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Are Local Commune Governments Interested in the Development of Photovoltaics in Their Area? An Inside View of Poland

Katarzyna Kocur-Bera

Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, 10-719 Olsztyn, Poland; katarzyna.kocur@uwm.edu.pl

Abstract: A growing number of installations for generating energy from renewable sources has provoked an increased response in society. The tendency to support such investments is noticeable. The main actors in the PV market include investors, administrative bodies that issue relevant permits, and communities in locations where such investment projects are planned. Not every property should be allotted for such investments. Some entities are interested in having Renewable Energy Source (RES) installed in their area. This study aims to demonstrate the benefits that local commune governments can gain from implementing PV farms in their area and to perform an analysis of socio-economic and spatial determinants of locating PV farms at the regional level. The scenario method and a multiple regression analysis were applied in this study. The research was conducted for the territory of Poland, taking into consideration the number of PV farms in individual regions/voivodeships (NUTS-2). The results show that the number of PV farms in Poland is not growing evenly. The growth of the investment project number is the greatest in the north and the northwest of Poland. Local commune governments are interested in implementing PV farms because of a much higher income from the real estate tax and because of a decrease in the rate of unemployment among agricultural farm owners. All of these results should be observed from a longer-term perspective to confirm the trends.

Keywords: PV farm; real estate tax; social; economic condition of region; spatial condition

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1. Introduction

The rapid rate of economic development, increasing environmental pollution, diminishing natural resources, and ignorance of concern for the quality of life of future generations make it crucial to take measures to halt the negative effects of the development of civilization. The mitigation of the effects of civilization can be achieved only through integrated actions in economic, social, and environmental areas.

The literature notes two parallel concepts: green growth (OECD) and green economy (UNEP, EEA). They can be identified as consistent stages of conduct. Green growth leads to a state of green economy, being one of the pillars of sustainable development alongside social development. The green economy is the sector of the national economy that takes into account the principles of sustainable development and uses local resources while being environmentally friendly. It ensures a proper relationship between the economy and ecosystems and responds to the global problems of environmental degradation via expansive, economic human activity.

The green economy has gained Its current popularity from the United Nations International Conference on Sustainable Development. Unlike the brown economy model, which relies heavily on the use of fossil fuels and other non-renewable resources, this model should ensure the right relationship between the economy and ecosystems (see Figure 1). The green economy provides a decoupling of economic growth from natural resource consumption, takes into account the finiteness of fossil fuels, promotes the use of renewable resources, protects biodiversity, considers intergenerational and interregional equity, and recommends sustainable consumption, energy efficiency, and clean production [1,2]. It enhances public confidence by incorporating corporate and investor green social responsibility.

The green economy promotes and implements green processes throughout the economy, i.e., reducing the consumption of energy and resources and the emissions of all pollutants, to ultimately achieve the decoupling of economic activity from emissions and the consumption of natural resources. Increasing the proportion of the green economy nationwide through the use of green technologies, green energy, and low-energy industries tends to ensure the good health of humans and the environment in the entire economic system.

The green economy is a driver of structural change in economic and social life. Changes in the economy through the introduction of environmental criteria in production, investment, and consumption processes generate the growth of the green economy, with green growth expressed as the increasing participation of the green economy in the creation of gross domestic product and green employment. The green economy attempts to balance the problems of socio-economic development and anthropogenic changes to the environment. The green economy is considered to best express a balance of three aspects: economic, social, and sustainable development.

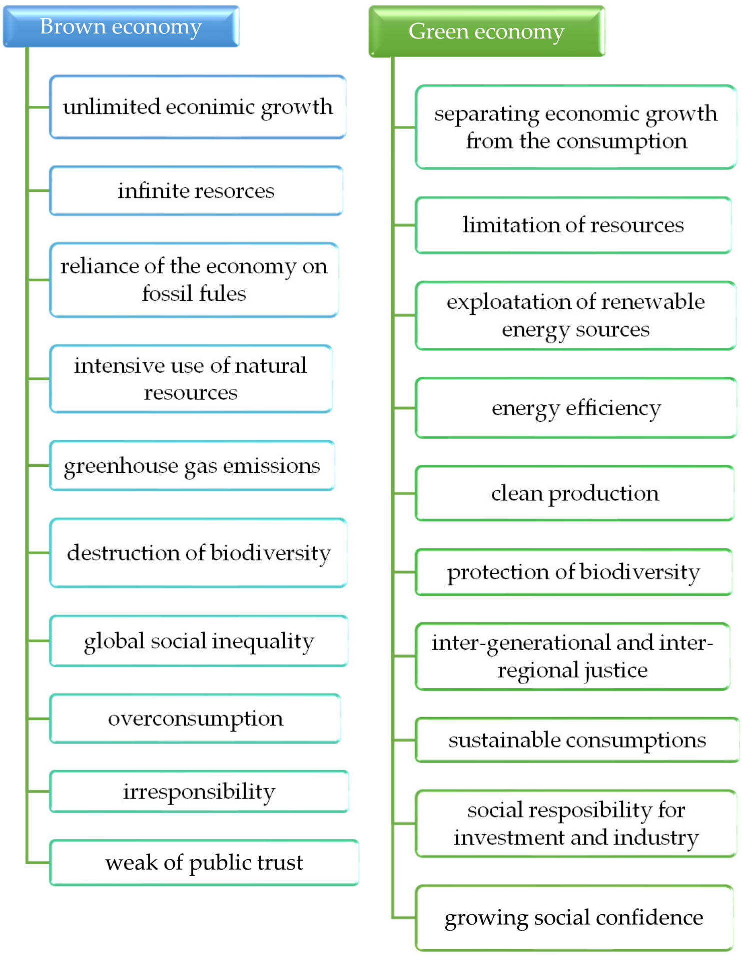

Figure 1. Features of green and brown economy. Source: created by the author based on [1,2].

The implementation of green economy principles is intended to provide the best opportunities to reduce greenhouse gas (GHG) emissions and use energy efficiently.

Energy production from natural sources, for example, from the sun, is one of the realizations of the green economy. It is a response to ongoing climate change [3–5], capable of paying off in the long term [6].

2. Theoretical Background

2.1. Development of Photovoltaic Projects

The increase in energy demand [3], the implementation of the European Union's climate and energy policy [4,5], and recent political events (the war in Ukraine) have been a verifier of the importance of energy policy. The countries' authorities observed that moving the power generation model from central to distributed with energy storage is preferable. RES complies with the assumptions of distributed models and improves the chances of survival during unexpected crises.

The Sun is the main source of energy reaching the Earth. The Sun is a warming gaseous sphere with a mass of 1989 $\times$ 10^{30} kg, a surface temperature of about 5800 K, and an average distance from the Earth of 149.6 million km [7]. The gigantic amount of energy emitted by the Sun is created in its core [8]. At a temperature of about 15 million degrees Celsius, thermonuclear reactions occur in which hydrogen nuclei are transformed into helium, and energy is emitted in the form of radiation and heat [9]. Scientists have calculated that every second, 657 million tons of hydrogen are transformed into 653 million tons of helium deep inside the Sun. The difference in mass, 4 million tons per second, is converted into energy. The power emitted by the Sun is not distributed evenly across the globe. Areas near the equator receive the most energy, while circumpolar areas receive the least. The total energy that reaches the horizontal surface throughout the year ranges from 600 kWh/m^2/year in Scandinavian countries to more than 2500 kWh/m^2/year in central Africa. In Poland, it is about 1100 kWh/m^2/year [10]. Nowadays, energy from the sun can be used in several ways, including solar panels for heat generation, heat pumps for heat generation, thermal solar power plants, and photovoltaic cells for electricity generation [11].

The main advantages of solar energy generation include locational availability, investment costs, low noise levels, and the predictability of energy production volumes relative to other RESs. Estimates of the number of hours of sunshine are more readily available than estimates of wind power, for example. In contrast to wind turbines, solar panels may be installed closer to residences because they generate low levels of noise. The extraction of energy from other sources, e.g., geothermal or water, has a local impact, and the construction of the installation represents a significant interference with the environment. In the case of hydroelectric power plants, riverbeds can often become silted up as a result of water movements, and this impedes the movement of fish. The construction of hydroelectric power plants also involves large investment costs and noise pollution for the surroundings. For geothermal sources, the main disadvantage is local availability. Favourable conditions for the use of geothermal sources are found in very few places on Earth. A huge advantage is the relatively cheap exploitation of energy.

Photovoltaics represent a zero-emission system. That means that it does not emit harmful compounds and carbon dioxide or greenhouse gases during energy production [12], which means it has one of the lowest environmental impacts of any energy production source during operation. It becomes virtually maintenance-free due to the use of semiconductor technology, the lack of moving parts, and the simplicity of the system. Electricity production from photovoltaic systems occurs at the time of day when the country's energy demand is highest. Therefore, the peak demand for electricity is covered. At the same time, this facilitates the integration of photovoltaics into the power system and relieves the burden on conventional power plants. The development of investments related to energy production using PV is a confirmation of the implementation of green economy principles. The highest growth in the installation of PV farms in recent years in Europe is observed in Germany, Spain, and Poland (see Figure 2).

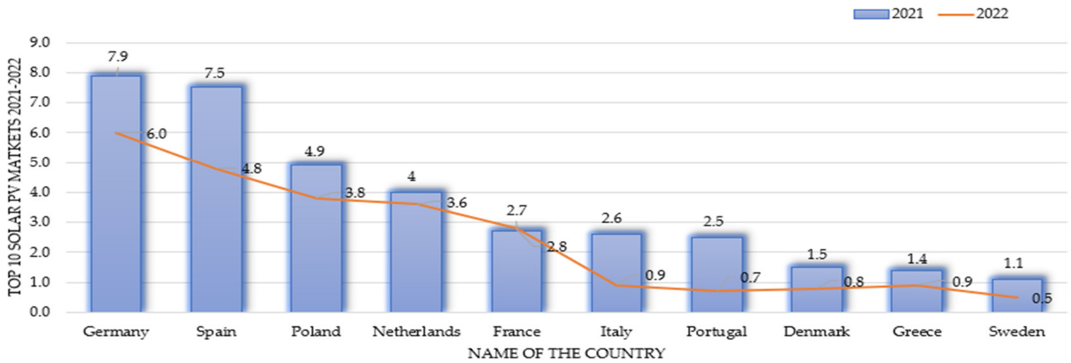

Figure 2. The PV power installed in Poland in 2021–2022 as compared with other European countries. Source: created by the author based on [13].

Germany is a leading European producer of solar energy. It added 7.9 GW in 2022 and 6.0 GW in 2021. This largest EU economy has held the first position since the start of the 21st century. After a phase of consolidation between parts of eastern and western Germany, the country experienced the first European solar PV boom based on guaranteed tariffs. Germany's solar sector is experiencing a second boost as of 2018. The result is a combination of self-consumption and attractive guaranteed fees for medium- and large-scale commercial systems, as well as auctions for systems up to 10 MW. The Green Party-led Ministry of Economy, creating a new solar PV target for 2030 with an installed capacity of 215 GW, has resulted in another amendment to the law on guaranteed supply (EEG). In 2022, it created, among other factors, a better investment environment for the rooftop segment: the guaranteed tariff for new systems was increased, while the monthly trend of decreasing guaranteed rates for new systems was blocked until 2024. In addition, high electricity prices improved the business justification for solar power, especially in combination with batteries.

Spain leads Europe in second place, increasing its market by 55% to 7.5 GW, up from 4.8 GW in 2021. The prohibitive tax on PV was lifted in 2019, triggering a revival. In the current energy market conditions, developers are opting for projects that sell on the open market, because it is more attractive than government-organized tenders.

Performance in Poland during the period under review was remarkable, as annual solar supply increased again—to 4.9 GW from the 3.8 GW added in 2021 [13]. The reason for such an increase was due to regulatory changes related to the billing of electricity produced. The existing system of accounting for post-production energy from photovoltaic installations until April 2022 used a rebate mechanism balancing all annual energy supplied to the grid and purchased from the grid. Prosumers generating energy in systems up to 10 kW were allowed to feed it back to the grid, with the billing receiving 0.8 units of energy per unit of energy free of charge (for installations above 10 kW, the relationship was 0.7). The prosumers paid no distribution fees for using the grid, either. Another incentive to establish systems was additional support under dedicated government programs. After 1 April 2022, the existing billing method was replaced by a new system called net billing.

Under this billing method, the amount of electricity supplied to and drawn from the grid is billed hourly using a metering system. Prosumers charge for energy injected into the grid at the wholesale price (the previous month's energy exchange price) and pay for the energy consumed, like other electricity consumers. The new balancing system has reduced prosumer investment in microgrids and extended the payback period (previously 8 to 10 years).

High electricity prices and serious concerns about energy security following the war in Russia have ensured a continued rate of growth in PV installations as countries strive to become independent of fossil fuels. Another country boasting sustained growth in PV energy production is the Netherlands. The country installed 4 GW in 2022, up 11% from the previous year. Attractive net-metering policies in the residential segment have contributed in large part to this growth. The Dutch market ranks first in Europe in per capita PV capacity. Despite tremendous problems in space availability, the industry is increasingly turning attention to multifunctional devices. Applications like floating solar panels or solar sheds, etc. have been found in the Netherlands [13].

France represented the fifth-largest photovoltaic market in the EU in 2022, with about 2.7 GW of annual growth from power generation. The year 2018 marked a marginal decline, followed by a record year in 2021. Rising solar prices and difficulties in accessing land seen in 2022 led developers to put projects on hold until economic and regulatory conditions improved.

Italy's solar production returned to annual GW for the first time since 2013, ranking the Mediterranean region 6th in the EU. With an estimated 174% (2.6 GW) year-on-year increase, the Italian market is booming. The small-scale PV market segment has strengthened thanks to the super-bonus premium and high electricity prices. They have also improved auto-consumption models. However, a big problem in Italy remains the matching of suitable land for photovoltaic projects and the challenging path of administrative and legal procedures for acquiring permits for investments.

Portugal joined the ranking for the first time in 2022. The country ranks 7th, through it experienced a reported 251% increase to 2.5 GW [13]. A large number of projects have permits until the end of 2022, meaning they will likely be completed before that time. The self-consumption segment, which has previously played a marginal role, has also been rapidly gaining momentum.

Denmark is ranked next, with 1.5 GW installed and 75% annual growth. PV parks provide the largest share of new installations, thanks to well-functioning and transparent regulations on permitting and grid connection procedures, despite the absence of subsidies. Growth was also recorded in the rooftop segment.

The Greek market grew by 62% from 2021 to 2022, driven mainly by small ground-mounted installations up to 500 kW, for which there is a guaranteed bonus (available until the end of 2022).

The graph closes with Sweden, where solar demand is driven by tax incentives and subsidies. Residential photovoltaic systems dominate the market segment there, with demand driven by rising energy prices.

2.2. PV's Impact on the Environment and on Humans

A choice of location for a PV farm is not easy as it involves an analysis of technical aspects (a permit for connecting to the power grid), the possibility of obtaining the relevant administrative permits, and environmental aspects, taking into consideration the impact on the surroundings, protected objects, and the landscape and social aspects that involve convincing the local communities that such an investment, at a selected location, will not have a negative impact on their life or health. Obtaining energy from sunlight is gaining an increasing number of supporters [14–16].

PV farms require large, peripheral land areas [14]. This is why they are usually located on suburban, mainly agricultural land. The value of this land is lower than that of urban land, which affects the profitability of the investments. From the perspective of agricultural land protection, PV farms should be located on soil of the lowest quality, with no agricultural production. Local governments, which are responsible for spatial management in communes, usually support investors in locating PV farms in their areas. This is motivated mainly by financial reasons. Commune authorities perform their actions using their own income (revenue from real estate tax on agricultural land), general subsidies from the state treasury, and special subsidies, also from the state treasury [17]. A change in the method of land use from agricultural to other has a serious consequence for the amount of the real estate tax. The tax system in Poland is based on the method of land use and its area [18–20]. The concept of tax calculation based on the cadastral value has still not been applied. The method of the use of land, which was used for agriculture until a PV farm was constructed on it, also changed [17,21]. This also applies to a situation where the position of a PV installation allows for the partial use of the land for the cultivation of cereals, grass, or other crops (e.g., agro-photovoltaics). A plot with a PV farm is divided into two zones of use. The first zone covers the space where the PV cells are situated, i.e., the business/industrial activity area [22]. The tax for this area is calculated for the land and the structure connecting the PV cells with the ground [23]. The second zone is the land service—the land occupied under transformers, transmission channels, and access roads to the PV structure [24]. The tax in this area is calculated only on the land (the other elements are not permanently fixed to the land; they are mobile and transferable to a different place, which prevents their taxation).

Commune authorities often face criticism when planning PV investments. The installation of PV cells on house roofs is widely accepted. Conflicts arise in the case of larger investments. Local communities justify their objections by the impact of PV installation on human health, the neighbouring nature and landscape, as well as on socio-economic development and entrepreneurship [25].

According to the study findings, the PV farm's impact on human health is associated with the air quality, i.e., with the dust particles carried in the air or toxic compounds, and their impact on personal health at different stages of the structure construction, use, and maintenance [26,27], and also with the noise and the electromagnetic field generated by the transformers and inverters when the farm is in operation. The main parts of the installation in transformer stations are coils with an iron core. The noise generated by a transformer comes from the transformation of the direct to alternating current, which causes audible noise. Such noise can be reduced a little by the proper construction of the transformer, but it cannot be eliminated completely. Mechanical vibrations are another cause of the noise generated by PV farms. They originate from the core vibrations, which are carried to the parts of the installation fixed to it. According to studies, applying this method of noise reduction by an anti-noise function decreases noise by approximately 10 dB (at the frequency of 100 Hz) at a distance of 100 m [28–30].

Communities are also concerned about the possible impact of the electromagnetic field on human health, i.e., the nervous system, cardiovascular system, immune system, cancer formation processes, and ailments, e.g., headaches, fatigue, and memory disorders [31]. However, studies of such concerns are scarce, and photovoltaics are the source of energy with the smallest impact compared to other sources.

The study authors also point out that communities are concerned about the impact of a PV farm on the neighbouring nature, landscape, and biodiversity. Due to the large area of land occupied by the cells, PV farms have an impact on agricultural land use. They also collide with the existing flora and fauna and reduce the area occupied by agriculture [32]. Removing plants from the land where PV farms are installed exposes the soil to various processes (e.g., compacting and levelling), which, with time, can degrade it and make it lose its productivity. Moreover, photovoltaic parks can change carbon circulation in the atmosphere by changing the soil temperature, atmospheric precipitation, and evapotranspiration [33]. This leads to a loss of ecosystem services as natural land conversion occurs. This creates a paradox, as actions aimed at alleviating global warming result in local aberrations in land use, which has an adverse impact on human well-being [34]. It is noteworthy that PV farms evolve towards solutions that minimize their impact on the landscape [35]. They depart from simple pieces of infrastructure intended for the conversion of solar energy towards multi-functional spaces [34].

A PV farm under construction is a new piece of infrastructure comprising new objects in space. Their location in the area will bring about consequences for the environment, consisting of the fragmentation of habitats (especially forests) and pushing out wild animals [36]. Although the strategy that limits the impact of PV farms on agricultural activity in farms, so-called agro-photovoltaics [37], minimizes disruptions in food production, it also affects the choice of local agricultural products that form monocultures. They, in turn, do not improve biodiversity [38,39]. The continuity of the local landscape is another matter. In the construction of PV farms, natural spaces are disrupted by images of photovoltaic systems lying on the ground or installed on supports close to each other. They have an impact on the visual perception of landscape elements, microclimate changes, land use, and the elimination of existing flora, and they cause sunlight reflexes [39]. Torres-Sibille et al. [40] conducted an in-depth study of the PV system's impact on the landscape based on four criteria: visibility, colour, fractality, and convergence. The study confirmed that the topography of the land where an installation is situated has a direct impact on visibility. Several plots of forest around an object, combined with flat land, can alleviate the visual and aesthetic effects. Placing an installation on a hill slope makes it more visible. The colour of PV panels, as juxtaposed with the natural flora, makes the landscape coloristically inconsistent. Choosing a mild hue of PV crystals or one that corresponds to the background colour (plants, soil) can alleviate the installation impact by achieving a basic harmony of colours [41]. Photovoltaic systems are constructions of a completely different shape than those occurring in the natural environment. For this reason, large rectangular or polygonal surfaces do not seem to match trees or bushes, and they do not create aesthetic harmony with the landscape. Kapetanakis and Kolokotsa [41] concluded that an increase in the number of photovoltaic systems must be accompanied by the adoption of specific rules and regulations to regulate their integration with the landscape, from areas of protected landscape to built-up spaces.

The literature on the subject also shows some positive aspects of PV farm locations with respect to space management. This concerns mainly the use of abandoned [42,43], degraded land, and sites of former mines. Restoring the original features of such land can be very costly, whereas constructing PV farms on it can be beneficial for the economy and the landscape.

Local communities are also concerned about a PV farm's impact on the socio-economic environment. Many entrepreneurs operating in the vicinity of PV farms stress the adverse impact of such projects on so-called "nature-oriented tourism". This concerns mainly accommodation facilities, hunting grounds for tourists, and restaurants. According to public opinion polls [44], PV farms reduce the demand for tourist services because potential tourists do not want to see large industrial objects while on holiday. There is also a noticeable long-term limitation of land use autonomy and management [34–38,45–49]. PV farms are expected to be used for approximately 25–30 years, which is the life span of photovoltaic cells. The landowners cannot change the method of land use during that time.

Photovoltaic farms in rural communes in Poland do not develop coherently. New investment projects of PV farm construction are carried out more frequently and in greater numbers in some regions than in others. Despite multiple barriers and problems, local governments try to encourage investors to build PV farms on their land.

This study aims to demonstrate the local government benefits from the placement of PV farms on agricultural land and to examine a region's potential for implementing a PV farm.

The scenario method and a multiple regression analysis were applied in the study. The scenarios were developed assuming three quality-related categories of land in four tax districts and with the assumptions of equivalent parameters of a PV farm. The potential of a region was based on an analysis with ten diagnostic variables describing the socio-economic and spatial dimensions.

This paper comprises the following sections: the Introduction discusses the development of solar power generation in Poland compared with other European countries. This is followed by a literature review concerning socio-economic and spatial (environmental) issues faced by local governments. The research part and discussion demonstrated the financial benefits gained by communes and showed the main determinants of the choice of a region with regard to PV farm development.

3. Materials and Methods

The research was conducted in two directions. The first pathway contained simulations for scenarios of real estate tax benefits when a PV farm is located on agricultural land (in a rural or urban–rural commune). The scenarios were carried out in 24 variants. The study did not take into account the highest quality soil (class I and II) because of their legal protection and high ecological value. The second pathway included an analysis of mutual relations between ten diagnostic variables representing a socio-economic and spatial dimension.

Data for the analyses were taken from the Local Data Bank [50], https://geoportal.gov.pl (accessed 3 December 2023) [51], and the module row distance calculator [52]. Figure 3 shows a methodology diagram for the analytical research part.

Calculations, modelling, and visualizations were performed with the licensed Statistica ver. 13.3 package, Microsoft Excel, and Bing, available under the university license.

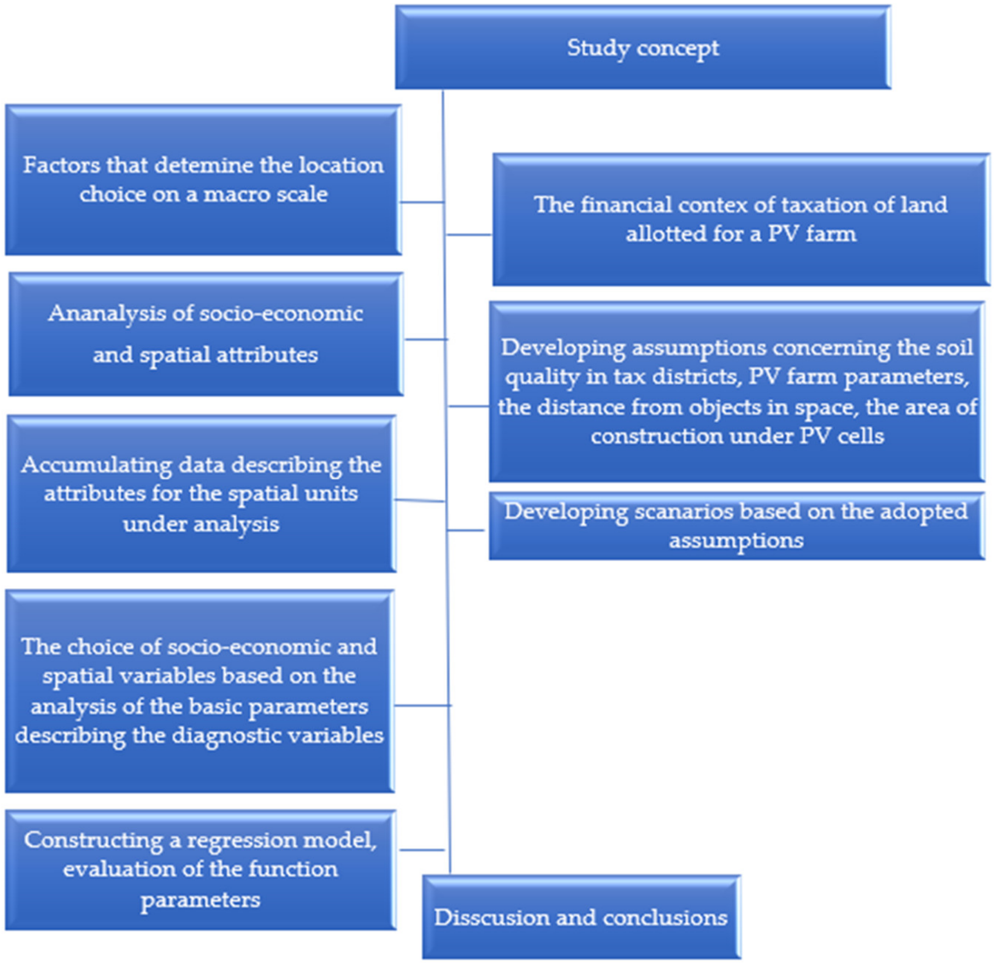

Figure 3. Methodology diagram for the analytical part of the research. Source: author's original figure.

The scenario method consists of forecasting phenomena/situations which may take place. The application of this method required making certain assumptions. The attribute describing quality took into account the soil quality classes occurring most frequently in the tax district under analysis. Poland is divided into four tax districts [53]. The soil quality is the highest in the first district. PV farms are not constructed on soils of the highest quality (class I–II) as they are under legal protection [54]. The soil of these classes was not taken into account in this study. The soil classification by quality is shown in Table 1.

Table 1. Soil classification by quality.

No.	Soil Quality	Soil Class in Arable Lands Group	Soil Class in Meadows/Pastures Group
1	High	IIIa, IIIb	III
2	Average	IVa, IVb	IV
3	Poor	V, VI	V, VI

Source: author's original table.

The following formula was used to calculate the area occupied by PV cells on a 2 ha plot while observing the safety-related guidelines and the distance to the borders with the neighbouring plots and roads (1):

$$A_{PV} = \frac{[A_p - A_s]}{N_r} \quad (1)$$

where the variables are defined as follows:

A_{pv}—area of PV farm;
A_p—area of rural parcel;
A_s—area of service part of PV farm;
N_r—number of rows of PV. [The area of a PV cell is 1 m × 1.5 m, the slope is 35 degrees, and the distance between rows is 3.5 m].

The index of PV development on agricultural land in 2019–2020, R_{PV}, for individual regions was calculated with the following Formula (2):

$$R_{PV} = \left(\frac{A_{PV2019-2020}}{A_p}\right) \times 100 \quad (2)$$

where the variables are defined as follows:

A_p—area of rural parcel;
A_r—area of PV farms built in 2019–2020 in region/voivodeship.

The I_{RA} index of agricultural land in a region/voivodeship was calculated with the following Formula (3):

$$I_{RA} = \left(\frac{A_p}{A_r}\right) \times 100 \quad (3)$$

where the variables are defined as follows:

A_p—area of rural parcel;
A_r—area of region/voivodeship.

The PV farm development potential in a region/voivodeship was determined by means of multiple regression [44]. The regression model is expressed with the following Formula (4):

$$Y = a_0 + a_1x_1 + a_2x_2 + \ldots + a_kx_k + \in \quad (4)$$

where the variables are defined as follows:

Y—multiple regression model, forecast dependent variable;
$x_1, x_2, \ldots, x_k$—dependent variable, an attribute describing the socio-economic and spatial conditions;
$\in$—random factor, difference between the observed value y_i and the theoretical one, calculated from the model;
$a_0, a_1, \ldots, a_k$—assessment of parameters of dependent variables.

Table 2 lists the main parameter values of the diagnostic variables analyzed in the model.

Table 2. Main parameters of diagnostic variables.

Symbol	Name of Variable	Unit	Aver.	Median	Min.	Max.	Coeff. of Var.
A_PV	Area of PV farms in region/voivodeship 2019–2020	ha	5308.2	3179.4	216.7	16,399.2	96.8
A_W	Index describing share of region/voivodeship area in the national area	%	6.1	5.6	2.9	11.0	35.0
I_RA	Share of arable land in region/voivodeship area [NUTS-2]	%	59.1	60.3	40.6	70.41	43.1
UA	Urban area	thousand ha	112.8	104.7	58.4	220.4	39.5
PA	Area under environmental protection	thousand ha	615.0	590.9	259.5	1128.2	38.8
LFS	Area where land management is hindered	thousand ha	767.1	681.9	158.1	1700.6	51.2
WA	Employed in agriculture	index	4552.9	3785.0	1236.0	14,675.0	69.0
UW	Unemployed who own an agricultural farm	number	1797.8	798.0	24.0	8300.0	129.6
GDP	Gross domestic product in region/voivodeship (2020)	PLN/person	146,187.2	95,864.50	46,806.0	538,344.0	86.1
WRPP	Index/potential of agricultural production space quality	index	67.1	66.75	55.0	81.4	9.71
MWe	Power generated from conventional sources in the region	MWe	1949.3	1160.4	0.0	6103.2	107.36

Source: author's original table.

4. Results

Benefits gained by local governments from the location of PV farms include mainly an increase in real estate tax revenue from the land used previously for agriculture. The presented and analyzed scenarios took into account the balanced land area allotted for a structure, on which PV cells were installed, and service land. This functional division of an area and a different method for tax calculation is a consequence of the court jurisprudence [22–24]. The results for different scenarios are shown in Table 3.

Table 3. List of scenarios taking into account the real estate tax revenue depending on the method of land use.

Nb of Scenario	A_PV [ha]	Area of Service Land [ha]	Soil Quality	Tax District	Adopted Price of 1 Quintal of Rye Grain	Real Estate Tax for Arable Land (PLN/Year)	Nb of Scenario	Real Estate Tax for PV Farm (PLN/Year)
1	2	3	4	5	6	7	8	9
S_1	1.7000	0.3000	high	1	185.12 PLN [47]	519.0	S_1pv	38,500.0
S_2			average	2		299.0	S_2pv	36,500.0
S_3			poor	3		55.0	S_3pv	34,500.0
S_4			high	4		403.0	S_4pv	38,500.0
S_5			average	1		324.0	S_5pv	36,500.0
S_6			poor	2		74.0	S_6pv	34,500.0
S_7			high	3		440.0	S_7pv	38,500.0
S_8			average	4		238.0	S_8pv	36,500.0
S_9			poor	1		83.0	S_9pv	34,500.0
S_10			high	2		476.0	S_10pv	38,500.0
S_11			average	3		263.0	S_11pv	36,500.0
S_12			poor	4		41.0	S_12pv	34,500.0

Source: author's original table.

A detailed analysis of the scenarios showed that local governments may be interested in gaining financial benefits from an increase in the real estate tax amount when a PV farm is installed in their commune. This applies to each variant. The rates of tax on arable land of the same quality but situated in different tax districts vary within 100 PLN/ha (see scenarios S_2, S_5, S_8, and S_11). The differences are greater for soils of different quality situated in the same tax district. A comparison of scenarios S_1, S_5, and S_9 reveals a six-fold increase in the tax revenue between the soil of the highest and the lowest quality. However, the greatest differences are noticeable when the method of land use changes (see Table 2, columns 8 and 9). Scenarios from S_1pv to S_12pv show that a position in a tax district and the soil quality group are no longer important when the method of land use changes. A resolution can be passed by the council of the commune on the rate of tax on land for business/industrial activity and on "other land", which includes land services [22–24]. According to the adopted tax model, the law regulates the maximum tax rates [53–59] for non-agricultural land. Commune authorities can only reduce the tax rates, and this does not happen often.

The greatest benefits from a change in the method of land use are gained from the poorest quality soils and those located in the fourth tax district.

A choice of a micro-location for a PV farm is not an easy task. A number of factors must be taken into account, which include sunlight conditions, the land ownership system, spatial management, technical conditions for connecting the PV farm to the existing power grid, the presence of protected areas, and the pool of land on which a PV farm can be installed [15,16,60]. Each region/voivodeship under analysis has a pool of land where PV farms can be installed (see Figure 4). Table 3 shows the PV farm development index for different regions/voivodeships (I_RA). The largest portion of land is occupied by PV farms in the Lubuskie, Zachodniopomorskie, and Warmińsko-Mazurskie voivodeships.

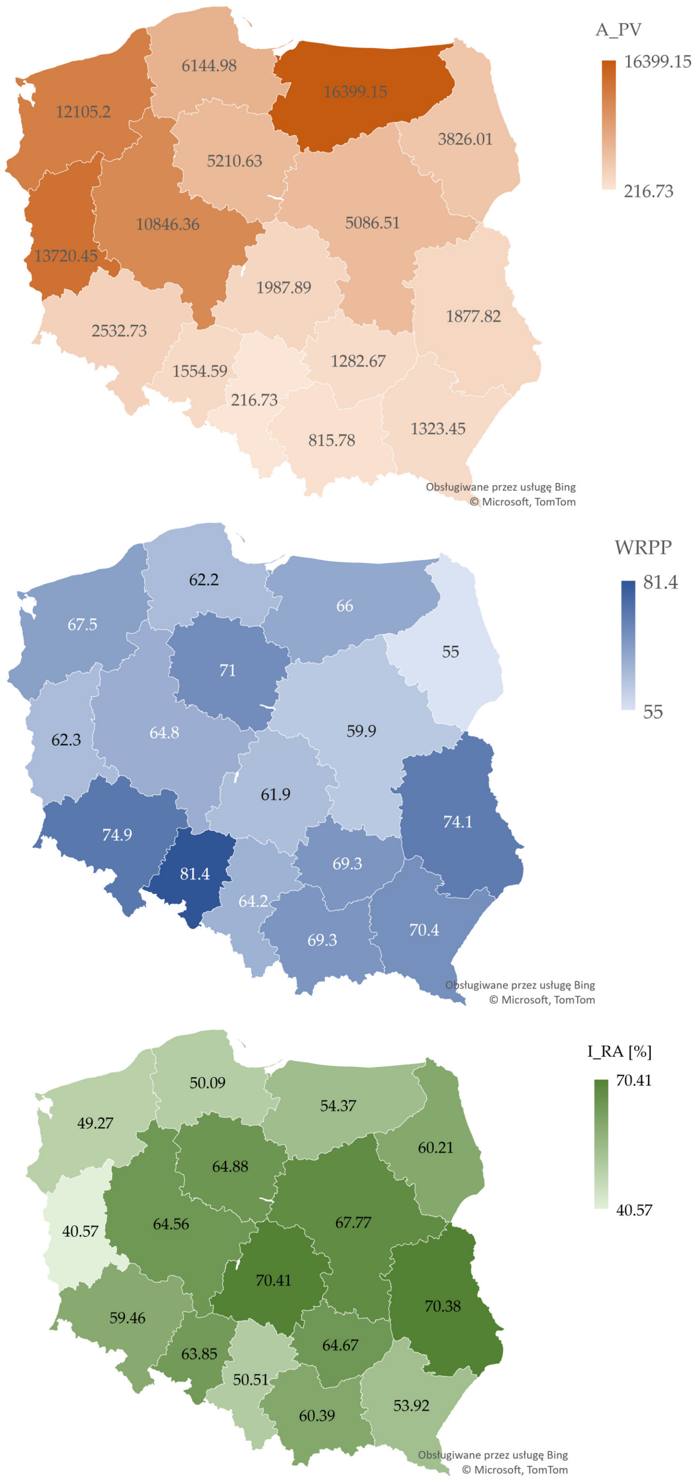

Figure 4. *Cont.*

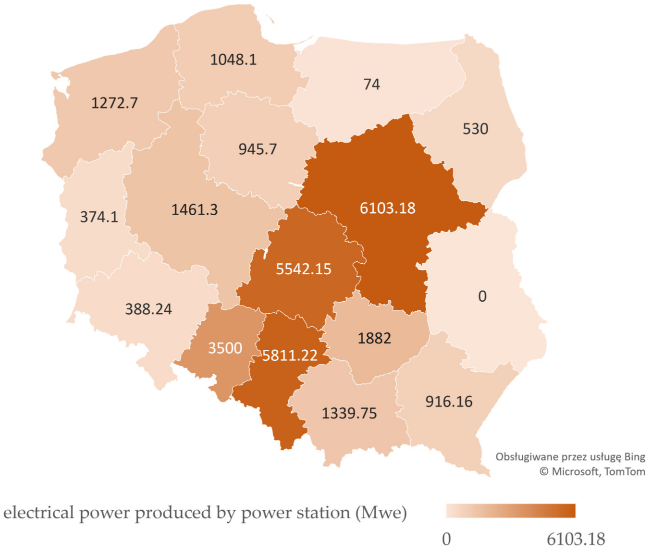

Figure 4. The index of PV development on arable land (A_PV) in the analyzed years 2019–2020, the index of valorization of the agricultural production space (WRPP), and the index of arable land area I_RA in the voivodeship/region, electricity production based on traditional sources in the region (Mwe). Source: author's original figure.

In contrast, the index of agricultural land in relation to the area of the region is highest in central and eastern Poland (see Figure 4, Index I_RA). The agricultural areas that are most valuable from the agricultural point of view (WRPP index) are found in the Lublin, Kuyavian-Pomeranian, lower Silesian, and Subcarpathian voivodeships.

It can be noted that the production of electricity (MWe) takes place mainly in central and southern Poland—in the Mazowieckie, Łódzkie, and Śląskie provinces, i.e., in regions other than areas where the development of PV farms is taking place.

The correlation analysis of diagnostic variables showed correlations between the variables A_PV, A_W, I_RA, UA, WA, PA, LFS, UW, GDP, WRPP, and MWe (see Table 4). An indicator describing areas with difficult economic conditions (LFS) was excluded from further analysis due to its high correlation with the other variables.

Table 4. Matrix of correlation between diagnostic variables.

Coefficient	A_PV	A_W	I_RA	UA	WA	PA	LFS	UW	GDP	WRPP	MWe
A_PV	1.000	0.371	−0.481	−0.026	0.441	0.579	0.360	−0.427	−0.148	−0.292	−0.372
A_W	0.372	1.000	0.301	0.685	0.489	0.569	0.922	0.225	0.583	−0.356	0.028
I_RA	−0.481	0.301	1.000	0.215	0.037	0.002	0.375	0.298	0.247	0.219	0.280
UA	−0.026	0.685	0.215	1.000	0.074	0.440	0.596	0.175	0.925	−0.270	0.503
WA	0.441	0.489	0.037	0.074	1.000	0.289	0.558	0.290	0.069	−0.258	−0.369
PA	0.579	0.569	0.003	0.440	0.289	1.000	0.477	−0.298	0.213	−0.056	−0.152
LFS	0.360	0.922	0.375	0.596	0.558	0.477	1.000	0.241	0.553	−0.536	0.154
UW	−0.427	0.225	0.298	0.175	0.290	−0.298	0.242	1.000	0.291	−0.009	0.218
GDP	−0.148	0.583	0.247	0.925	0.069	0.213	0.553	0.291	1.000	−0.290	0.640
WRPP	−0.292	−0.345	0.219	−0.270	−0.258	−0.056	−0.536	−0.009	−0.290	1.000	−0.196
MWe	−0.372	0.028	0.282	0.503	−0.369	−0.152	0.155	0.218	0.640	0.196	1.000

Source: author's original table.

The results of the indices estimation for the model of regression are shown in Table 5. The estimation of the parameters of the regression function showed that the following variables were statistically significant at the level of confidence of 90%: the index showing the share of the area of the region/voivodeship in the area of the country (A_W), the share of arable land in the region/voivodeship (I_RA), the number of the unemployed owning an agricultural farm (UW), the area of land in the region covered by a form of environmental protection (PA), and the power of electricity produced without PV (MWe). The regression equation explains 82% of the dependent variable A_PV's variance (size of the area occupied by PV farms), which indicates a good fit of the model to diagnostic variables (see Table 5).

Table 5. Estimation results for the regression model for the dependent variable R_PV.

Coefficient	Coefficient	t-Student	*p*
Const.	8518.42		
A_W	2249.33	3.81	0.008
I_RA	−385.39	−4.50	0.004
UA	−65.49	−1.37	0.217
PA	7.65	2.10	0.079
WA	0.33	1.06	0.330
UW	−0.94	−2.87	0.028
GDP	−0.01	−0.54	0.604
WRPP	116.15	0.99	0.358
MWe	1.22	2.32	0.059
R	0.96		
R^2 Adjusted	0.829		

Source: author's original table with analyses in Statistica 13.3.

5. Discussion

The political events of the past two years in Europe have diverted public attention from the green transformation. One can claim today that it was a short-term perspective. Currently, the EU is increasing RES-related goals not only because of climate protection but also because of the will to replace gas in heat and electricity generation and a plan for a fast and complete departure from fuel import from Russia. According to the IEO report [13,61], RES production in EU countries in 2022 increased by 27% in the case of solar power and by 11% for wind power in land farms [13,61]. A new EU strategy for solar power sets a goal of installing over 320 GW of photovoltaic power by 2025 and nearly 600 GW by 2030 [13,61].

Prosumers have the greatest share in the photovoltaic market in Poland. Despite the implementation of the new system of settlement for the prosumer market in Poland, the interest in PV micro-installations did not decrease considerably. However, a change in the settlement method increased the self-consumption index, which resulted in choosing the optimum size of a PV installation for the day-to-day use of the generated electricity by the households [62].

One of the determinants of site selection for PV projects is the meteorological conditions in Poland. They are characterized by an uneven distribution of solar radiation over the annual cycle: 80% of the total annual insolation falls in the six months of the spring–summer season (from early April to late September). In addition, the time of solar operation in winter is reduced to 8 h per day, and in summer, during the sunniest months, it increases to 16 h [12]. Considering the annual sums of total radiation falling on the horizontal surface, four basic regions can be distinguished in Poland: the coastal belt (1100 kWh/m^2/year), the eastern part of Poland (1100–1200 kWh/m^2/year), the southern part (900–1000 kWh/m^2/year), and the rest of Poland (900 kWh/m^2/year) [62,63]. The analysis suggests that in Poland, the development of photovoltaic farms is taking place in rural, peripheral areas in the northern and northwestern parts (see Figure 4, Index A_PV).

Statistical analysis showed that the larger the area of the region/province (A_W), the larger the area of PV farms (A_PV).

A large land area resource increases the possibility of finding a suitable plot/land predisposed to PV farm installation. As the model demonstrates, the increase in the area of PV farmland has an impact on the decrease in the area of land used for agricultural purposes (I_RA). The development of investments related to the construction of PV farms takes place mainly on agricultural land [12], and the model built confirms this fact. The growth of A_PV in Polish conditions often occurs in areas under environmental protection (PA). Poland is a country wealthy in that kind of land—39.65% of the country's area is covered by some form of protection [64]. Placing PV farms in national parks and nature reserves is completely prohibited, and for other forms of protection, an environmental impact assessment is required. The areas of northern and northwestern Poland are very extensive in this aspect, so the statistical correlation built shows an increase in the area of these areas with an increase in the area under PV.

The growth in the area covered by PV farms is also causing a decline in the number of unemployed farm owners (UW). This is due to legal regulations on unemployed status. In Poland, the development of PV farms occurs mainly on leased agricultural land. The lease rent paid to the farmer who makes his property available to build a PV farm becomes income. This applies to agricultural real estate of more than 2 hectares of converted land (the measure used to calculate tax on agricultural land) [54]. The farmer/owner loses his unemployed status by leasing his land to install a PV farm [65]. The subject letter indicates that the location of PV farms also takes place in areas away from traditional coal-fired thermal power plants [12]. Looking at the largest regions of energy production, such a conclusion can be made. However, a closer analysis and the built model do not confirm this position. The built dependency model showed a statistical relationship that as the area of a PV farm increases, the power produced in the province/region from traditional sources increases.

In general, local governments are interested in investing in PV farms in the municipality. This is justified by the financial benefit associated with the change in the amount of property taxation. The scenario analysis (see Table 2) shows that regardless of the variant related to location (tax district) and soil quality, the beneficial impact of changes in property taxation is indisputable. A map with the average increase in property taxes, taking into account the number of rural or urban–rural municipalities (analysis area), is shown in Figure 5. In the study area, municipal governments located in Lubuskie, Warmian-Masurian, and West Pomeranian provinces gain the most. Taxes are the municipality's income, which the municipal authorities can spend to meet local needs. The huge number of tasks to be carried out causes the search for funds to cover them. Tax revenues are the easiest way to raise a larger pool of funds. If the area of the municipality is not attractive in terms of the environment or location (away from major cities), developing energy extraction activities is one of the better and at the same time profitable solutions for municipalities.

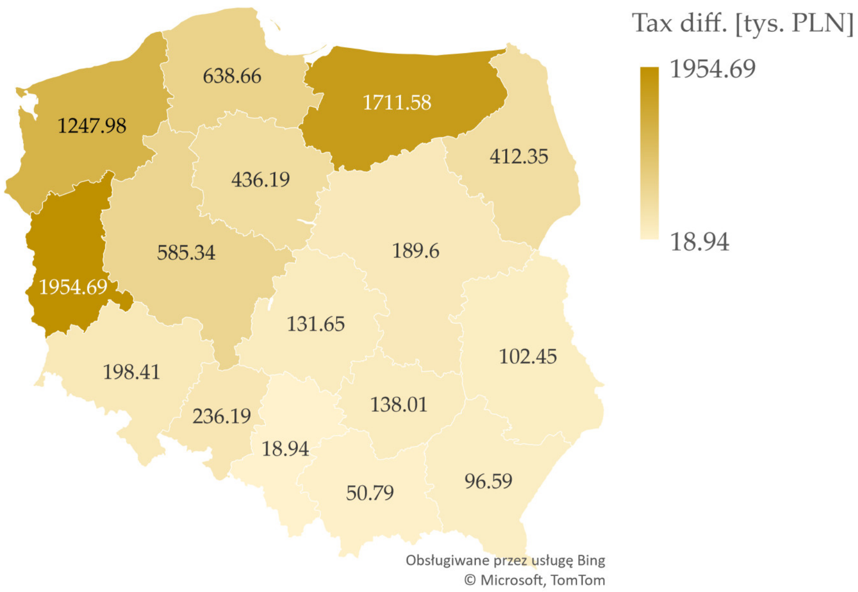

Figure 5. The differences between the revenue from tax on arable land and on a PV farm in 2019–2020, considering the number of rural and urban–rural communes. Source: author's original figure.

Looking from a broader perspective, PV farms cause a lot of controversy among some citizens. They affect the visual (landscape, light reflection) and economic components of a space. They affect, therefore, the functioning of society, especially in areas that are wealthy in terms of nature and developed for tourism. Therefore, municipal governments should consider the benefits and losses that may arise from the placement of a PV farm.

From an economic and climate point of view, the development of energy production from renewable sources is advisable. Renewable energy sources offer the advantage that they are not depleted, provide constancy in energy supply and cost, and are efficient and maintenance-free. These features reduce fuel supply risks and build energy independence both at the micro (individual household) and macro levels.

6. Conclusions

The development of energy generation from renewable sources is recommended, given the current energy and climate-related crisis. The energy demand is growing, which is why authorities should support this way of obtaining energy.

Being the leader in the EU concerning the development of photovoltaics encourages the PV industry and administration to intensify their actions. Whether Poland can keep this development rate at a similar level during the next years depends on subsequent actions regarding energy policy. Local governments are interested in placing PV farms in their communes, mainly because of the revenue from the real estate tax. However, they have to take into account the fact that commune residents do not always want such objects in their neighborhood. Despite the increase in public awareness of the effects of using sources that produce energy in traditional ways and the low environmental impact of photovoltaics, the installation of PV farms is still met with disagreement from citizens. In most instances, the economics behind the argument are in not the first priority. Citizens are not afraid of losing income if it depends on local landscape values. In such a conflict, there are always two sides: the side that would be losing and the side that would be benefiting. Municipal governments are most often the party that benefits (an increase in financial revenues related to land taxation), even when economic activity in the municipality will be significantly reduced due to the installation of a PV farm. Looking at the wider perspective, at the existing local socio-economic and spatial conditions, the skillful incorporation of a PV farm with the use of unusable, degraded areas can cause many positive effects. One of them is the reduction in unemployment among farm owners. This is especially true in peripherally located areas. In these locations, the implementation of PV projects finds more favor.

The research presented here covered a short time frame and employed two research methods. This is a limitation arising from the research. It was due to the scale of the observed phenomenon that has occurred in Poland recently. The observation of the processes and impacts of PV projects on the socio-economic and spatial dimensions of life requires permanent monitoring to gain a more comprehensive understanding of the long-term effects. Future research by the author of the study will focus on analyzing the challenges and barriers faced by local municipalities in promoting and implementing PV farm projects, considering the views of all stakeholders, and implementing the principles of sustainability in terms of PV farm development.

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