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Article

Methodology for Selecting a Location for a Photovoltaic Farm on the Example of Poland

Katarzyna Stala-Szlugaj [1], Piotr Olczak [1,*], Jaroslaw Kulpa [1] and Maciej Soltysik [2]

[1] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Wybickiego 7A, 31-261 Krakow, Poland; kszlugaj@min-pan.krakow.pl (K.S.-S.); kulpa@min-pan.krakow.pl (J.K.)
[2] Faculty of Electrical Engineering, Czestochowa University of Technology, Armii Krajowej 17, 42-200 Czestochowa, Poland; maciej.soltysik@pcz.pl
* Correspondence: olczak@min-pan.krakow.pl

Abstract: As the LCOE for photovoltaics has decreased several times, it is once again gaining popularity. The intensification of the development of PV installations is contributing to the duck curve phenomenon in an increasing number of countries and, consequently, affecting current electricity prices. Decisions on new investments in large-scale PV sources are driven by potential economic and environmental effects, and these, in turn, are subject to locational considerations, both as to the country and its region. In calculating the economic impact of locating a 1 MWp PV farm, it was assumed that the electricity generated by the farm would be fed into the national grid, and that the life of the PV farm would be 20 years. Poland was considered as an example country for the placement of a photovoltaic farm. The authors of this paper proposed that the main verification parameter is the availability of connection capacities to feed the produced electricity into the country's electricity grid. The methodology proposed by the authors for the selection of the location of a PV farm consists of four steps: step (i) identification and selection of the administrative division of a given country; step (ii) verification of available connection capacities; step (iii) (two stages) verification of other factors related to the location of the PV farm (e.g., information on land availability and the distance of the land from the substation), and analysis of productivity at each potential location and electricity prices achieved on the power exchange; step (iv) economic analysis of the investment—analyses of PV farm energy productivity in monetary terms on an annual basis, cost analysis (CAPEX, OPEX) and evaluation of economic efficiency (DPP, NPV, IRR). The greatest impact on the economic efficiency of a PV project is shown by the value of land (as part of CAPEX), which is specific to a given location, and revenues from energy sales, which are pretty similar for all locations.

Keywords: renewable energy; solar PV farm; selection methodology; NPV; IRR; photovoltaic; Poland

Citation: Stala-Szlugaj, K.; Olczak, P.; Kulpa, J.; Soltysik, M. Methodology for Selecting a Location for a Photovoltaic Farm on the Example of Poland. *Energies* **2024**, *17*, 2394. https://doi.org/10.3390/en17102394

Academic Editor: Alon Kuperman

Received: 28 March 2024
Revised: 12 May 2024
Accepted: 13 May 2024
Published: 16 May 2024

1. Introduction

In recent years, many countries have begun to intensify their decarbonisation targets under the Paris Agreement [1] (with its subsequent ratifications) for reducing greenhouse gas emissions. These changes particularly accelerated in the face of the 2022 energy crisis triggered by Russia's aggression against Ukraine. At that time, many countries became independent of Russian raw materials [2].

In the case of the European Union, in order to become independent of Russian fossil fuels, the EU Commission presented the REPowerEU Plan [3] for the transformation of the European energy system, involving, among others, the accelerated introduction of renewable energy. This also coincided with the first upgrade of the National Energy and Climate Plans (NECPs), which were due in 2023. The NECPs are implemented by the European Union Member States, which are obliged to implement them by virtue of the regulation [4]. The regulation (Regulation EU, 2018) was agreed in the Clean Energy for All Europeans package [5], in line with the objectives of the European Green Deal [6]. At the beginning of December 2023, a draft of the first update had already been submitted by 22 EU Member States [7].

Analysing the drafts first update of the NECPs, it can be seen that some of the countries listed have set very ambitious emission reduction targets (relative to 1990) of 55% or more by 2030, among others: 78% Romania [8] 70% each Denmark [9] and Lithuania [10], 65% Germany [11], 63% Czechia [12], 60% Finland [13], and 55% each Italy [14], Luxemburg [15] (relative 2005), Malta [16], Slovakia [17] and Portugal [18]. Some of the EU countries set reduction targets at a slightly lower level than the October 2023 updated Fit to 55 climate package [19], at just above 50%. These were: Greece, emission reduction of 54% [20]; France [21] and Hungary [22], emission reductions of 50% each.

Some countries have also revised their national energy policies, introducing not only ambitious climate targets, but also including an energy security aspect. In Poland, the assumptions for the update of the current energy policy until 2040 were adopted on 29 March 2022 [23]. According to the assumptions presented in [23], by 2040, among other things, around half of the electricity generation is to come from renewable sources. In 2022, the US presented the National Security Strategy [24]. According to this strategy [24], a target was set for the regional electricity sector to reach a 70% share of installed renewable energy capacity in 2030. Still, in 2021, the country ratified the Paris Agreement and set a new target for greenhouse gas emission reductions in the 2030 horizon of 50–52% net [25]. In June 2022, China's National Development and Reform Commission published its 14th Five-Year Renewable Energy Plan, consistent with existing targets and policies [26]. According to the assumptions presented, the share of renewable energy in electricity generation is expected to reach 33% in 2025.

Solar energy is one of the most important clean energy carriers. It has experienced significant growth in recent years. Between 2010 and 2022, solar power experienced the largest increase in generation capacity globally: according to data [27], it increased 29-fold to 1145 GW, and solar PV-based electricity generation increased 40-fold to 1291 TWh. According to the Net Zero Emissions scenario [27], solar PV is still expected to be one of the fastest-growing generation streams in the 2030 timeframe. Compared to 2022, its share of the global generation mix is expected to increase by as much as 17 percentage points, to 21%.

It should also be mentioned that solar energy is a sustainable, as well as relatively clean and relatively inexpensive, energy source [28,29]; however, it is unstable. A detailed description of the selection of a photovoltaic farm location in Poland is presented in [30]. This article also presents other formal legal procedures related to the construction of a photovoltaic farm; among others [30]: its design, the environmental permit, an individual planning permit, and the document that specifies the grid connection requirements.

The use of the AHP method for selecting a plot of land for the location of a PV farm in Poland is described by [31]. In [31], for the municipality of Czarnia (north-eastern Poland), the authors presented a ranking of land plots from the point of view of a potential PV farm location.

An analysis of the economic and social, as well as spatial, determinants of the location of a photovoltaic farm was carried out by [32]. In the analyses presented, ref. [32] focused on the regional division of Poland (at the level of provinces), using the scenario method as well as multiple regression analysis.

In the case of a photovoltaic farm, the selection of its location is an important issue; however, it is fraught with some risk. In order to determine this risk [28], the use of the Dempster–Shafer method was proposed. Geographical Information Systems (GIS) are often used to assess the optimal location of PV farms [28,33–36], combined with multi-criteria decision-making (MCDM) [28,33–35,37].

Due to such a significant development of solar PV generation, and based on a literature review, the authors of this article decided to analyse the site selection methodology for the location of a 1 MWp PV farm. The purpose of the study is to demonstrate how significantly the choices of different locations within the scale of one region or country can influence investment decisions. Poland was chosen as an example country for the location of a PV farm in this article. The innovation of the proposed scheme lies in its incorporation of the relationship between photovoltaic-specific yields for different regions of the country and actual energy prices (hour by hour). This enables the identification of locations where energy productivity may not be the highest, but the potential for additional revenue is greater. This aspect is often overlooked in the identified analyses, for example, by Demir et al. [38].

The main limitations of this study include the reliance on highly fluctuating electricity prices (2018–2022), as well as the scarcity of available locations for PV installations due to national grid capacity and regulations, and also land prices.

2. Materials and Methods

When considering the methodology for locating a PV farm anywhere in the world, it was assumed that a 1 MWp PV farm would be built. It was also assumed that the investor has sufficient funds available to build a PV farm installation on the scale of at least 1 MWp, which means funds of approximately EUR 500,000. The electricity generated by the farm will be fed into the national electricity grid. It was also assumed that the lifetime will be 20 years. In their analysis, the authors did not take into account any subsidies or certain facilities/investor incentives from the local government administration (in the case of Poland: municipality/county/province).

The site selection methodology algorithm proposed by the authors of this article for the location of a photovoltaic farm (Figure 1) consists of four steps.

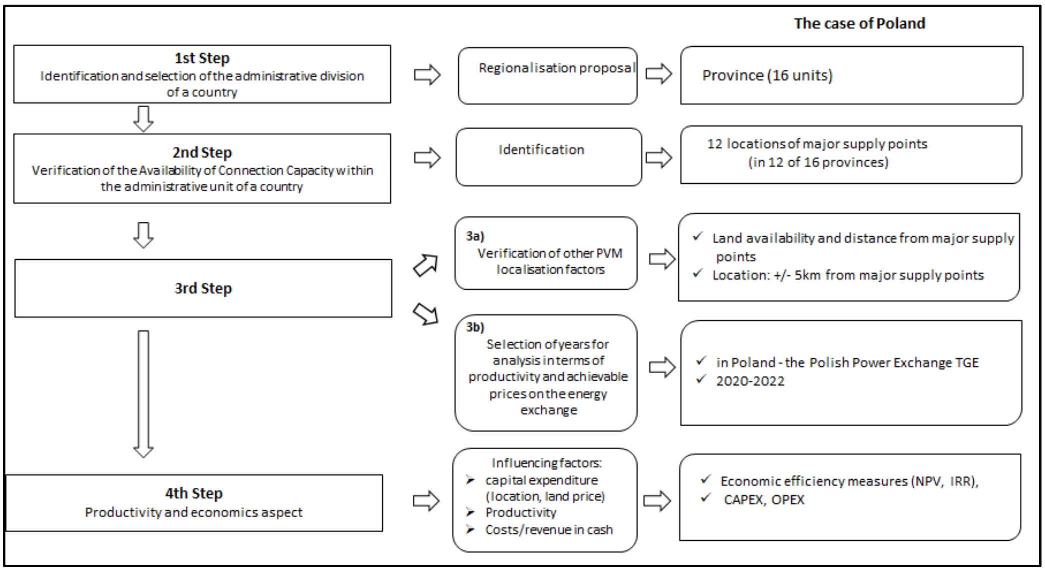


Figure 1. Proposed algorithm as part of the site selection methodology for the location of the farm. (Source: own study).

2.1. Choice of Administrative Division

In the first step, the region was identified and selected, e.g., according to the administrative division of the country. In the case of Poland, there is a three-tier administrative division of the country [39]. The following administrative units are distinguished [39]: first level—16 provinces, second level—314 powiats and 66 cities with powiat (the second-level unit of local government and administration in Poland) status, third level—2489 municipalities (including 11 municipalities of the capital city of Warsaw). In this article, the authors propose to focus on the first degree of administrative division, which is the provinces.

2.2. Verification of Available Connection Capacities

In the second step, a proposal was made for available connection capacities within a given country/region to be verified. In the case of Poland, each voivodship was taken into account as the region under consideration. Then, information from Distribution Network Operators in Poland was used to analyse the available connection capacities. Pursuant to the Energy Law [40], they were obliged to publish values of the total available connection capacity for sources, as well as planned changes to those values within the next 5 years from the date of their publication. This applies for the entire network of the companies with rated voltage above 1 kV, with a division into substations or their groups included in the network with rated voltage of 110 kV and higher. The data obtained were estimates, but reflect the state of each network at the date of the study. The author team analysed the data made available by the operators that are part of the capital groups: Tauron [41], Polska Grupa Energetyczna [42], Enea [43] and Energa [44].

On the basis of the information obtained, it was found that 12 of the 16 provinces analysed had available connection capacities. For each of the 12 provinces, one main supply point was randomly selected. The locations of these selected points are presented in Figure 2. For each of these selected points, the geographical coordinates were determined (longitude and latitude) using a publicly available web portal showing the electricity grid map [45]. This information will be used to calculate the productivity at the selected points of the analysis.

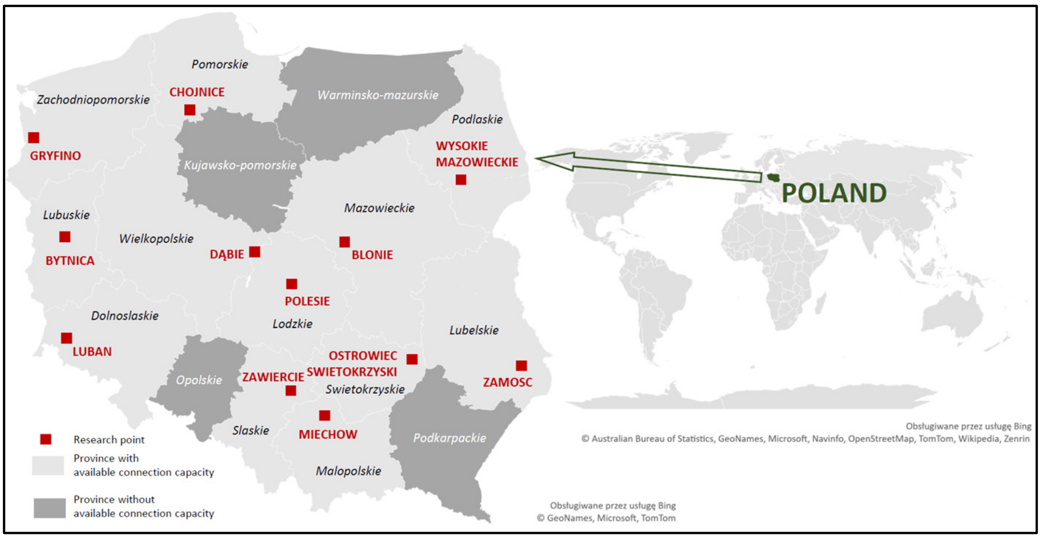


Figure 2. Poland map with the location of research points (Source: map base [46]).

2.3. PV Specific Yields Analyses for Each Region and Year

The third step of the proposed methodology for the verification of factors affecting the productivity of the farm is divided into two stages. In the first stage, other factors related to the location of the photovoltaic farm are verified. The following are analysed, among others: information on land availability and the distance of the land from the main feed-in point (feed-in station). In the case considered in this article, land availability within a ±5 km radius from the main feed point was taken into account.

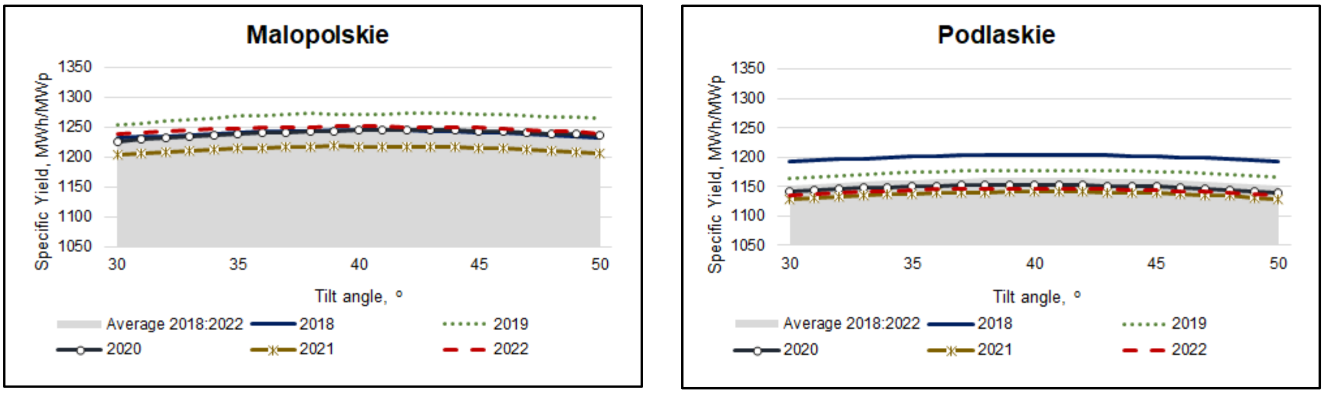
The second stage in step three concerns the analysis of productivity at each potential location and the electricity prices achieved on the power exchange. For each of the 12 selected locations, productivity was calculated for an angle of inclination ranging from 30 to 50 degrees, in increments of 1 degree. This range was chosen based on [30,47]. Hourly energy values produced by the PV installation were calculated according to Formula (1). This formula has been validated under Polish conditions and is based on the work of [47–50]:

$$PPV(\tau, \beta, reg., y.) = YPV \times FPV \times \frac{G(\tau, \beta, reg., y)}{GSTC} \times (1 + \alpha p(TC(\tau, reg., y.) - TSTC)) \times 1h \quad (1)$$

where

PPV—hourly energy output of photovoltaic panels, kWh/kWp;
YPV—rated capacity of the PV array, which implies that its output power under standard test conditions was used (1 MWp), MW/MWp;
FPV—PV derating factor, 0.90 based on [51];
G—available intensity of solar radiation incident on surface dependent on time and panel tilt angle, based on ERA5 data [52] and HDKR mode, W/m^2;
GSTC—incident radiation at Standard Test Conditions, 1 kW/m^2;
αp—temperature coefficient of power, based on Longhi PV Data (0.37) %/°C;
TC—PV cell temperature, based on the equation included in [53] and ERA5 data for each region, °C;
TSTC—PV cell temperature under standard test conditions (25 °C);
reg.—region;
y.—year.

The PPV values were then summed for each region and each panel angle considered. The graphs in Figure 3 show the results of the productivity thus calculated, expressed in [MWh/MWp], for the two extreme cases: the provinces with minimum (Podlaskie) and maximum (Malopolskie) productivity.



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

Figure 3. Calculated productivity on the basis of maximum values achieved for provinces in Poland; example, province with maximum (**a**) and minimum productivity (**b**) (Source: own calculations).

In the next step, an analysis of electricity prices on the exchange between 2018 and 2022 was carried out. In the case of Poland, hourly electricity prices formed in the Day-Ahead Market and published on the web portal of the Polish Power Exchange (Towarowa Gielda Energii—TGE) were used [54]. Hourly prices expressed in PLN/MWh for the period from 1 January 2018 to 31 December 2022 were taken into account for the calculations. These prices were converted using the fixed exchange rate EUR/PLN = 4.5, and are presented in Figure 4.

Considering the time aspect, the last five years were taken at the beginning of the analysis: 2018–2022. However, due to the fact that the share of solar power in the Polish energy mix only became relatively significant between 2020 and 2022, this time period was chosen for further financial analysis. As recently as 2020, Poland (according to [55]) produced 2.0 TWh based on solar energy, which accounted for 1.2% of the Polish energy mix. In 2021, solar-based generation in Poland increased to 3.9 TWh (data [56]), and the share in the national energy mix increased to 2.2%. The year 2022 saw a further increase in solar generation to 8.1 TWh (according to [56]), and its share in the Polish fuel mix increased to 4.6%. According to [57], analysing photovoltaic generation globally, Poland's share increased annually by 0.2 percentage points from 0.2% to 0.6% between 2020 and 2022, respectively.

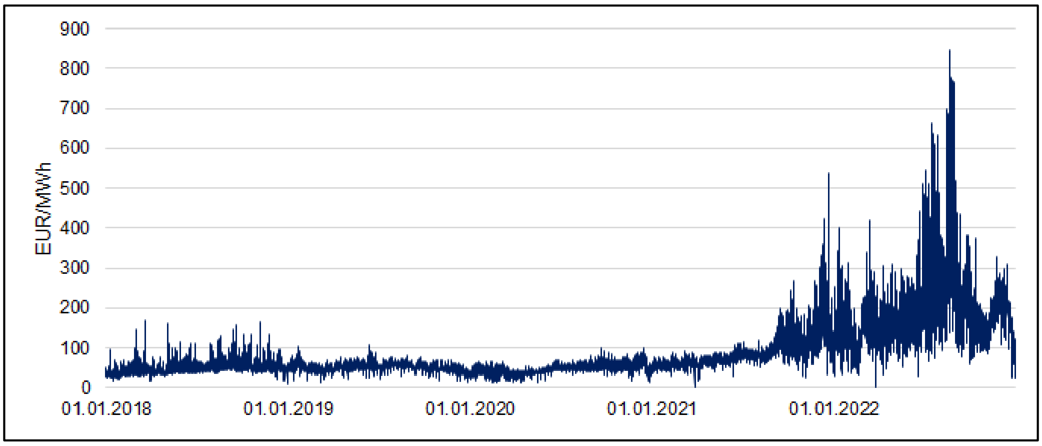


Figure 4. The course of the volatility of hourly electricity prices based on the Day-Ahead Market on TGE, 2018–2022 (Source: own elaboration on the basis of data [54]).

2.4. Economic Analysis of the Investment

The fourth step of the proposed methodology analyses the final effects of interest to the investor, related to the financial aspect. In the end, it tentatively answers the question: will the investment be economically viable in the analysed location?

2.4.1. Factors Affecting Capital Expenditure

Among the important factors influencing the capital expenditure is the price of the land. In order to minimise costs, it was assumed that the land for the future photovoltaic farm would be a maximum of ±5 km from the substation. According to the applicable Polish regulation [58], all land uses are shown in the land and building register, with an additional soil quality class shown for agricultural and forest land. In Poland, land classification is carried out in accordance with the Regulation [58].

When recognising land prices, prices from official national statistics [59] and price offers from the current market were considered (Figure 5). In the case of market prices, three land price offers were retrieved for each selected potential location, using a publicly available online property trading portal [60].

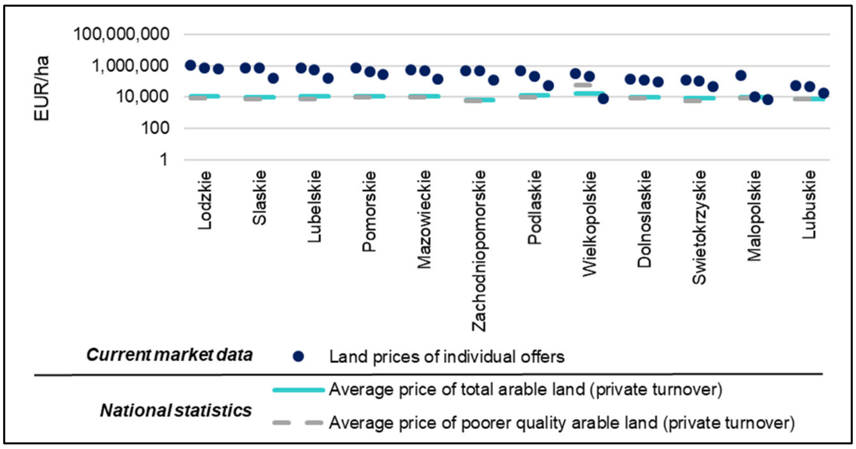


Figure 5. Summary of land prices in the analysed survey points in Poland—logarithmic scale (Source: own elaboration on the basis of data [59,60]).

2.4.2. Productivity Analysis in Monetary Terms

Another research element in the proposed methodology is the analysis of productivity in monetary terms. For each hour of the year, productivity was calculated and multiplied by the energy price (from the TGE quotation) according to Formula (2):

$$\text{Input}(\tau, \beta, \text{reg.}, \text{y.}) = \text{PPV}(\tau, \beta, \text{reg.}, \text{y.}) \times \text{DAM}(\tau, \text{y.}) \quad (2)$$

where

Input—revenues from the energy exchange or equivalent revenues;
DAM—energy market price, Day-Ahead Market.

The results of the maximum monetary value analysis for all analysed potential locations are presented in Figure 6. The data of the results of the maximum monetary value of productivity obtained in 2022 are presented in descending order. An important element influencing the obtained monetary values of productivity was the electricity prices from 2018 to 2022. The highest electricity prices occurred in 2022 (see Figure 4). For most of the year, they were several times higher than the energy prices of earlier years and, therefore, had a strong impact on the result, as shown in Figure 6.

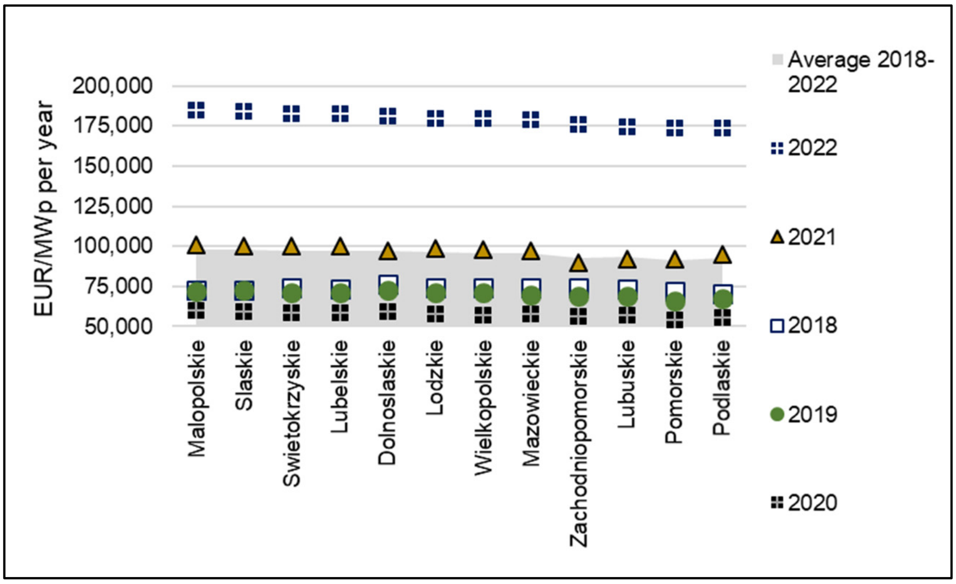


Figure 6. Results of the analysis of the maximum energy productivity of a PV farm in monetary terms on an annual basis (Source: own calculations).

2.4.3. Project Cost (CAPEX, OPEX)

In performing the economic analysis of the investment, the authors made the following assumptions:

- The funds allocated for the investment in a 1 MWp photovoltaic farm are approximately EUR 500,000;
- Weighted average cost of capital (WACC)—10%;
- Depreciation rate—10%;
- Tax rate—12%;
- The costs of purchasing and installing PV farm components in each province are assumed to be the same;
- OPEX assumed that the annual operating costs of the farm would be 2% of the total capital expenditure [61], with half of this amount covering expenses related to materials, energy, fuel, etc., and this would be the same for all locations and the rest would be labour costs;

- Labour cost of operating the farm—in this case official national statistics on wages were used [59] (Table 1), whereby these statistics referred to salaries obtained within the county (County—administrative unit of the second order in Poland) in which the potential location of the photovoltaic farm is situated;
- Land cost—in this case, land price offers from the current market were used (Figure 4).

Table 1. Table with data adopted for further calculations.

Specification		Salary	Land Price	Maximum Productivity		
Province	County	2021	2022	2020	2021	2022
		EUR/month	EUR/ha	MWh/MWp	MWh/MWp	MWh/MWp
Dolnoslaskie	Luban	1107	97,667	1219	1167	1254
Lubelskie	Zamosc	972	171,911	1204	1207	1203
Lubuskie	Krosno	1139	17,778	1180	1118	1212
Lodzkie	city Łodz	1347	666,511	1199	1179	1223
Malopolskie	Miechow	1090	7733	1244	1218	1251
Mazowieckie	Warsaw-Western	1450	149,822	1193	1169	1201
Podlaskie	Wysokie Mazowieckie	1199	55,556	1153	1141	1147
Pomorskie	Chojnice	1068	295,578	1109	1123	1192
Slaskie	Zawiercie	1291	167,600	1227	1207	1251
Swietokrzyskie	Ostrowiec Swietokrzyski	1092	51,467	1210	1203	1223
Wielkopolskie	Kolo	1188	8466	1191	1173	1223
Zachodniopomorskie	Gryfino	1177	125,244	1167	1115	1211
Discount Rate (WACC)	10.0%					
Deprecation Rate	10.0%					
Tax Rate	12.0%					

2.4.4. Measures of Economic Efficiency of the Investment (DPP, NPV, IRR)

Three commonly used indicators were used to assess the economic efficiency of a 1 MWp PV farm for the twelve sites analysed: Discounted Pay-Back Period (DPP), Net Present Value (NPV) and Internal Rate of Return (IRR).

Discounted Pay-Back Period

The Discounted Pay-Back Period determines the time over which the invested funds will be returned, taking into account a discounting factor (e.g., inflation or the assumed cost of capital) [62]. It is determined according to Formula (3):

$$DPP = \frac{TDCF}{CAPEX} \quad (3)$$

where

DPP—Discounted Pay-Back Period [year];
TDCF—total discounted incoming cash flow [EUR];
CAPEX—capital expenditure [EUR].

Net Present Value

The NPV method is still one of the most popular and profitable valuation methods, and is also used in the appraisal of renewable energy installations such as photovoltaic farms [63]. NPV reflects the value of the project at the discount rate used and a number of other cash flow assumptions, such as revenue projection, depreciation, residual value, etc., when capital expenditure is incurred only in the initial year of the investment. According to Formula (4), the net present value is the sum of the present values of the future annual cash flows:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+d)^t} \quad (4)$$

where

CF_t—cash flow for the year [PLN];
d—discount rate [%];
n—the total number of years required to complete the licensed operation.

Where capital expenditure is incurred in the initial year of investment only, the above formula takes the form of Equation (5).

$$NPV = \left[\sum_{t=1}^{n} \frac{CF_t}{(1+d)^t}\right] - I_0 \quad (5)$$

where

I_0—initial investment [PLN].

Internal Rate of Return (IRR)

IRR can be defined as the rate that aligns the size of the initial investment with the present value of future cash flows. The higher the Internal Rate of Return, the greater the return on invested capital. The internal rate of return is defined as the discount rate at which the NPV is zero. The relationship between NPV and IRR is represented by Equation (6),

$$NPV = 0 = \left[\sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t}\right] - I_0 \quad (6)$$

where

CF_t—cash flow in year t [PLN];
I_0—initial investment [PLN];
IRR—Internal Rate of Return [%];
n—the total number of years required to complete the licensed operation.

From the perspective of the decision-maker, an investment should be made if the IRR is greater than the so-called MARR (minimum acceptable rate of return) that the investor is willing to accept before starting the project, given its risks [64]. When the IRR is greater than or equal to the discount rate, then we assume that the project generates flows capable of covering inputs and operating costs over the life of the investment project.

3. Results and Discussion

An important issue facing the developer is the choice of location for a photovoltaic farm. In their study on the optimal location for a photovoltaic farm, ref. [28] focused on choosing a site characterised by a high number of sunshine hours per year; in this case, the south-east of Fars province in Iran. The authors of this paper proposed that the main parameter was the availability of connection capacity to feed the electricity produced back into the national grid.

Table 2 presents the economic results obtained for 12 potential 1 MWp photovoltaic farm locations in Poland. Economic results were obtained on the basis of calculated annual productivity, specific CAPEX values (resulting from the same installation cost and variable land price) and the diversified value of annual OPEX.

Table 2. Economic results calculated for 12 potential 1 MWp photovoltaic farm locations in Poland.

Specification	Revenue	CAPEX	OPEX	NPV	IRR	Undisc. Payback Period	Partial Year Payback Period	Discounted Payback Period	Partial Year Payback Period
Province	EUR/ MWp/ Year	EUR	EUR	EUR/ 20 Year	%	First Year Positive	Actual Number of Years	First Year Positive	Actual Number of Years
Dolnoslaskie	139,249	−597,667	9150	310,013	18%	5	4.6	7	6.5
Lubelskie	141,562	−671,911	8645	250,023	16%	6	5.1	8	7.4
Lubuskie	133,502	−517,778	9270	353,651	20%	5	4.2	6	5.7
Lodzkie	139,315	−1,166,511	10,050	−315,936	5%	10	9.0	25	24.4
Malopolskie	143,184	−507,733	9090	437,535	23%	4	3.8	5	5.0
Mazowieckie	138,266	−649,822	10,435	236,299	16%	6	5.1	8	7.5
Podlaskie	134,289	−555,556	9495	316,630	19%	5	4.5	7	6.2
Pomorskie	132,689	−795,578	9005	46,991	11%	7	6.4	11	10.8
Slaskie	142,346	−667,600	9840	251,559	16%	6	5.0	8	7.4
Swietokrzyskie	141,490	−551,467	9095	377,327	20%	5	4.2	6	5.7
Wielkopolskie	139,057	−508,466	9455	403,484	22%	4	3.9	6	5.2
Zachodnio-pomorskie	132,747	−625,244	9415	229,906	16%	6	5.1	8	7.4

As a result of the analysis, it was found that out of 12 analysed cases, the investment would be unprofitable only in 1 province (Lodz Province). The land purchase price was the main factor influencing this investment's unprofitability. The price offer of land, in addition to the valuation class and technical classification (e.g., agricultural, forestry, construction land), is also influenced by, among others: location (in the city, in the countryside, outside built-up areas, etc.), utilities in the area, accessibility to access roads. In the case of the Lodz Province, the plot was located within an urban area, significantly increasing the plot's value. In the remaining 11 locations, regional differences in profits were noted. An Internal Rate of Return (IRR) above 20% was achieved in four provinces: Malopolskie, Wielkopolskie, Swietokrzyskie and Lubuskie. A relationship was found between a shorter investment payback time and a higher NPV value for two provinces: Malopolskie and Wielkopolskie. In these two cases, the NPV exceeded EUR 400,000.

Figure 7 presents the results of the NPV sensitivity analysis for 12 potential locations of a 1 MWp PV farm in Poland. In each of the analysed cases, a ±20% change in CAPEX, Income and OPEX compared to the base value was taken into account.

Analysing the results presented in Figure 7, it can be stated that the profitability of individual investment projects depends mainly on the change in revenues and investment outlays. In the 12 cases analysed, a change of ±20% in annual revenues resulted in a modification of the NPV ranging from 48 to 418% compared to the base value. In the case of total investment outlays, their change of ±20% compared to the initial value resulted in an update of the NPV value ranging from 25 to 369%. The change in annual operating costs (OPEX) has a much smaller impact on the profitability of projects expressed in NPV (from 3.1 to 28.7%). With the exception of two locations (Lodzkie and Pomorskie Provinces), the sensitivity analysis in the range of ±20% in the remaining cases always indicated the profitability of a 1 MWp photovoltaic farm. In the case of a PV farm in the Pomorskie Province, an increase in CAPEX by 10% or a reduction in revenues by the same value resulted in a situation where the project becomes economically ineffective (NPV < 0); for this location, due to balancing on the verge of profitability, the largest relative changes in NPV occurred depending on the base amount. High investment outlays in the case of the

Lodzkie province, related to the high cost of purchasing real estate, cause the permanent ineffectiveness of the project in the subject area of the sensitivity analysis.

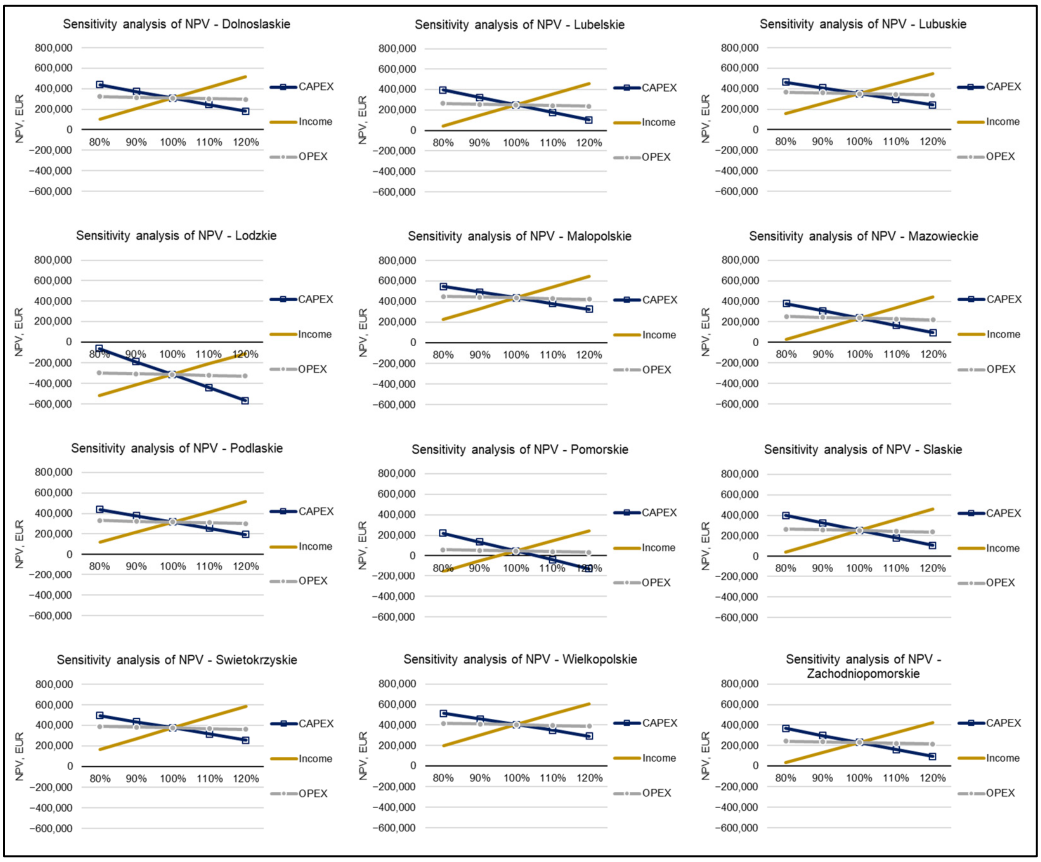


Figure 7. NPV sensitivity analysis for 12 potential locations of a 1 MWp PV farm in Poland. CAPEX, Income and OPEX in the range of 80–120% in relation to the base value [EUR in 20 years] (Source: own study).

4. Conclusions

This article proposes a methodology for selecting a site for locating a 1 MWp photovoltaic farm in Poland. It takes into account the location (network connection capacity, weather conditions over the years, land prices), installation prices and electricity prices occurring in periods of electricity production (2020–2022), as well as the sensitivity analysis. The results calculated according to the method were the IRR values, Discounted Pay-Back Time, and NPV for selected locations (according to network connection possibilities). The highest NPV value was shown for the Malopolskie Province and the lowest for the Lodzkie Province (mainly due to the high CAPEX resulting from the land price).

The proposed scheme can also be used in other regions or countries because it is based on the assessment of a given location in terms of PV productivity, OPEX, land cost and, above all, the available connection resulting from the energy policy of a given region and its characteristics.

The greatest advantage of the proposed scheme is the comparison of only those locations that can realistically be created due to the availability of connection power for renewable energy installations and their evaluation using proven and commonly understood economic measures. One of the most important aspects is that our method involves searching for locations where the energy production values peak during hours when electricity prices are potentially higher than in other places (energy production values). While the differences in value may not be significant on their own, when considering additional profit, they can sometimes be substantial (as comparison), especially in the future (higher RES/photovoltaic impact in national grid).

Investments in renewable energy sources increase the energy security of a given country. In the case of Poland, they are included in energy policy until 2040 [23].

A financial challenge for photovoltaics will be the introduction of the CBAM carbon border tax (Carbon Border Adjustment Mechanism) [65]. This tax will be levied on goods imported into the EU customs territory whose production involves high CO_2 emissions. Until 1 October 2023, it was in a transitional phase, and from 1 January 2026, it will be in permanent force. The introduction of this tax will burden the supply of PV components from Asia, which will translate into an increase in costs.

The topics of further research will include a comparison of different countries in Europe in terms of economic indicators assessing the investment in a photovoltaic farm (including tax aspects), taking into account the value of land after the life of the photovoltaic installation, including the costs of dismantling/disposal. An additional area for future research is to ascertain the prospective relationships between the productivity of photovoltaic farms and electricity prices. Presently, there is an inverse correlation, as the high value of energy from PV at national scale coincides with relatively low electricity prices.

Author Contributions: Conceptualization, P.O., K.S.-S. and J.K.; methodology, P.O., K.S.-S. and J.K.; validation, P.O., K.S.-S. and J.K.; formal analysis P.O., K.S.-S., J.K. and M.S.; resources, P.O., K.S.-S., J.K. and M.S.; data curation, P.O. and K.S.-S.; writing—original draft preparation, P.O., K.S.-S., J.K. and M.S.; writing—review and editing, P.O., K.S.-S., J.K. and M.S.; visualization, K.S.-S.; supervision, P.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Acknowledgments: This work was carried out as part of the statutory research activity of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences.

Conflicts of Interest: The authors declare no conflicts of interest.

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