availability of respondents [130]. The study was carried out in the spring of 2019 in the city of Bydgoszcz, which was a case study and functioned as a research and analysis testing ground for the survey and a good example of the use of smart-city RES solutions. Bydgoszcz is also distinguished for its involvement in international initiatives relating to sustainable development and the dissemination of renewable energy sources. There is a RES Demonstration Centre in the city that teaches how individual installations work. Using Bydgoszcz as a case study allowed for an in-depth analysis of RES-based smart-city solutions and of how they are perceived by the local communities that benefit from "smart" changes [131].

3. Results

3.1. RES Installations in the Largest Cities of Poland

Taking into account the structure of RES facilities according to the number of installations in cities in Poland, it should be stated, the dominant energy source is solar energy (Figure 2). In the case of small installations, photovoltaic (PV) technologies account for almost 72% of all RES (Table 1). The undisputed leader in the use of solar technologies, including PV, is Silesia [132], with such cities as Katowice, Gliwice, and Zabrze. They top the national ranking in terms of number of PV installations. The average installed PV capacity does not exceed 0.5 MW. The growing popularity of solar technologies, including in the field of electricity production, is conditioned by several factors: they are usually located very close to both the producer and the consumer; they are the most environmentally friendly energy technologies; and they do not conflict with architectural and aesthetic solutions in buildings [133]. Moreover, they have the best public image of all RES [134].

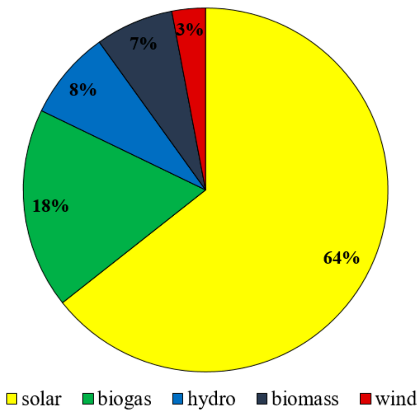


Figure 2. The structure of renewable energy installations according to the number of installations in major Polish cities. Source: own study based on data from the Energy Regulatory Office (ERO) [85].

Biogas also plays an important role in the structure of RES installations. Facilities of this type are based on processing waste—mainly in sewage treatment plants—and the average installed capacity is approximately 1 MW. Their advantages are in co-generation, meaning the production of both electricity and heat, and in allowing the principles of a circular economy to be implemented [135]. In third place was hydropower (Figure 3), whose development corresponds with the occurrence of appropriate environmental conditions. Half of the hydroelectric power plants located in the cities studied, including the largest (with a capacity of 5.5 MW), are to be found in Bydgoszcz. It is a city at a forking of rivers, including Poland's largest river, the Vistula, and it is criss-crossed by numerous canals.

Looking at the number of RES installations alone, it should be noted that the most (more than 10) are in Katowice (18), Warsaw (14), and Szczecin (12) (Figure 3). Szczecin also has the largest number of small renewable energy installations (11). The largest, though among the least numerous, are installations using biomass, including those that are co-fired by fossil fuels. Their installed capacity reaches, for example, 170 MW in Warsaw. It is in Warsaw that the highest total installed RES capacity was recorded, at 180.6 MW (Table 2). Warsaw follows the trends observed in many European cities, moving towards sustainable and smart development. Numerous activities are carried out in this city with the aim of improving the everyday functioning of the city, thus increasing the systematic share of RES in the overall energy balance.

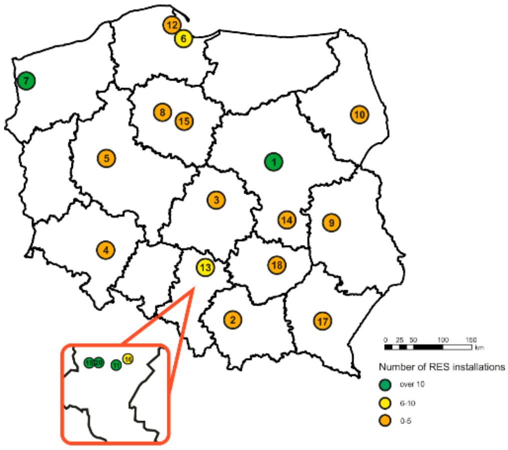


Figure 3. RES installations in cities in Poland. Explanations: 1 Warsaw, 2 Kraków, 3 Łódź, 4 Wrocław, 5 Poznań, 6 Gdańsk, 7 Szczecin, 8 Bydgoszcz, 9 Lublin, 10 Białystok, 11 Katowice, 12 Gdynia, 13 Częstochowa, 14 Radom, 15 Toruń, 16 Częstochowa, 17 Rzeszów, 18 Kielce, 19 Gliwice, 20 Zabrze. Source: own study based on data from ERO (2020) [85].

Table 2. RES installations in cities in Poland.

City	Population	RES Installations								
		Number of RES Installations	Total Installed RES Capacity (MW)	Average Power of RES Installations (MW)	Small RES Installations *					
					Number of Installations by RES					
					Sum	Biogas	Biomass	Sun	Water	Wind
Warsaw	1,790,658	14	180.60	12.90	4	0	0	4	0	0
Kraków	779,115	5	19.85	3.97	3	0	0	3	0	0
Łódź	679,941	4	59.36	14.84	5	0	0	5	0	0
Wrocław	642,869	1	0.07	0.07	2	0	0	0	2	0
Poznań	534,813	2	2.13	1.07	2	0	0	2	0	0
Gdańsk	470,907	7	4.97	0.71	4	0	0	3	0	1
Szczecin	401,907	12	93.47	7.79	11	2	0	7	2	0
Bydgoszcz	348,190	5	6.51	1.30	3	1	0	0	2	0
Lublin	339,784	3	1.73	0,58	1	0	0	1	0	0
Białystok	297,554		no data		2	0	0	2	0	0
Katowice	292,774	18	1.15	0.06	6	0	0	6	0	0
Gdynia	246,348	3	0.07	0.02	0	0	0	0	0	0
Częstochowa	220,433	9	2.21	0.25	4	0	0	3	1	0
Radom	211,371	4	0.95	0.24	1	0	0	0	0	1
Toruń	201,447	1	0.93	0.93	1	0	0	1	0	0
Sosnowiec	199,974	7	1.75	0.25	2	0	0	2	0	0
Rzeszów	196,208		no data		2	0	0	2	0	0
Kielce	194,852	2	6.73	3.36	0	0	0	0	0	0
Gliwice	178,603	12	1.35	0.11	6	1	0	3	2	0
Zabrze	172,360	11	78.33	7.12	5	2	0	3	0	0
Sum		120	462.15	3.85	60	6	0	43	9	2

* The small RES Installations according to the Art. 8 s. 1 of the Act on renewable energy sources (Journal of Laws of 2018, item 1269, as amended) [84]. Source: own study based on data from ERO (2020) [85].

It is worth emphasizing that the number of power plants does not correspond with total installed capacity. Some renewable energy sources are typified by large-scale installations. These include biomass (which is often also co-fired by conventional raw materials) and biogas produced in municipal wastewater treatment plants. Of all RES installations, it is biogas plants that ensure the most stable, predictable, and efficient energy production. Their operation is not subject to fluctuations in natural conditions—as, for example, wind, solar or water power plants are—but depends primarily on human labor [80]. These large renewable energy technologies (which use biogas, but also biomass) result from the modernizing of existing key municipal facilities, including: municipal heat and power plants, wastewater treatment plants, and waste treatment sites. In turn, new RES investments include small-scale installations—mainly PV. One example is Katowice, which has the most RES installations of the cities studied, with a total capacity of 1.15 MW. Nevertheless, it is the development and growing popularity of place-based DG systems based on local resources that will determine the future of smart cities, ensuring the development of prosumer attitudes among city residents on the energy services market.

3.2. RES in City Development Documents

The development strategies of Polish cities increasingly refer to the smart city concept, as a result of national activities for smart urban development. The strategic goals of Polish policy documents, i.e., the Long-term National Development Strategy and the Strategy for Responsible Development, are: economic competitiveness and innovation; achieving sustainable development potential; sustained economic growth based increasingly on knowledge, data, and organizational excellence; and socially sensitive and territorially balanced development [87,136]. These top-down guidelines mobilize city authorities to implement intelligent solutions in urban spaces, including in the field of renewable energy sources.

The analyzed cities in Poland contain renewable energy provision in almost all their strategic documents, such as Urban Development Strategies and Low-Emission Economy Plans (Figure 4, Table S1 in Supplementary Materials). These two documents are of key importance in creating modern and ecological urban development in line with smart city principles. They usually concern improving energy efficiency and energy security—as is the case in Gdańsk, Kraków, Kielce, and Gliwice. An equally important goal chosen by Polish cities is to increase diversification of energy sources and to increase the use of energy from renewable sources (Toruń, Radom, Rzeszów). Another important goal in city strategies is to promote and disseminate RES and other energy-efficient solutions—as exemplified by Wrocław, Warsaw, Gdynia, and Sosnowiec. In turn, cities such as Poznań and Białystok have already indicated specific activities aimed at introducing modern, energy-saving technologies and solutions in public spaces and buildings, including using intelligent solutions for greater use of renewable energy.

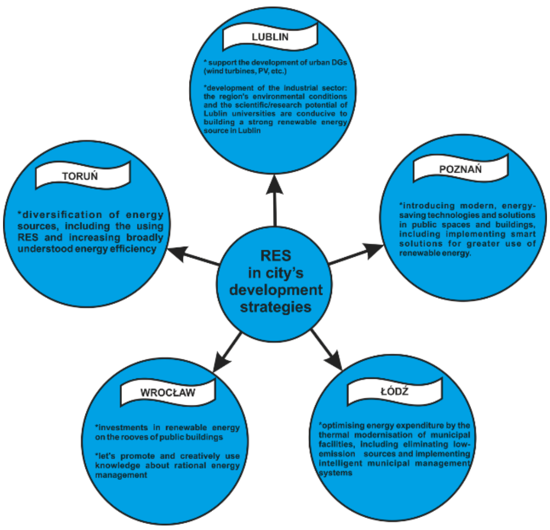


Figure 4. RES in urban development strategy. Source: own study based on urban development strategies [88–107].

In implementing RES in cities, low-emission economy plans are an important document, setting the path for the development of RES installations (Figure 5, Table S1 in Supplementary Materials). These documents already contain specific directions for renewable energy investments. Taking the example of Warsaw, new or adapted power plants generating electricity and heat in high-efficiency co-generation with RES are planned, as are new or adapted intelligent medium- and low-voltage distribution networks dedicated to increasing RES generation. It should be noted that most cities are focusing on solar energy, which is why many low-emission economy plans mention increasing the share of renewable energy in the total energy consumption by installing PV in public buildings

(Rzeszów, Bydgoszcz, and Radom). In Kraków too, it is planned to install PVs, this time on bus roofs, and in Gdynia, on parking shelters at the trolleybus depot. In Łódź, however, it is planned to construct a reinforced-concrete passive office building and to install photovoltaic panels.

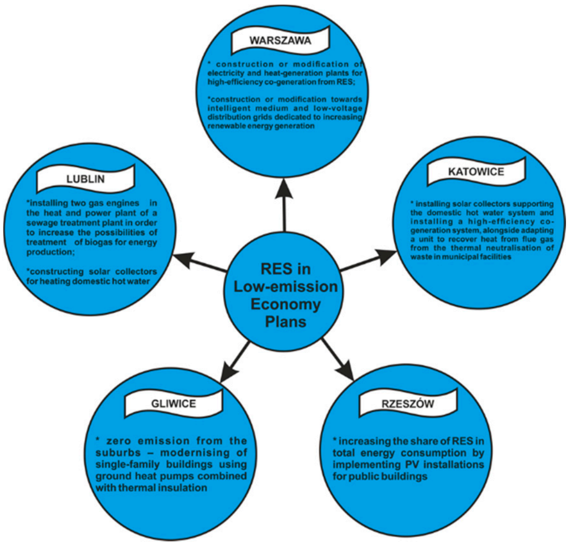


Figure 5. RES in low-emission economy plans. Source: own study based on low-emission economy plans [108–126].

It is worth emphasizing that some large cities in Poland also have separate documents outlining how to achieve the level of "smart city". Of the cities analyzed in this article, five have such documents: Warsaw, Kraków, Wrocław, Poznań, and Kielce. Smart city strategies also contain references to the desire to implement intelligent RES solutions (Figure 6). These are generally broad statements, such as about striving to increase the extent of RES use. However, in Kraków and Warsaw, for example, specific investments using PV are indicated.

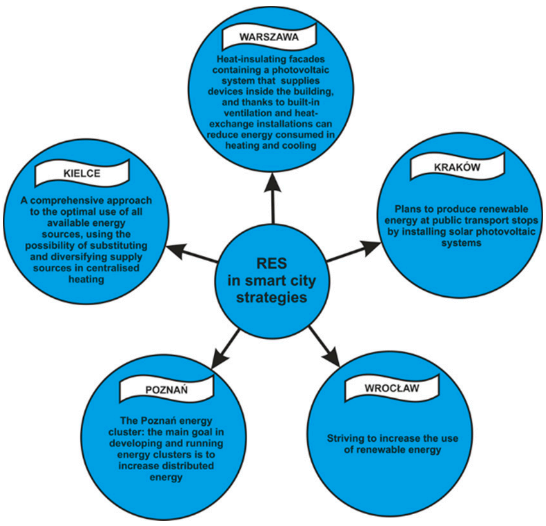


Figure 6. RSE in smart city strategies. Source: own study based on smart city strategies [137–141].

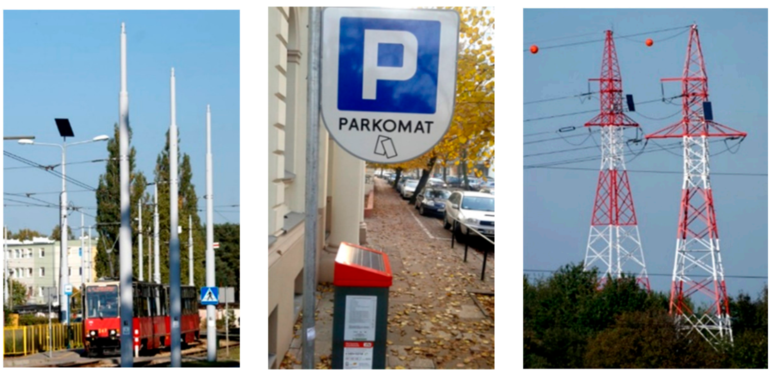
The conducted research shows that Polish cities focus first on safe and reliable energy supplies, and then on diversification of energy sources. Large global metropolises are applying a similar energy strategy [11,142–145]. It is much easier for city authorities to include only broad statements about increasing the share of renewable energy sources in strategic documents than to indicate specific types of investments in renewable energy sources and timeframes for their implementation.

3.3. Case Study: Bydgoszcz

Bydgoszcz was selected for detailed research as one of the greenest cities in Poland every year. For instance, in 2019, Bydgoszcz took second place in terms of the share of green areas in the total area among the studied Polish cities [146]. It is also distinguished for its involvement in international initiatives relating to sustainable development and the dissemination of renewable energy sources. There is also a RES Demonstration Centre in the city that teaches how individual installations work. Bydgoszcz is a member of the Association of Municipalities Polish Network "Energie Cités" [147], an international organization working to adapt cities to climate change, including supporting the development of distributed generation (a DG system). It has received distinctions in international competitions: in 2020, the city won the international Eco-City 2020 competition in the energy efficiency category. The implementation of RES projects in diverse facilities within the city was singled out for praise [148]. There are a total of six on-grid RES installations in Bydgoszcz, i.e., those selling generated energy to the national power grid. These are hydroelectric plants and a biogas plant [85].

This raises the question of what other renewable energy installations exist within the city and what attitude Bydgoszcz residents have towards new energy solutions. A total of 18.4% of respondents claim to use energy generated from RES, mainly in their homes. This is mainly solar energy (54.2%) in the form of solar collectors for the production of heat and domestic hot water. This small share of people claiming to use renewable energy technologies is due to the respondents (and city residents in general) mainly living in apartments in multi-family buildings (70% of respondents). Inhabitants of multi-family buildings have limited options for individual investment in renewable energy. Such decisions are shifted from the individual level to the level of housing cooperatives or communities, i.e., to building administrators.

This situation does not mean that RES installations are absent from buildings and public spaces in Bydgoszcz (Figure 7). On the contrary, in the urban space, there are various locations with RES installations, as confirmed by half of the respondents. The respondents mainly mentioned small and micro RES installations in autonomous power systems (Figure 8). Solar-powered road signs or hybrid devices (solar and wind energy) dominate. These installations are used to improve the visibility and legibility of existing road signs, and to increase delivery of information by installing additional signals and devices. Illuminated road signs are located in particularly sensitive places, such as pedestrian crossings, junctions, and bends in the road. In addition, the respondents noted renewable energy installations supplying city bike stations and lighting for bus and tram stops. The use of off-grid RES devices also enables the operation of vehicles and means of transport, such as the Bydgoszcz Water Tram that runs as part of the municipal public transport system and is a local tourist attraction.



(**a**) (**b**) (**c**)

Figure 7. Examples of small PV autonomous installations. (**a**) Tramway infrastructural feature, Bydgoszcz, Glinki district. (**b**) Parking meter, Bydgoszcz, Śródmieście district. (**c**) Aeronautical infrastructure feature, Bydgoszcz, Wzgórze Wolności district. Source: own study.

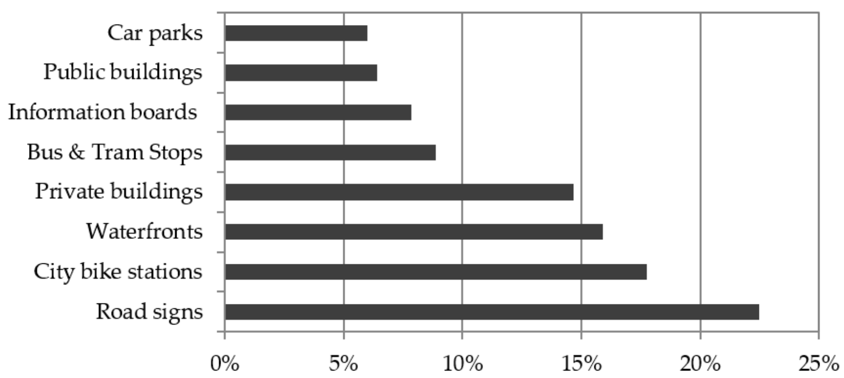


Figure 8. Breakdown of answers to the question "Have you seen renewable energy installations within the city of Bydgoszcz?" Source: own study.

According to the respondents, it is inhabitants who should have the greatest influence on the direction that RES development takes in the city. Thus, when asked as potential decision-makers what types of RES have the greatest growth potential in Bydgoszcz, they mention hydro energy in first place (Figure 9). Respondents' arguments for developing hydropower in Bydgoszcz emphasize the city's waterside location (its rivers and numerous canals) and the existing and prospering hydro-electric power plants, including two small facilities. It is also important to focus the municipal policy in Bydgoszcz on revitalizing waterfronts and emphasizing their priority role in the urban fabric. They also see the potential of solar energy as an inexhaustible and environmentally friendly source of energy, whose installations can be placed on building roofs and facades.

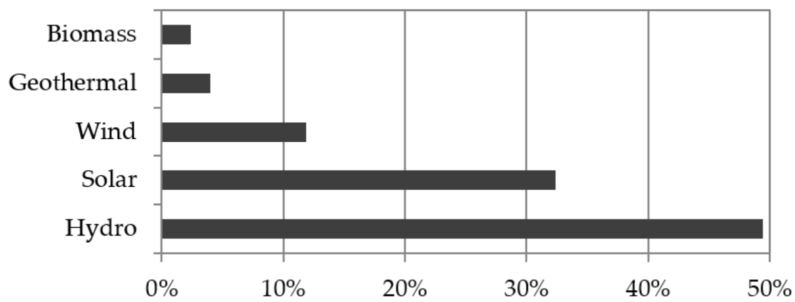


Figure 9. Breakdown of answers to the question "Which renewable energy sources, in your opinion, have the best growth potential in Bydgoszcz?" Source: own study.

Renewable energy installations are an increasingly common feature of the urban landscape of Bydgoszcz. They are developing mainly in the public sphere of the city, where the use of solar energy dominates in the form of off-grid systems. Solar energy (solar thermal collectors and photovoltaics) are also popular in private and public buildings to meet consumer energy needs. Due to its natural conditions, on-grid hydropower is also being developed in Bydgoszcz.

4. Discussion

Progressive urbanization is pushing the search for modern solutions to maintain balance in urban ecosystems. As mentioned in the introduction, demographic growth and the increased activity of various economic sectors in cities are increasing the demand for electricity. Today, there are sustainable urban development strategies aimed at maintaining harmony between the economy, society, and the environment. Rapid changes in these three areas, as well as the need for cities to adapt to climate change, are requiring that cities transform. Cities are unlikely to be transformed in absolute accordance with a single concept of urban development such as the concept of sustainable development, of the digital city, of the eco-city, of the low-emission city, or of the smart city. Rather, all these concepts are affecting cities, and will also do so in the future.

Smart cities also need to develop in a sustainable manner, and thus be environmentally friendly by reducing harmful emissions and switching to renewable energy sources [149,150]. Hence, providing cities with safe and permanent access to energy seems to be the issue of key importance. As Kammen and Sunter (2016) [151] noted in their research, a particular challenge is posed by the limited access to areas where energy installations may be located in urban areas. The balance between the high energy demand in cities and the energy density provided by renewable sources should therefore be the starting point for designing any analytical framework for a decarbonized urban space. Moreover, many studies show that cities' potential for RES generation remains untapped [152–155] This is the case in cities in the UK, for example, where the potential of solar and wind energy is not being exploited [156]. The situation in Polish cities is similar.

The presented results are evidence of the spread of RES in Polish cities. This is also confirmed by other Polish RES research [25,82,157]. There are similar trends in the popularization of urban RES in Poland's neighbor, Germany. There, it is being popularized via the energy transition known as *Energiewende*, which refers to the ongoing energy experiment to create sustainable energy transitions (SETs) by (radically and) increasingly selecting renewable energy sources and systems while abandoning the unsustainable use of energy resources [158,159]. This is also evident in German cities, the best example of which is Munich.

It should also be emphasized that the popularity of photovoltaic installations is increasing in Polish cities, which is a very positive sign in the context of a smart city. These installations are very cost effective and are having a real effect on municipal budgets. The economic aspect of PV has been emphasized by, for example, Abrao et al. (2017) [160]. The significant increase in the number of solar PV roof installations has made buildings the largest source of urban space available for deployment [161]. It should also be noted that the growing threats of climate change and the global challenges of sustainable development, in combination with the significant decrease in the cost of renewable energy sources, has led to solar power systems being recognized as a major feature of a mitigation strategy [152].

At this point, it is worth emphasizing that some of the analysed cities in Poland have their own smart development strategies that mention the development of RES, considering it to be a priority in becoming a smart city. This approach is not surprising as, by the end of 2018, more than 230 cities around the world had adopted targets for 100% renewable energy in at least one sector of the economy [162]. Therefore, the present study confirms the energy transformation that is being seen to be taking place in many cities around the world in the spirit of sustainable, smart development. Thus, the future success of RES development in Polish cities will be determined by properly conducted urban policies that focus on smart solutions and on raising residents' awareness of "green energy", which in addition to its economic benefits, carries the recently popular environmentally friendly message of saving a degraded planet.

5. Conclusions

Moving from conventional to renewable energy is an extremely complex and problematic process, both conceptually (creating strategies and action plans) and in practice (developing RES installations). Additionally, in Poland, the pace and scope of the energy transition are hampered by historical factors related to the centrally planned socialist economy. Nevertheless, in cities in Poland, the local authorities and the local community are interested in and disposed towards renewable energy sources. All the development strategies and low-emission economy plans of the analyzed cities contain provisions referring favourably to RES. However, there are some disproportions in this respect, because it is far easier to address RES in a general manner in strategic documents than to indicate specific investments planned in the urban space. The superficiality of assumptions relating to the growing importance of RES in urban strategies may cause concern. On the one hand, the imprecision of the municipal documents allows for ongoing changes to RES projects being implemented, which is especially relevant given that the energy transition has diverse implications: from spatial, political, and socio-economic aspects, to structural changes. Meanwhile, it may also offer some security in the face of changes to energy policy and to current legislative and fiscal instruments for developing renewable energy. Given that actions stimulating the energy transition should be integrated into the local context and programmed with regard to local conditions, far more clearly formulated place-based planning assumptions are needed.

In addressing the article's titular question, it should be stated that renewable energy installations are a reality in cities in Poland and they are increasingly becoming important features within urban spaces, as evidenced by the conducted analyses. These changes vary in pace and scope, as do the conditions in which cities function. We see a progressive diversification of energy sources. Nevertheless, the most popular is photovoltaics, which is being used in infrastructure dedicated both to buildings (public and private) and to autonomous power systems. Small-scale RES installations are spreading fast. Meanwhile, large-scale ones are the result of the modernization of municipal sewage treatment plants, municipal heat and power plants, and waste processing sites, where biogas and biomass are used in energy production. The identified place-based DG facilities prove that the smart city idea is increasing in popularity in Polish cities. This situation should be seen as an opportunity for cities, including post-socialist ones, to create a modern, functional, and environmentally friendly city (a smart city), and thus to build international market competitiveness. It must be noted that the concept of smart city should be a pillar of further development of Polish cities—it is the present reality, the reality of the future.

Supplementary Materials: The following are available online at http://www.mdpi.com/1996-1073/13/21/5795/s1, Table S1: RES in city development documents.

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