

Article

Renewable Energy Sources in the Residential Property Market, Exemplified by the City of Krakow (Poland)

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Abstract: Krakow has a permanent population of over 800,000. The number of inhabitants is increasing year on year due to the influx of working people and students, who often settle in Krakow permanently. This is leading to increased demand and consequently more flats and houses being put into use by developers. The increasing environmental awareness of the population and the resulting financial benefits—particularly evident in 2022—have meant that the classic, or rather ill-considered, building industry is gradually being replaced by better, environmentally friendly solutions. In the first part of the article, the authors focus on smart buildings, and in the second part, they combine them with financial changes in the real estate market. The aim of the publication is to draw conclusions from the changes in the real estate market in Krakow that have taken place in the last decade and to assess these activities from the point of view of environmental solutions. The data are mainly derived from official statistics and trade reports published by research institutes, marketing agencies operating in the real estate sector in Poland, as well as specialist portals and publications dealing with real estate market analysis. The publication analyzes changes in the real estate market in terms of changes in unit prices, number of transactions, and availability. The analysis covers landed property, the primary and secondary premises market, developed property, and tenement buildings.

Keywords: market analysis; real estate market; smart city; green building; smart housing; smart economy; cities; urban development



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1. Introduction

The development processes taking place in real estate result in various measures, including, but not limited to, the volume of residential properties completed, the area, the number of flats returned, the number of built houses, the development of the land around the development, the material from which the houses are built, and the rate of return on investment in real estate.

After studying, the authors decided to name five cities as leaders in the use of renewable energy sources in the property market. These cities are known for their advanced infrastructure and supportive policies for renewable energy and environmentally friendly buildings. According to botanicalozen.bg, these cities are Amsterdam, Berlin, Copenhagen, Sydney, and Portland [1]. Following the smartcitiesindex.org ranking, the top five smart cities are: Amsterdam, Barcelona, Berlin, Brisbane, and Brussels.

Investments in developer projects utilizing renewable energy sources in Poland are becoming increasingly popular. More and more developers are joining the trend, creating buildings that are more energy-efficient and environmentally friendly. What are the most important benefits of investing in renewable energy sources?

1. Improving air quality—Renewable energy sources allow for the reduction of harmful substances emitted into the atmosphere. This in turn helps to reduce air pollution and improve the health of local residents.

2. Energy savings—Renewable energy sources allow for energy to be produced in an efficient and cost-effective manner. This helps to reduce energy consumption and the cost for its delivery.
3. Investing in the future—Investments in renewable energy sources are an investment in the future. They contribute to reducing climate change and creating an environment friendly to future generations.
4. Increasing competitiveness—Utilizing renewable energy sources can help businesses gain an edge over their competition. By reducing energy costs and increasing efficiency, profits can be increased and an advantage can be gained over other companies.

2. Literature Review

The need and opportunity to use green buildings can be seen most clearly in China, where the government is supporting developers [2]. Although the energy sector is already moving towards hydrogen [3] the real estate sector is not yet so developed regarding the criteria, but there are retrofitting heating and district heating networks, which can bring real financial benefits [4]. This article looks at the origins of green energy for housing. In the literature on the subject, it is emphasized that it is a function of fundamental economic variables. If ecological factors are disregarded, such investments are considered outliers [5], and one environmental sector is becoming an important part of the construction industry [6], which can be seen both in the European market [7] and the Polish market [8]. Furthermore, due to the specificity of local markets, individual economic factors may influence their development with varying strengths [9].

In the UK, almost one-third of total energy consumption is allocated to the needs of households, as more than half (57%) of the 23.2 million homes in England were built before 1965, when building regulations first required a basic level of thermal insulation. The UK government's policy of zero-carbon homes, introduced by the Labour Party in 2006, was aimed at ensuring the sustainability of future housing stock. The aim was to improve the practices of current house builders in terms of the sustainable properties offered by their products and the infrastructure to which they are connected (low-emission heating and electricity) [10–12]. A much better example worth emulating here is China, where in the sector of new urban buildings, it is required that 50% of new buildings be green buildings [13].

The most energy-efficient settlements in Poland are located in the Masovian, Greater Poland, Silesian, and Lesser Poland voivodeships [14]. The largest numbers of energy-efficient settlements are located in Warsaw, Krakow, Wroclaw, and Katowice. Due to its history and well-developed transport network, Krakow has become very attractive to potential buyers. The economic, business, and political situation significantly affects the real estate market. Additionally, one must take into account the influence of the isolation caused by COVID-19, which has allowed us to look at real estate from the perspective of permanent residence in it, relaxation, and rest [15]. Based on previous and current market behavior, we can draw conclusions and forecast future changes, including a shift towards eco-friendly solutions that have been successfully implemented in other European countries. [16–18] Nevertheless, the best pro-environmental solutions have to find their way into the difficult situation of the residential property market, which throughout Europe is a market strongly linked to the economic situation of the country concerned. There is a noticeable correlation between economic development in the macroeconomic scale and the development of the real estate market [19]. It is consequently vulnerable to any financial crisis, viewed as a Central and Eastern European Union countries market as a whole [20] or as an example of a particular country such as the Czech Republic [21].

For “ecological” projects, an important action is to match the formal requirements with applicable laws. Therefore, European countries apply EU directives to adapt building regulations to energy efficiency standards. In this case, the Energy Performance of Buildings Directive (EPBD) is important, which imposes minimum quality standards and also requires the issuance of an energy performance certificate for both sold and rented

apartments. Another way to achieve ecological standards in residential construction is to use the appropriate certification, which allows for the development of the most optimal solutions [2,7,22]. The most popular systems used in Poland are the British BREEAM and the American LEED. The German DGNB and the French HQE, which are typical for dwellings, are used less often [23]. In Poland, the “Polish Energy Policy to 2040” is in force, within which the main goal in terms of the use of RESs is to increase their share in final gross energy consumption in 2030 to at least 23 percent and further increase this indicator in subsequent years [24].

Intelligent city is a new term that has only started to be discussed in the 21st century. R. Horbaty proposed a definition of such a city as one that offers its inhabitants the highest quality of life while using minimal resources. This is possible through the use of the right combination of infrastructural systems, such as transportation or energy transmission. J. Belissent proposed another definition, suggesting that an intelligent city is one that uses information and communication technologies to make key services and urban infrastructure elements more efficient. The University of Technology in Vienna provides yet another definition of a smart city, describing it as a city that achieves good results now and in the future, created through the intelligent connection of resources and decision making, and independent and engaged citizens. Each definition is different, yet they all have common elements [25].

The concept of a smart city aims to create a sustainable city, one where resource conservation applies to both the environment and economic, social, and spatial activities. The creation and development of intelligent cities are closely linked to the reality that surrounds us. However, intelligent cities are not only large concentrations of people in the most developed countries in the world. They can also be linked to their smaller counterparts. It is a fact that improving the quality of life of the inhabitants of larger agglomerations is highly effective and economically desirable. As we know, innovations are much easier and faster to adopt in large centers, and then they are dispersed to smaller centers. However, everyone benefits from this, including increased quality of life for residents, accelerated economic growth, increased security, and competitiveness.

The concept of a smart city should also be linked to smart housing construction. To characterize its components and distinguish those that drive the development of smart housing markets, attention must be paid to describing a specific driving force and then the dimension of the concept of smart housing construction that it affects. The Figure 1 illustrates the concept of smart residential buildings [26].

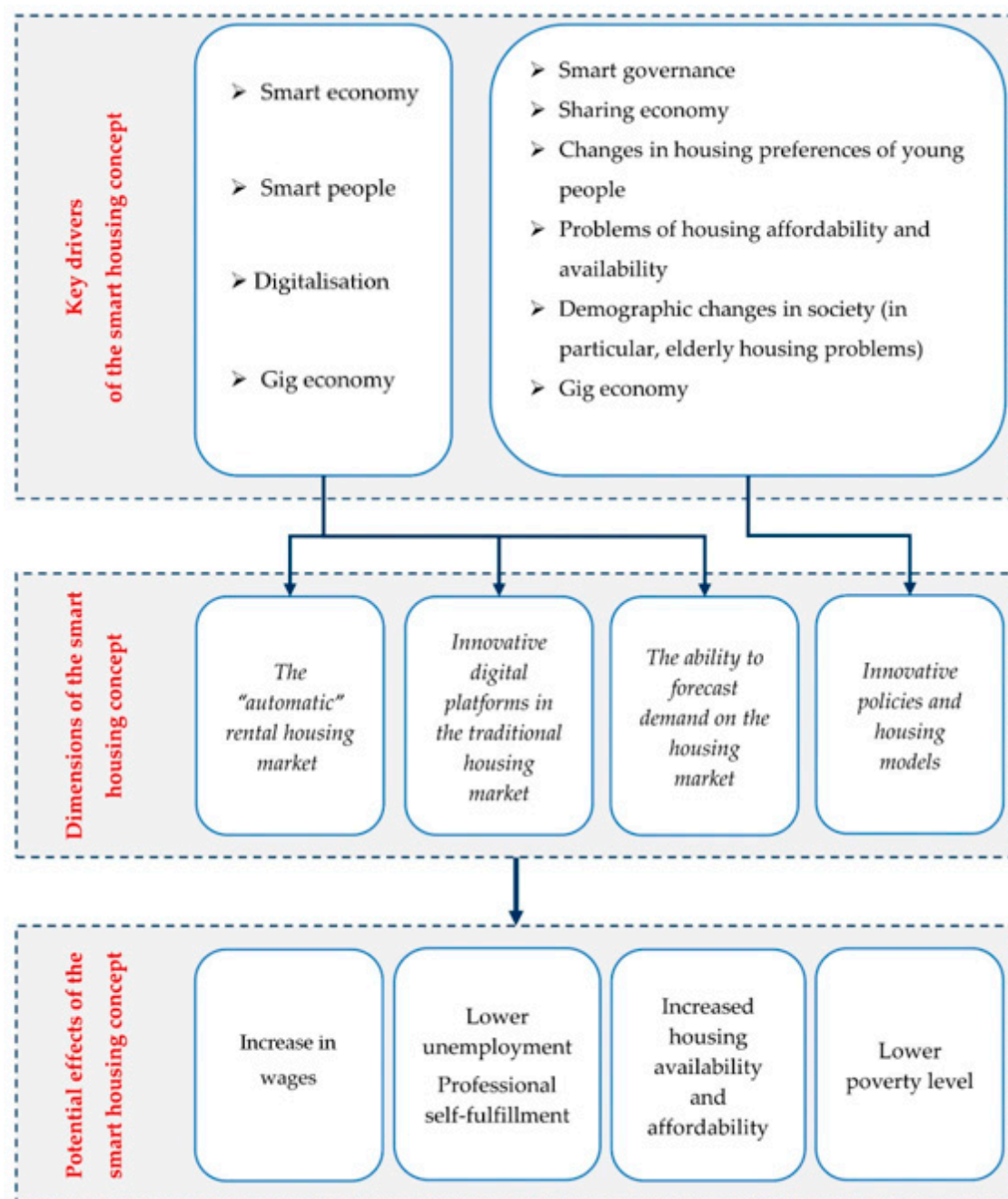


Figure 1. Key drivers, dimensions, and potential effects of the smart housing concept [26].

3. The Subject of the Analysis

Data on changes in the real estate market in Krakow over the last ten years were used in the research. This time frame was deliberately chosen to observe changes in a stable market (up to 2019), the pandemic period (2020–2021), and the last year, which is exceptional for many reasons, such as the influx of refugees from Ukraine to the market and problems with the energy supply, mainly from Russia. The last few years have been decisive, as buyers have noticed the need and financial advantage of eco-friendly solutions in construction. Quantitative and qualitative analyses were used, and a statistical hypothesis test was performed for two averages—for eco-friendly estates and those built with older technology.

Krakow, located in southern Poland, is the second largest city in the country in terms of population and area (326.8 km²) [27]. According to the 2022 census, Krakow has 800,653 inhabitants, and around 8 million additional people live within a 100 km (62 miles)

radius of the city center. It is located on the Vistula River, in the Nida Basin, the Western Beskids and the Krakow Gate. It is one of the oldest cities in Poland with a long history, and it contains many valuable architectural objects. It is a center of tourist and student interest compared to other Polish cities. National and European roads 4/E40, 7/E77, 44, 79, and 94 pass through the city, and the A4/E40 motorway runs through the southern part of the city. Krakow also has the John Paul II Airport, a sports airport in Pobiednik Wielki near Krakow, and a landing strip at the Polish Aviation Museum in Krakow. The capital of Lesser Poland is also one of the most important railway junctions in Poland. It has express connections to Gdansk and Warsaw (PKP InterCity), as well as the Euro City connection to Vienna and the Euro City Wawel to Wroclaw, Berlin, and Hamburg. One can also get to Prague, Bucharest, Odessa, Kiev, Budapest, Lviv, and Bratislava from Krakow. There are also often express trains to Czestochowa, Lodz, Kielce, Lublin, Katowice, Rzeszow, Przemyśl, Wroclaw, Poznan, Torun, Bydgoszcz, Olsztyn, and many other cities.

In the academic year 2020/2021, 130,400 people were studying at a higher level in Krakow. Of this number, 7800 were foreigners. There are seventeen universities in the whole of Krakow. It is an economic center of Lesser Poland and one of the most important economic centers in Poland. Since the fall of communism, the private sector has been constantly developing. Around 50 large, significant international companies operate in the city, including Google, Uber, IBM, Shell, UBS, HSBC, Motorola, and many others. There are also many cultural institutions and facilities rich in priceless monuments. The city serves as an administrative, scientific, educational, cultural, tourist, service, and economic center. Krakow is second in terms of the size of modern office space. It is one of the most important railway and road junctions in Poland. The city is divided into 18 administrative districts—this division is visible in Figure 2.

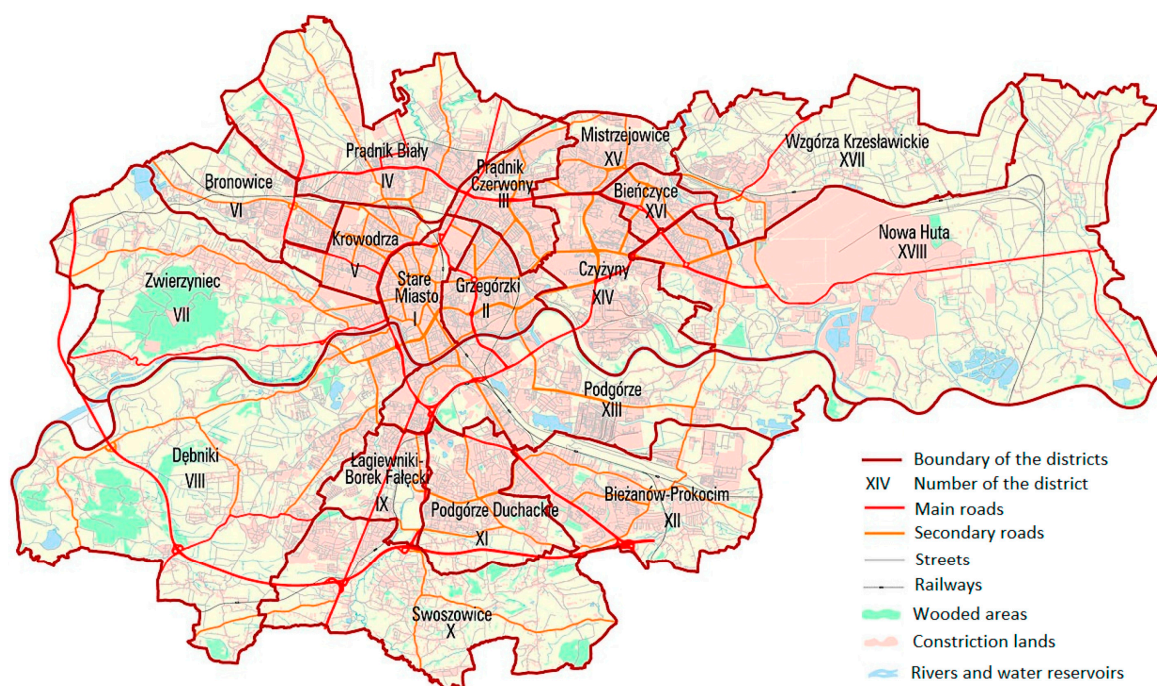


Figure 2. Districts of Krakow [28].

In November 2022, the registered unemployment rate in Krakow was 2.3%. This is significantly lower than the whole of Malopolska (4.5%) and significantly lower than the whole of Poland (4.8%). The average gross monthly salary in the business sector was PLN 8258.62 [29]. Due to the low unemployment rate, the inhabitants of Krakow have high creditworthiness, which translates into frequent purchases of apartments for both private and investment purposes. This market is characterized by high liquidity.

To verify the impact of pro-ecological solutions on the real estate market, a significance test was applied for two means to compare the parameters of two random samples (Student's *t*-test) [30]. The hypothesis that the average values of properties from ecological investments are equal to the average values of local properties without ecological and energy-saving factors was verified. It was assumed that the characteristics have a normal distribution at a significance level of 5%.

Let X and Y represent the average unit prices of local properties, where X is the average price of properties in ecological settlements and Y is the average price of properties in settlements without ecological actions. Furthermore, n_X and n_Y are the sizes of the populations, while k_X and k_Y represent the degrees of freedom for each population. The notations σ_X^2 and σ_Y^2 represent the variance for the two populations. The mean value and variance were calculated for each random sample.

The formulated hypotheses are:

- Null hypothesis $H_0: X = Y$;
- Alternative hypothesis $H_1: X \neq Y$.

The *T*-Student test (formula below) was used in the study to compare two means. This choice was justified by the fact that the characteristic has a normal distribution in both populations, a small sample size ($n_1 = n_2 = 30$), and similar variances.

Formula for *T*-Student test:

$$T = \frac{\hat{X} - \hat{Y}}{\sqrt{\frac{k_X \cdot \sigma_X^2 + k_Y \cdot \sigma_Y^2}{n_X + n_Y - 2} \cdot \left(\frac{n_X + n_Y}{n_X \cdot n_Y} \right)}}$$

Such analyses were carried out for three key moments:

- Year 2020—Introduction of the Renewable Energy Development Program;
- Year 2022 (III and IV quarters)—Changes introduced in the Renewable Energy Development Program;
- Year 2023 (I quarter)—As the latest data for the housing and building market.

4. Analysis of the Market and Eco-Friendly Solutions

4.1. Krakow as a Smart City

Using the criteria presented in Figure 1, Krakow can boast high indicators among:

- the automatic rental housing market;
- the ability to forecast demand on the housing market;
- innovative digital platforms in the housing market;
- innovative policies (as the last one).

Important in this context are the city's activities concerning support for pro-environmental solutions (eclectic city transport), strengthening the IT industry linked to the eleven spatial plans and analyses (as described in the Development Strategy of Krakow 2030).

There is a large variation in estimates for all dimensions of smart housing concepts between cities in Poland. Cities such as Krakow, Warsaw, and Wroclaw achieve relatively good results in almost every category of smart housing. This is not the case for cities such as Zielona Góra, Kielce, and Bialystok [26].

The above statements are typical for Poland, where large disparities between regions or cities are observed and are presented in the following diagram (Figure 3). The diagram is based on data extracted from state registers and divided into four categories:

- The "automatic" rental housing market (as the number of rental offers per 1000 inhabitants available on online platforms operating in the "automatic" rental housing market. Platforms included: Flatio.pl, Pepehousing.pl; Rentflat24.pl and Easyrenting.pl);
- Innovative digital platforms in the traditional housing market (based on the number of rental and sales offers per 1000 inhabitants offering a virtual reality option on poorly/highly innovative online platforms operating in the traditional housing market;

- Innovative housing policies and models (as an indicator measuring the innovativeness of housing policies in the city);
- The ability to forecast demand in the housing market—the difference between the average size of dwellings sold (demand) and the average size of dwellings delivered (supply) in the primary market.

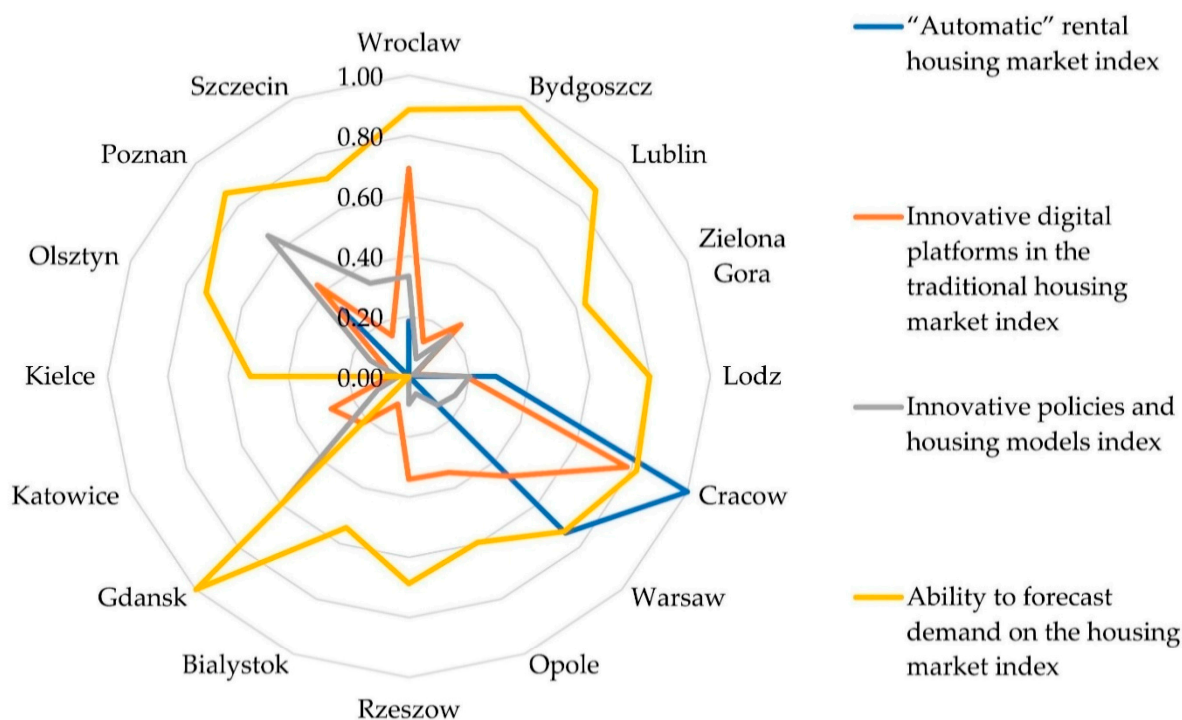


Figure 3. The level of smartness of housing markets by city and dimension [26].

All calculations and explanations are provided in [26].

Smart cities are also characterized by a wide range of technological progress, reflected in the economy. Innovation and entrepreneurship lead to the creation of new jobs, among other things. Well-organized infrastructure generates lower costs. However, in addition to the obvious benefits, one must take into account the risks associated with “smart cities”. In this case, we are talking about ICTs that have an impact on privacy, which manifests itself, for example, in traffic intensity monitoring through the possibility of tracking a vehicle. Another threat may be the instability and vulnerability of a smart city to cyberattacks. With such a high degree of dependence on technology, an anomaly in one sector can lead to the disorganization of the entire system.

4.2. Renewable Energy Sources

Smart cities are able to utilize their ecological potential, value energy, and change the way cities are developed. In the case of Krakow, such actions have been most visible since 2016, however, the last few years have also shown the financial benefits that the real estate market has taken on. Since 2020, the city has been running the Renewable Energy Development Program (PROZE in Polish), through which residents have the opportunity to receive grants for environmental protection tasks related to local renewable energy sources and the introduction of more environmentally friendly energy carriers. The program allows for the financing of heat pumps (ground and air), solar collectors, and photovoltaic installations in buildings and residential premises. The program has been very popular with Krakow residents since its inception, especially in the field of photovoltaics. In two years, the city has granted 1332 grants for RES installations, including 1120 (84%) for photovoltaic panels. The total amount of grants granted under PROZE is over PLN 19.6 million. Figure 4

shows existing renewable energy source installations taking into account the districts of the city of Krakow.

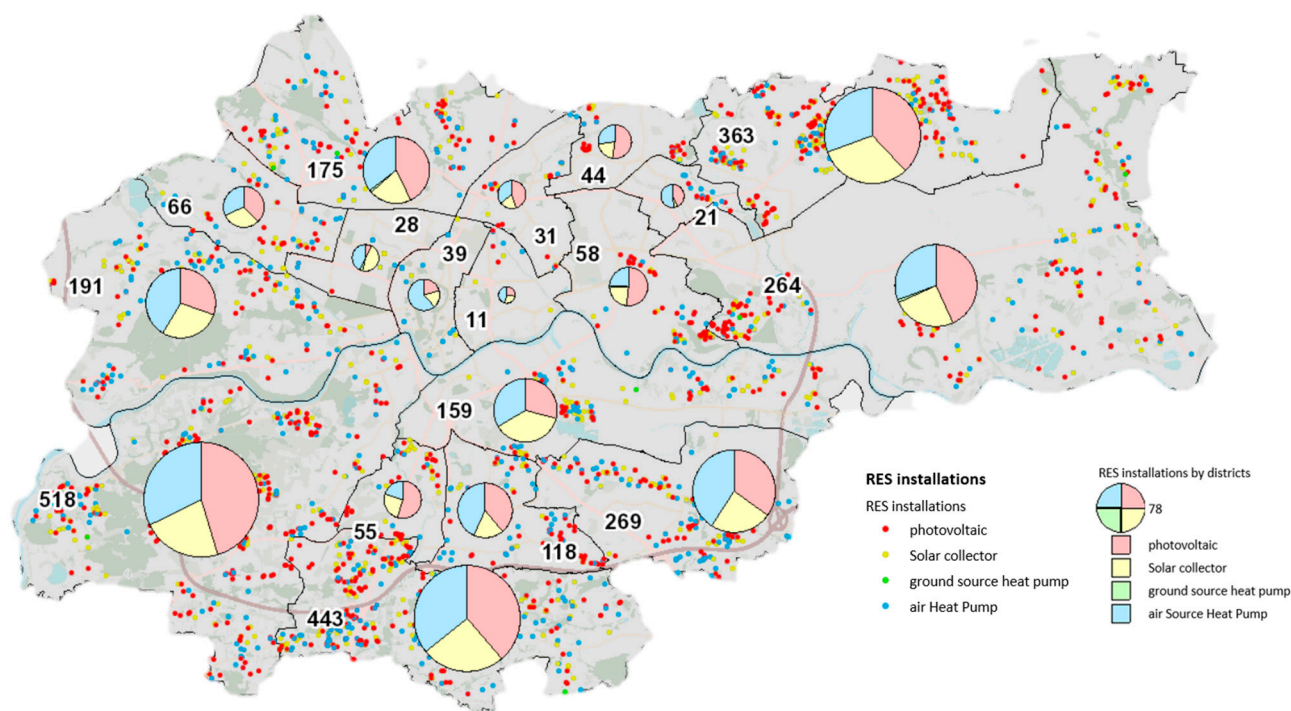


Figure 4. Renewable energy installations used in Krakow [31].

Details are presented in Table 1.

Table 1. Grants provided under the PROZE program in the area of the City of Krakow in the years 2020–2021 [32].

Year	Installation of Renewable Energy Sources	The Number of Installed Renewable Energy Installations Funded by the City	The Power of Installed Installations	Total Amount of Grants Provided (PLN)
2020	Air source heat pumps	129	1.4	10,309,316.70
	Ground source heat pumps	2		
	Solar collectors	8		
	Photovoltaics	553	3.56	
2021	Air source heat pumps	67	0.72	9,328,382.92
	Ground source heat pumps	2		
	Solar collectors	4		
	Photovoltaics	567	3.6	
Summary		1332	9.28	19,637,699.62

4.3. Solar Energy

Solar (Sun) energy was one of the first to be realistically used in the real estate market. It is best used in the construction of houses, mainly due to the fact that the construction of the installation is refinanced by the city or state. Changes are planned to provide financial support to housing communities and investors, which will quickly move to multi-family housing and entire neighborhoods. In 2016, Krakow created a publicly available solar potential map. Red indicates the highest solar potential and yellow the lowest (Figure 5).



Figure 5. Solar potential in Krakow [31].

In most of Krakow, the predominant color is orange—good conditions for taking advantage of solar energy—however, in the case of housing estates it is used as energy for lighting. The construction of one-hour houses looks completely different—here the use of photovoltaics predominates, and existing buildings are also modernized for this purpose. According to data from the Central Statistical Office in Krakow, around 1500 photovoltaic installations were set up in 2022, of which around 1200 were on single-family homes and only 300 were on multi-family homes and housing estates [29].

In June 2022, changes were made to the resolution regarding the increase in subsidies for the use of renewable energy sources [33]. The document proposes that not only single-family homeowners but also housing cooperatives and communities could benefit from the funding. The support would not only cover the installation of solar energy devices, but also the creation of energy storage or electric car charging stations. It was estimated, among other things, that the average power of a photovoltaic micro installation to meet the energy needs of common properties in high-rise buildings is about 16 kWp. The cost of a photovoltaic micro installation of the above power is about PLN 80,000. The maximum subsidies are to be (amounts including purchase and installation):

- For each kilowatt peak of power, PLN 5000 will be paid for micro photovoltaic installations, but not more than PLN 80,000;
- PLN 12,500 for energy storage;
- PLN 2500 for an energy management system;
- PLN 10,000 for an electric vehicle charging station. The maximum grant amount will be up to 60 percent of the eligible costs, but not more than:
- PLN 48,000 for the purchase and installation of micro photovoltaic installations;
- PLN 7500 for energy storage;
- PLN 1500 for an energy management system;
- PLN 6000 for an electric vehicle charging station.

In summary, in 2020 only one out of every sixteen residential buildings in Krakow had photovoltaics installed. In 2021, it was already one out of every eight residential buildings in Krakow. It is worth noting that more than 83% of all photovoltaic micro installations connected in Krakow overall were micro installations connected in the last two years, so this was a key period for the development of this type of RES installation in the city. Additionally, it is expected that due to the amendment of the Renewable Energy Sources Act and some other acts [33], whose provisions from 1 April 2022 abolish the rebate system

(non-cash system) and introduce net billing (sales system), the number of photovoltaic micro installations in the first quarter of 2022 increased even more.

4.4. Water

The use of water in a closed loop is still a difficult topic for multi-family housing, although single-family homes also have problems with it. What the market is working on is the use of rainwater. Previously, this was carried out through the appropriate western area of the plot, as a biologically active surface. The city supported residents by subsidizing the purchase of rainwater tanks, but in recent years it has become involved in its own program for rational water use by building public transport stops with green roofs. The key task of such a green roof is to reduce the temperature felt by the passenger standing under the shelter. The city's research showed that this difference can be as much as 9 degrees. This is a huge relief for passengers and at the same time another brick in reducing so-called urban heat islands. Green roofs have been accepted on estates, although they are relatively expensive to build. Building a green roof allows an investor to fulfil their obligation to leave an area or other buildings on the plot free from concrete.

Green roofs are increasingly becoming popular eco-friendly building installations. These kinds of roofs retain 70–90% of rainwater and delay the runoff from 24 h to several days. Additionally, green roofs do not heat up as much on hot days compared to traditional roofs such as black tar. This helps save energy used for air conditioning in rooms. In winter, they also prevent heat loss and act as thermal insulation. The downside of green roofs is the cost, so developers who decide to install one often opt for rolled turf carpets instead of intensive green gardens (including trees and shrubs). This investment amounts to PLN 1500–2000 per square meter.

In the last year, the rules for paying the rain tax have been changed—the tax on concreting is based on the Water Law [34,35]. This tax also applies in Italy, Germany, and the USA. The fee is intended to encourage owners of land and property to install water retention devices. By installing, for example, rainwater tanks, one can significantly reduce the amount of tax paid. Complete avoidance of the rain tax is possible if the area of concrete is reduced below 50% of the property area or if the plot is limited to an area below 600 m². In practice, this fee should not affect typical building plots.

Those who do not have any retention infrastructure on their property pay the highest rate. In this case, the tax rate is PLN 1.50 per m² of surface area. The rate of PLN 0.90 per m² applies to those who have a retention infrastructure with an efficiency of up to 10% of the annual outflow. Installations achieving a retention range of 11–30% provide an even lower rate—PLN 0.45 per m². Previously, the obligation to pay the tax arose when a permanent building was built on a terrain with an area greater than 3500 m², reducing retention by excluding more than 70% of the real estate from the biologically active surface area. Now, according to plans, all property owners must pay a fee for 600 m² and an occupancy index of at least 50%. By “occupancy” we mean house, garage, terrace, utility room, driveway, or other paved surfaces with paving stones. However, negotiations are still ongoing; the next step is to hold public consultations as part of work on the law.

4.5. Real Estate Land Market

Investment in land and its subsequent development is the main target of ecological investments. Here, photovoltaics, heat pumps, and rainwater tanks are found. Additionally, as previously shown, these investments are subsidized by the state.

In 2020, surprising trends and behaviors were observed in the Krakow land market. The beginning of the COVID-19 pandemic at the end of February surprised a market that had not previously encountered such an event and could not predict what economic and social effects it would cause. In recent years, investors have been active in the land sector for residential development—currently, they have focused both on land designated for residential development and single-family homes. Due to good sales results of apartments, developers replenished their land banks. A novelty in 2020 was the demand for plots for

single-family houses from individuals. The reason for this phenomenon was redirecting money from bank deposits to other places, i.e., plots for single-family housing that were within reach of individual investors as well as an increase in interest in single-family construction during the pandemic. For the second year in a row, there has been a decrease in buyers in the land segment for service development. The cause of this phenomenon was an increase in vacancies in office buildings and closed hotels—the effects of the pandemic. There were no significant transactions for service-designated plots. There were occasional sales of small plots with attractive locations and high prices, allowing investors to safely invest their capital. Developers can consider 2020 a successful year despite the pandemic, which led to the search for new areas for investment. Data presenting income from the land real estate market is shown in Figure 6.

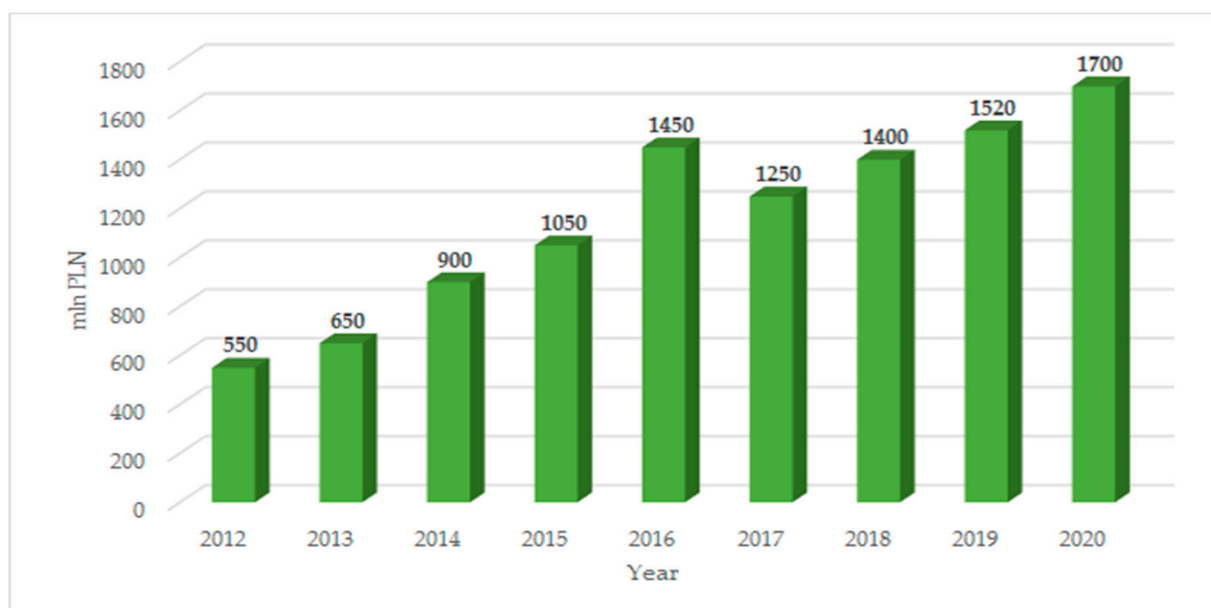


Figure 6. Income from land markets in Krakow (in millions of PLN) [36].

In 2019, developers mainly focused on the outskirts of Krakow, with the last plots still being purchased. The small amount of investment land in prestigious locations caused transactions to be made at record prices, such as the purchase of a 23-acre plot in Salwator for around PLN 23 million (10 thousand PLN/m² of land) [36,37].

Data from 2020 show that there were more transactions and turnover on the plot market in Krakow compared to the previous year—with around 1700 transactions and a turnover of around PLN 1.7 billion. It should be noted that these are preliminary data and some transactions have not yet been included. The turnover in 2019 was ultimately PLN 1.52 billion with 1450 transactions.

In 2020, an increase of 16% was observed in prices for land for multi-family residential development in Krakow.

According to GUS data, a total of 9914 plots were sold in Krakow between 2016 and 2023. The most, 3711 plots, were sold in 2017. The least, only nine plots, were sold in 2018. [29]. In 2020, the largest share of land transactions in Krakow (60%) was for plots for residential and multi-family housing and service development. The share of plots for single-family construction was around 23%. Transactions of service plots significantly decreased to around 13%. The causes of this decrease are the previously described effects of the pandemic on the services sector. For another year in a row, there was a significant share (4%) of plots designated for green areas and agricultural land compared to this segment. In 2020, developers continued to buy land on the outskirts of Krakow, and the prices of plots depending on their purpose are shown in Figure 7.

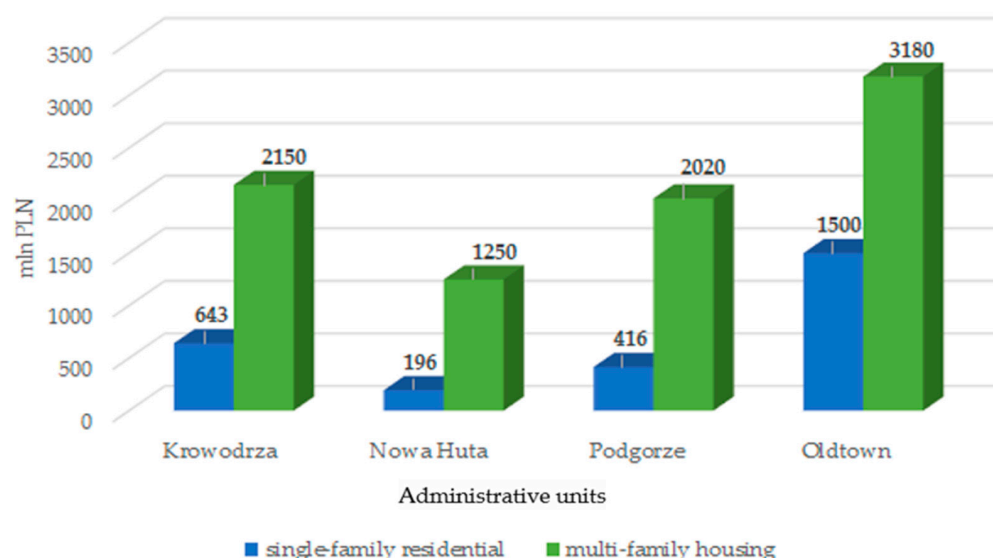


Figure 7. Income from land markets in Krakow (in millions of PLN per administrative units) [36].

4.6. Primary Residential Market

The primary market is the basis for shaping SMART solutions, including eco-friendly ones. However, we observe its beginnings mainly in the form of photovoltaic installations and water retention tanks. From 2016, the number of investments carried out decreased until the start of the COVID-19 pandemic lockdown, which proved to be a gap both in terms of investment volume and sales offers. From the second quarter of 2020, the number of investments in Krakow has been slowly but steadily increasing due to a clear decrease in demand compared to several years ago. At the end of 2020, 106 investments were being carried out in Krakow. The price of apartments on the primary market in 2020 rose to an unprecedented level of 9900 PLN/m² and remained at this level during the second half of 2020. This level was maintained until the end of the pandemic restrictions.

March 2020 was a turning point in the primary housing market in Krakow. The lockdown distorted the entire real estate market. Before the pandemic, prices were rising at a two-digit rate annually. Subsequent years brought price increases, reduced apartment sizes, and exclusive eco-friendly and resident-friendly investments. This can be seen in the southern part of the city, where substantial changes in property prices (orange in Figure 8) are visible. In subsequent years there was an increase in investments, averaging 20 per year, with 300 new ones planned for 2023.

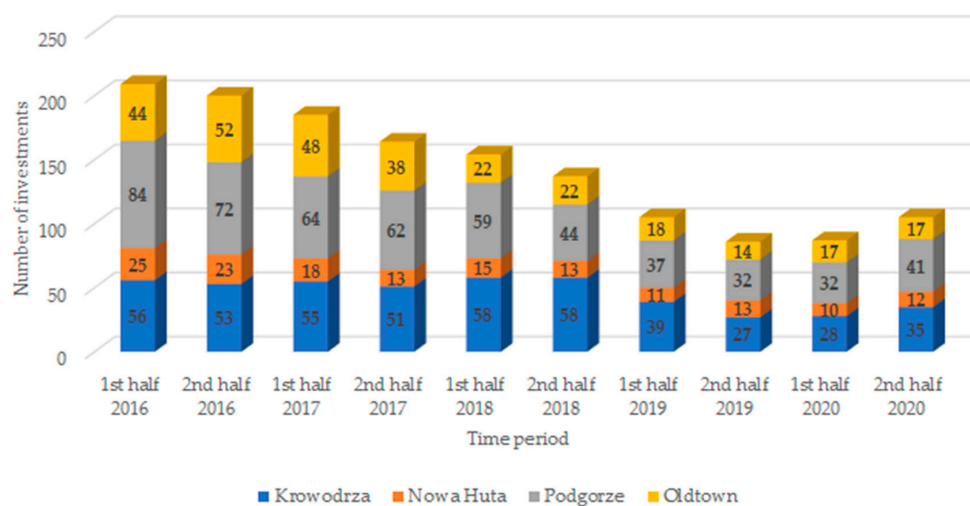


Figure 8. The number of residential investments in the city from 2016 to 2020 in administrative units [36].

The average level of prices of developers' properties offered on the primary market is a derivative of the location in Krakow. Taking into account the situation in different cadastral units of the city, one can see differences in prices depending on the area of Krakow. The downtown area is the area with the highest average price for apartments. The reason for this is its prestigious location and standard of apartments (see Figure 9).

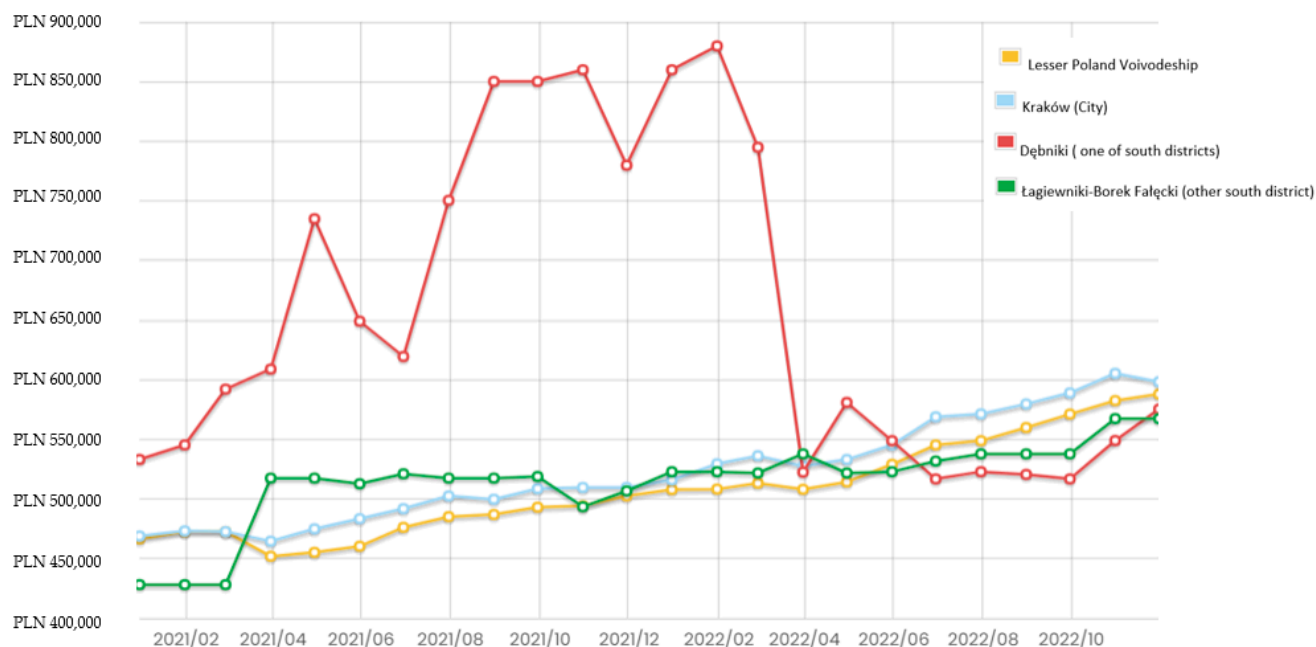


Figure 9. Land market turnover in Krakow (mln PLN) [37].

5. Discussion

We, therefore, have a real incentive for financial savings and even support from the city and a tax discouraging excessive concreting of properties. Both solutions are effective, especially when based on financial matters. Additionally, the climate changes of recent years contribute to a rational approach to ecological solutions in construction areas. Summer 2022 was difficult in this regard—droughts led to water supply interruptions in suburban areas.

These actions are reflected in the primary real estate market—buyers choose consciously, and SMART investments enjoy better returns. This is particularly visible in the southern part of Krakow, which can produce up to 12 times more electricity than required [31].

The issue of renewable energy is also a question of money saved. This translates into real reductions in energy bills, especially since we are talking about a market that requires a considerable financial outlay, usually coming from a loan that is repaid over the next 30 years. It has been found that the young generation has minimum change to buy own their housing not only because of increased housing prices, which can be seen in the example of the Czech Republic [38], but also because of increased costs and lower accessibility of mortgage financing, as exemplified by Lisbon [39]. Housing contributes to poverty and the level of deprivation is an important topic in countries experiencing a decrease in the overall poverty level, which was evident even before COVID-19 [40], but also after, as can be seen from the example of the Czech Republic [40]. In some countries this share of housing costs makes housing unaffordable even for households having their homes in their own possession.

The question, therefore, arises as to what extent the state should support the property market. Is it only by supporting pro-environmental investments or also by refinancing part of the maintenance and energy supply charges for citizens? This is a resonant issue in Europe currently, visible in the example of the Czech Republic [21,41]. In Poland, the

situation is somewhat different. The government has begun refinancing energy supply programs for individuals since 2022 and has been regulating electricity prices for two years. This gives an effective dimension to the number of housing costs. Poland also has mortgage support programs for first-time buyers, dating back to 2012 and the “Family on Your Own” program. Subsequently, further programs were introduced, and in 2023, the “First Apartment” program was launched.

The Polish real estate market is developing well, new and interesting investments are emerging [42,43], and apartment prices are rising throughout the city regardless of property type. Only at the end of 2022 did stagnation set in, however, at the time of writing, there were no official data so the authors will return to this topic another time.

Additional financial support for the multi-family housing sector gives hope for improving the quality of life for residents and modernization of existing investments in subsequent years. The authors will gladly look into this phenomenon, expecting increasing apartment prices with simultaneous application of SMART solutions including energy.

At designated checkpoints, average prices of apartments and buildings were compared. Groups were distinguished based on the nature of investment (Group A—pro-eco-logical, Group B—built using classical technology). In order to minimize differences, investments located in close proximity (max 2 km) and subject to turnover (registered in the national PL-Price Register system, previously the Price and Real Estate Value Register) were compared. Then, a *T*-Student test was conducted, and the results are shown in the tables below (Tables 2 and 3).

Table 2. Mean values of 1 square meter of developed land (single-family residential building) sold in investments.

Year	Group A: Average Price $\pm$ Standard Deviation/Number of Trades	Group B: Average Price $\pm$ Standard Deviation/Number of Trades	The Result of Inference Based on the <i>T</i> -Student Test
2020	————	PLN 6500/30	Lack of possibility for inference
2022	PLN 7600 $\pm$ PLN 350/65	PLN 7400 $\pm$ PLN 400/65	The means in the samples differ significantly
2023	PLN 9500 $\pm$ PLN 220/52	PLN 9300 $\pm$ PLN 360/52	The means in the samples differ significantly

Table 3. Mean values of 1 square meter of local real estate (apartments) sold in investments.

Year	Group A: Average Price/Number of Trades	Group B: Average Price/Number of Trades	The Result of Inference Based on the <i>T</i> -Student Test
2020	PLN 9800 $\pm$ PLN 451/90	PLN 9700 $\pm$ PLN 398/90	Failure to reject the null hypothesis
2022	PLN 11,900 $\pm$ PLN 542/110	PLN 11,650 $\pm$ PLN 683/110	The means in the samples differ significantly
2023	PLN 11,800 $\pm$ PLN 221/80	PLN 11,400 $\pm$ PLN 198/80	The means in the samples differ significantly

6. Conclusions

Krakow is a city where the historic center meets buildings demolished from the 1960s to the 1980s and beyond for newer construction. There is new construction and pro-ecological modernization will spread to neighboring districts and gradually occupy more and more territory. The city is running campaigns to support renewable energy sources, but the authors are counting on more. The period during the pandemic when interest in the construction market increased and the environment around investments are interesting. The city seems to be prepared for developing pro-ecological activities, as public transport is mainly electric and further restrictions are planned for cars that do not meet

environmental standards. We have to wait for the multi-family real estate market where, however, investment amounts are much higher than buying a new car. The authors assume that the last few years have seen the beginning of an expansion of the SMART market, especially for housing. The need to support both the developer sector and homebuyers can be seen here. Eco-friendly investments are becoming visible to buyers and their time in the market is shorter than for traditional investments. At the same time, the COVID-19 years and later the war in Ukraine have changed the way we look at residential property. Now it should be friendly not only to the inhabitants but also to the environment and, importantly, cheap to maintain.

The authors consider the commitment of financial support from both sides of the property market to be good practice worth replicating. Special support can be counted on by first-time buyers, as they will benefit threefold, as:

- beneficiaries of a mortgage subsidy;
- owners of a property benefiting from a smart investment;
- those who benefit from a subsidy for the energy supply of their purchased home.

The article shows what the support of the state and the city in the process of developing ecological construction may look like. For now, the first effects are in the form of new investments, mainly in the southern part of the city. In order to see the financial impact on the scale of the entire city, we will have to wait for investments subsidized in the field of photovoltaics, because this one has received the best response, mainly due to the reduction of energy maintenance costs. Photovoltaic panels, installed on the roofs of houses, are of great interest. We hope that the financial support for developers will translate into similar popularity among multi-family investments. It is apparent that neighboring countries (especially the Czech Republic) are having a harder time with the financial and energy crisis.

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