Article

Location and Technical Requirements for Photovoltaic Power Stations in Poland

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Abstract: The objective of Poland’s energy policy is to guarantee energy security while enhancing economic competitiveness and energy efficiency, thus minimizing the power sector’s environmental impact and optimizing the use of energy resources in the country. Poland is not the only European country to rely on coal for power generation. Historical factors and large coal deposits act as natural barriers to increasing the share of renewable energy in the Polish power sector. Yet, today, environmental concerns and climate change are prompting many countries to move away from fossil fuels. Renewable energy sources, such as solar and wind energy, are an alternative to traditional energy generated from fossil fuels. However, investors developing solar and wind farms in Poland encounter numerous problems at each stage of the project. These difficulties are associated mainly with the location, technical requirements, infrastructure and formal and legal documents. This study aimed to identify the key factors that influence the development of photovoltaic power stations in Poland, with special emphasis on the choice of location and technical aspects of the investment process. The demand for clean energy and the renewable energy prospects for Poland are discussed based on the example of solar farms. Sixty-seven prospective farm locations were analyzed, and the results of the analysis were used to identify the main barriers and opportunities for renewable energy development in Poland. The option of connecting solar farms to the existing power grid was also examined. This study demonstrates that the development of solar farms in Poland is inhibited mainly by technical barriers, in particular the lack of options for connecting farms to the power grid, as well as the absence of support mechanisms and dedicated legislative solutions, rather than environmental obstacles.

Keywords: renewable energy sources; photovoltaic power stations; planning requirements; connection to the power grid

1. Introduction

The European Union’s climate and energy policy significantly influences the energy strategies of all EU Member States, though many EU countries were initially opposed to a pan-European energy policy [1]. Energy security is defined as a country’s ability to supply sufficient electricity at an affordable price without violating environmental protection regulations [2,3]. In Poland, the energy sector has become an important topic of public debate in recent years. Poland’s previous energy policy relied on two strategic documents: Poland’s Energy Policy Until 2030 (PEP 2030), adopted in 2009 [4], and the Energy Security and Environment Strategy Until 2020 (ESE Strategy), implemented in 2014 [5]. A new strategic document, Poland’s Energy Policy Until 2040 (PEP 2040), was adopted on 2 February 2021, i.e., 12 years after the implementation of the previous policy paper [6]. This breakthrough document sets new directions for the development of the Polish energy sector, and it prescribes strategic investments that will harness domestic resources and tap into Poland’s economic, technological and human potential. The planned investments in the energy sector will boost economic growth and contribute to a just transition [6].
According to PEP 2040, more than 50% of installed power will be generated from zero-emission sources by 2040. Offshore wind farms and a nuclear power plant will be incorporated into Poland’s power-generation system, and they will play a very important role in achieving these ambitious goals [6]. Considerable emphasis will also be placed on distributed generation and civic energy projects involving local capital. To date, the Polish green energy sector relies mainly on biofuel (approx. 80%) and wind (12%). Hydropower (2%), biogas (2.88%) and solar power (0.68%) have a much smaller share of the renewable energy mix. Municipal waste incineration plants, geothermal energy and heat pumps play only a marginal role in energy generation [7,8].

Investments in green energy provide access to local and renewable sources of energy [9]. Similar to Germany, the European leader in renewable energy development, Poland has high photovoltaic (PV) and wind power potential (due to its similar geographic location and climate zone) [10,11]. Only the USA and Japan have higher installed solar capacities than Germany. China is also an unquestioned leader in this respect [12]. According to Huang et al. [13], the success story of China’s PV industry on the global market started as early as the 1980s, although the real acceleration did not occur until 2004. In China, the industrialization of PV modules and the establishment of global dominance took place in less than 10 years. The rapid development of the PV market led to the establishment of solar power plants. However, Poland lags far behind most EU countries in this respect due to legal and political regulations. The solar power potential has never been fully used. The main barriers to renewable energy development include limited funding, absence of legal support, complex administrative procedures and insufficient hosting capacity of the national power grid. In Poland, the first PV modules were installed in the second half of the 1980s, but large solar power stations have not been developed to date. At the end of 2012, there were around 130 PV systems in Poland, including 120 home PV systems with a total installed power of around 1.8 MW, which were not connected to the grid [14].

The number and capacity of renewable energy systems increased between 2016 and 2020. More than 209 TWh of power was contracted as part of renewable energy auctions. The largest amounts of renewable energy were purchased from wind farms and PV installations, while much less power was contracted from biogas plants and hydraulic power plants. In the last decade, the growth of the PV market and rapid advancements in PV technology have decreased the prices of components that are used in the construction of solar farms. However, the COVID-19 pandemic contributed to an increase in the prices of materials and land, as well as subcontractor rates. The Russian invasion of Ukraine may lead to a further increase in energy prices by disrupting the global supply chains for the key raw materials. The recent increase in the prices of PV modules had a negative impact on new investments. High demand, high component prices and growing shipping costs have increased the prices of PV installations for end-clients.

Renewable sources of energy are characterized by very low or no pollutant emissions. In Poland, the PV power capacity differs across regions. Annual solar radiation is lowest in northeastern (voivodeships of Warmia and Mazury, along with Podlasie) and southern Poland (Silesia, Małopolska and Podkarpacie). Poland has a similar solar power capacity to the United Kingdom, Belgium, the Netherlands, Denmark, Germany and Switzerland [15–17]. The energy yield from PV systems is influenced by the season (solar irradiance is highest between April and August), weather conditions, shading and the solar inclination angle. The optimal tilt angle for south-facing PV panels is 30–35° [18–20]. Modern PV systems installed in open spaces are equipped with trackers that orient panels in the direction of the sun at an optimal angle. Tracking systems support the optimal harvesting of the existing solar resources [21–23]. Reference models are also being developed to forecast the energy yield from PV systems. The developed models can generate forecasts with a horizon of up to 72 h [24]. The design specification for PV systems is determined mainly by the operating environment and the purpose of the installation. Decisions regarding the choice of a given PV system are influenced mainly by the available area for installing PV panels, the intended usage, a PV system’s capacity and the required power demand [25]. This is why the hosting capacity of regions
must be identified before new PV systems are connected to the grid. The hosting capacity is defined as the maximum amount of new energy generation and consumption that can be connected to the electrical grid without endangering its reliability or compromising the voltage quality [26]. The term “hosting capacity” was coined in the context of distributed generation by André Even in March 2004 during discussions within the integrated European EU-DEEP project [27,28]. An approach for quantifying hosting capacity was further developed during that project [29]. Hosting capacity is now widely used as both a term and a methodology by network operators, energy regulators and researchers. Numerous research studies have been undertaken to calculate the hosting capacity, in particular for distribution networks and new power sources [30]. Hosting capacity analyses are conducted by large network operators as part of their strategies to integrate renewable electricity production into their grids [26,31].

In Poland, PV systems were initially installed to supply low-power devices in locations with limited grid access, such as traffic lights, street lights, digital signs, emergency power supply systems, low-power equipment in retail outlets, environmental monitoring equipment and telecommunications relays. At present, electricity is generated by numerous PV power plants for commercial purposes. Large wind farms began to be developed after 2015. Poland’s largest wind farm in Jaworzno was commissioned for use in late December 2020. The farm is a part of a comprehensive project that was initiated on the site of a former coal-fired power plant owned by Tauron Polska Energia (TAURON). The projected wind farms will have a combined capacity of 150 MW. Elsewhere, a PV power plant composed of 16,000 modules with an output of 240 W each was built in Czernikowo in 2015. In late 2018, a solar farm comprising 7920 polycrystalline PV panels with an output of 260 W each was commissioned for use in Bierutow. New investments in the solar power market are underway. Yet, only some of the largest PV plants are owned by power companies, with most of the existing farms developed by private investors. Poland has a large number of low-capacity solar stations (up to 1 MW) built specifically for renewable energy auctions (smaller power stations generate higher profits in this model). As a result, the solar energy sector in Poland is highly decentralized.

According to Abromas [32], wind farms, hydraulic power plants and PV power plants are the energy production facilities that exert the greatest visual impact on the rural landscape but also have a high environmental impact [33]. The visual landscape quality is an intangible resource that affects the quality of life. Photovoltaic panels have no negative impact on their surroundings, which contributes to the development of large solar farms in Poland. Photovoltaic power plants have a smaller visual impact than other renewable power installations, and they generate energy from sources that are naturally replenished and limitless. Unlike wind farms or agricultural biogas plants, PV power plants are also more socially acceptable. However, large PV power plants that occupy an area similar to large-scale crop farms are a new phenomenon. The main advantage of large solar farms is that they can be established on poor soils or in industrially degraded areas that cannot be used for agricultural purposes [14]. Agrophotovoltaics (APV) or agrivoltaic systems combine photovoltaics and crop cultivation, and these solar agriculture systems offer new opportunities for aggregating renewable energy and food production [34,35].

This study aimed to identify the key factors that influence the development of photovoltaic power stations in Poland, with special emphasis on the choice of location and technical aspects of the investment process. The results of the analysis of 68 prospective farm locations were used to identify the main barriers and opportunities for renewable energy development in Poland. The option of connecting solar farms to the existing power grid was also examined. Administrative procedures, including formal approvals, construction permits and connection to the national power grid, were found to play an important role in the development of PV power plants.

The study demonstrates that the development of solar farms in Poland is inhibited mainly by technical barriers, in particular the lack of options for connecting farms to the power grid, as well as the absence of support mechanisms and dedicated legislative solutions, rather than environmental obstacles.
This paper is divided into five sections. This section introduced the state of photovoltaic development and achievements to date. The following section describes the study’s materials and methods. The third is a research section that includes a description of the formal administrative procedure for building photovoltaic power plants in Poland, hosting capacity analysis and an identification of the determinants of solar development based on 95 potential PV installations. The last two sections discuss the problems that emerge during the formal legal process for building photovoltaic power plants and highlight the findings of our research, before concluding this paper.

2. Materials and Methods

The main source of data for the study was project charters developed by a Polish engineering consulting firm that provides comprehensive support for renewable energy projects, from the design stage to site commissioning. A total of 67 potential locations for the construction of PV power plants, mostly in northern and western Poland (voivodeships of Western Pomerania, Wielkopolska and Lower Silesia), were analyzed. Individual sites in the voivodeships of Lubusz, Opole, Warmia and Mazury, Kuyavia-Pomerania, and Mazovia were also evaluated (Figure 1). In some locations, administrative proceedings had been initiated for several investment projects; therefore, a total of 95 project charters were analyzed.

![Figure 1. Locations of photovoltaic farm sites analyzed by voivodeship.](image-url)

The analysis involved solar power projects initiated in 2019–2020. Relevant information on these was used to create a database. In successive stages of the study, the database was analyzed to identify the main factors that influence the development of PV power plants in Poland. The following types of data describing each location were entered into the database: voivodeship, county, municipality, cadastral district, plot number, plot area, soil type and class, property title, designation in the local zoning plan, presence of protected areas, technical and engineering data, including road access (type of access road), availability of medium-voltage lines and distance from the main transformer station. Project charters also contained information about the plot shape, landforms and natural barriers such as open drainage ditches or wind and snow load zones. Sunlight exposure and shading were also very important considerations.

The hosting capacity of the national power grid was also analyzed based on the information obtained from Polish power grid operators: Polska Grupa Energetyczna (PGE), Tauron Polska Energia S.A. (TAURON), Enea S.A. (ENEA) and Energa S.A. (ENERGA). This study aimed to identify the main factors that influence renewable energy development
in Poland (PV power stations). Accordingly, the formal administrative procedure for designing and building a solar farm was described in detail based on Polish laws and regulations applicable to the construction of PV power stations.

3. Results

3.1. Formal Administrative Procedure for Building Photovoltaic Power Plants in Poland

The construction of a PV power plant is a process that requires considerable preparation and legal support. The administrative procedures are complex and lengthy, and the preparatory process can last for up to two years. The formal legal procedure is presented in a procedural diagram (Figure 2).

![Procedural diagram](image)

Figure 2. Stages of a solar development project.

(1) The location of a planned PV power plant and a specific land plot are selected in the first stage of the solar development project. Not all land plots are suitable for the construction of a solar plant. The following factors have to be considered:

- Location—the selected site should not be surrounded by objects that could cast a shadow (trees, buildings, hills). The land plot should be flat or have a south-facing slope;
- Plot size and dimensions—PV panels should be separated by a certain distance to avoid the shading effect. For these requirements to be met, the plot should have an appropriate size and dimensions. A solar farm with an estimated capacity of 1 MW requires a plot with an area of around 1.5 ha and minimum width of 50 m;
- Infrastructure—to minimize costs, the selected site should have access to a power line, preferably within a distance of up to 200 m (the greater the distance, the higher the connection cost). A hard-top access road is also needed to accommodate heavy-duty vehicles during construction and subsequent farm operations and maintenance;
• Soil class—class IV (a, b), V or VI soils are most commonly selected for solar development in Poland. Higher-quality soils can be also used for this purpose, but the relevant procedure is more complex (the conversion of farmland for a non-agricultural use has to be approved by the competent ministry) and costly (high farmland conversion fees). Planning permission for a solar development project on class I–III soil cannot be obtained if a local zoning plan is not available;

(2) Design of a PV power plant. The following parameters should be considered in the design: installed capacity, technology, equipment specification, layout (modules, inverters), cable routes, circuit diagrams, transformer station, lighting and security systems (fencing, security monitoring, guards), power generation analyses and profitability analyses. The design stage is important for several reasons. Firstly, technical parameters will determine the farm’s performance and profits. Secondly, design parameters constitute the formal basis for administrative decisions, such as grid connection requirements. Therefore, the initial design should be prepared ahead of time to avoid changes and corrections that will require new approvals and prolong project implementation;

(3) Formal procedures must be observed and the required permits, including the environmental permit, obtained in the process of developing a PV power plant. An environmental permit is required for projects with a significant environmental impact and a developed area larger than 0.5 ha (in protected areas) or 1 ha (in the remaining cases). The developer must obtain an environmental permit before applying for a construction permit. The following documents have to be submitted in the process of applying for an environmental permit: application form, project charter, property title (notarial deed, lease contract) and a certified extract from the local zoning plan (including a map) detailing the zoning requirements for the site. When a local zoning plan is not available, the developer has to submit the relevant information (statement on zoning regulations in the local zoning plan or statement on permitted land uses in the spatial development plan), with a certified extract from the land register of the part concerning the site and land plots situated within a 100 m radius, a map of the area with an indication of the site and its impact zone (within a 100 m radius), a document confirming payment of administrative fees and the company’s particulars in the National Court Register (KRS);

(4) As previously mentioned, not all land plots in Poland are covered by local zoning plans. If this is the case, the investor has to apply for an individual planning permit specifying general building regulations and land management requirements. The project has to meet numerous criteria to be eligible for an individual planning permit. The environmental permit is also acquired at this stage. Individual permits are frequently issued to PV power plants because zoning coverage is generally low in Poland;

(5) Investors who have acquired an individual planning permit can apply for a document specifying grid connection requirements. The solar farm cannot generate energy unless it is connected to the power grid; therefore, a grid connection request has to be submitted to the grid operator. The following documents have to be attached to the application: planning permission detailing building regulations, certified extract from the land and mortgage register, lease contract, certified extract from the National Court Register confirming the company’s identity and particulars, site plan on a topographic map of the area (with an indication of the existing power lines), simple extract from the land register, detailed specification of PV modules and devices to be installed in the solar farm (manufacturer’s data, certificates, etc.—grid connection requirements are issued for specific devices), circuit diagrams and a document confirming payment of the grid connection fee;

(6) Investors who have acquired all of the above documents can apply for the construction permit, which is the last administrative procedure in a solar development project. The following documents have to be attached to the construction permit application:
architectural, engineering and electrical designs developed by licensed professionals, environmental permit, planning permission specifying building regulations and land management requirements, property title and a document confirming payment of administrative fees;

(7) Photovoltaic power plants with an installed capacity higher than 1000 kW have to apply for an operating license. According to the Renewable Energy Act, only micro (up to 50 kW) and small (up to 500 kW) PV installations are exempt from the licensing requirement, and installations with a capacity of >50 kW and <1000 kW have to be entered into the register of energy producers. During construction, solar farms with an installed power higher than 1000 kW should acquire a promissory note as a guarantee that an operating license will be issued when the project has been completed. The following documents have to be submitted to the Energy Regulatory Office (ERO): license application, documents confirming the project’s compliance with formal administrative requirements (extract from the National Court Register, document certifying the investor’s Tax Identification Number, certificate from the National Criminal Register confirming that the investor, its representatives and the applicant do not have a criminal record), certificate that the investor is a registered VAT payer, list of partners or shareholders, list of supervisory board members, articles of partnership, company’s ownership or control structure, statement that the company has not filed for bankruptcy and that bankruptcy proceedings have not been initiated against the company, certificate confirming the company’s excise number (if applicable), statement that the PV installation will be maintained by qualified personnel, powers of attorney, documents confirming the observance of technical requirements (legal title to property and infrastructure, e.g., notarial deed, lease contract and extract from the land register; technical parameters, current state of power generation equipment, construction permit, planning permission specifying building regulations, grid connection requirements and connection agreement), financial documents or documents confirming sources of funding for the project (financial statements for the last three years, balance sheet for the last three years, bank guarantees, insurance guarantees, tax clearance certificate from the revenue office, clearance certificate from the Social Insurance Company, statement of account from the company’s bank) and a document certifying payment of administrative fees;

(8) After the solar farm has been built, the investor has to apply for the operating license with the ERO. The following documents should be attached to the application: promissory note, use permit, survey map developed after the construction process has been completed and a profit and loss statement for the last three years. A licensed solar farm can sell the generated electricity.

The above formal administrative process has to be observed before the construction of a PV power plant can begin on the site.

3.2. Hosting Capacity Analysis

In a distribution grid, the transition from no solar PV to very high solar PV penetration is a three-stage process [36,37]. In the first stage, when the penetration of solar PV is low to medium, local consumption is higher than solar PV production. During this stage, only minimal adverse effects on the distribution grid are observed in most cases. In the second stage, where local solar PV production begins to exceed power consumption, there are periods with net power injection into the upstream grid. This is where significant adverse effects begin to show. In the last stage, when penetration is very high, local solar PV production is higher than the local power consumption demand. This leads to large amounts of power injection into the distribution grid [37]. At this level, which is above local power consumption, adverse impacts can become unacceptable, and therefore, need to be mapped and quantified. This acceptable limit is referred to as the ‘hosting capacity’ of the distribution grid [27,29,38]. When the amount of solar PV exceeds this limit, at least one of the impacts on the distribution grid is unacceptable, and relevant
mitigation measures are needed. For instance, the quality of power deteriorates, and control equipment or grid strengthening may be required. The distribution of the deterioration in grid performance includes the voltage magnitude, voltage unbalance, losses, harmonics and line loading [39–42].

The Distribution System Operator (DSO), namely the entity responsible for the distribution of electricity in a given Polish region, is appointed by the President of the ERO. The DSO operates distribution networks that deliver electricity to end-users. Distribution networks comprise high-voltage (110 kV), medium-voltage (15 kV) and low-voltage (400 V) lines.

Pursuant to the provisions of the Act of 19 August 2011 amending the Energy Law and other legal acts [43], the DSO has to publish information on the hosting capacity of the power grid, as well as planned changes to these values in the next five years. The structure of the national power grid is regularly updated to account for planned changes to the grid’s hosting capacity until 2026–2027. These changes are introduced based on the DSO’s plans concerning the energy demand and supply projection for 2020–2025, which have to be approved by the President of the ERO. Poland has four DSOs that supply energy in different regions of the country.

The main distribution companies that supply electricity to Polish regions (Figure 3) are [44]:

- **ENEA**—voivodeships of West Pomerania (Szczecin), Lubusz (Gorzów Wielkopolski, Zielona Góra) Wielkopolska (Poznań), Kuyavia-Pomerania (Bydgoszcz);
- **ENERGA**—voivodeships of Pomerania (Gdańsk, Gdynia, Ślupsk, Koszalin), Wielkopolska (Kalisz), Kuyavia-Pomerania (Toruń), Warmia and Mazury (Olsztyn, Elbląg);
- **PGE**—voivodeships of Podlaskie (Białystok), Mazovia (excluding Warsaw), Łódź (Łódź), Świętokrzyskie (Kielce), Lublin (Lublin), Podkarpackie (Rzeszów);
- **TAURON**—voivodeships of Małopolska (Kraków), Silesia (Katowice), Opole (Opole), Lower Silesia (Wrocław);
- **Innogy**—capital city of Warsaw.

There are different hosting capacity in different regions of the country (Figure 4).
Figure 4. Hosting capacity in MW for Polish regions (as of 31 December 2021).

The hosting capacity of DSOs in different Polish regions (excluding Warsaw), including the installed capacity and projected integration of renewables, is presented in Figure 5.

Figure 5. Hosting capacity of DSOs in Polish regions.

The presented data indicate that the planned increase in the hosting capacity of the Polish power grid is not sufficient to integrate renewables. The above results from infrastructure deficiencies as well as the fact that the Polish power grid is outdated. Considerable funding is needed to modernize and expand the power grid. The absence of capital investments in power infrastructure is one of the main barriers to the development of PV power plants and other renewables. As a result, Poland may be unable to fulfill its duties and commitments under the EU’s climate and energy policy. According to Szczerbowski and
Ceran [45], the hosting capacity requirements and energy consumption will significantly exceed the predicted values.

3.3. Identification of the Determinants of Solar Development in Poland

The results of the conducted analyses clearly indicate that investors specializing in solar development projects opt for sites and land plots without natural barriers. Furthermore, the business models developed for solar photovoltaics can overcome the barriers to the diffusion of renewable energy [46].

Sites characterized by favorable landforms, an absence of protected areas, absence of shading, convenient access, availability of medium-voltage power lines and main transformer stations in the vicinity are preferred. The zoning classification of a given area also plays an important role in the process of selecting a site for the construction of a PV power plant. Many of the plots selected for solar energy investments had a very large area (up to 100 ha), and in these cases, formal proceedings were initiated for several projects. Large sites were divided into smaller plots with an area of around 2 ha each. The characteristics of the analyzed investments are presented in Table 1.

Table 1. Characteristics of selected locations for the development of photovoltaic power plants.

| Specification                  | Characteristics/ Number of Projects |
|-------------------------------|------------------------------------|
| Predicted power               | up to 1 MW/90                      |
| Zoning classification         | zoning plan/0                      |
| Distance to a medium-voltage line | on a parcel/40                    |
| Protected areas               | none/89                            |
| Landform                      | favorable/95                       |
| Plot shape                    | regular/35                         |
| Access to a paved road        | direct access/77                   |
| Construction permit           | yes/86                             |
| Solar exposure                | up to 1000 kWh/m²/76               |
|                              | up to 50 MW/5                      |
|                              | individual planning permit/95      |
|                              | up to 500 m/16                     |
|                              | above 500 m/39                     |
|                              | in the vicinity/6                  |
|                              | unfavorable/0                      |
|                              | irregular/60                       |
|                              | must be provided/18                |
|                              | no/9                               |
|                              | >1000 kWh/m²/19                    |

Most of the planned installations had an installed capacity of up to 1 MW. Only five solar farms had a higher power output (30 MW, 32 MW and 40 MW, each in one case, and 50 MW in two cases). Polish investors show the greatest interest in small solar power systems of up to 1 MW, which are the most profitable.

Areas that are appropriate for the construction of a PV power plant (with an installed capacity higher than 100 kW) should be indicated in the local spatial development or zoning plan. If a local zoning plan is not available, the investor has to apply for an individual planning permit detailing building regulations [47]. In the group of 67 analyzed locations, none of the plots were covered by local zoning plans, which implies that all investors had to apply for individual planning permissions specifying building regulations and land management requirements. All solar power plants were developed on sites characterized by low-quality soils (soil classes IVa, IVb, V, VI). Solar farm proposals have a higher chance of being approved if they are planned in areas with poor soils. None of the examined sites featured protected areas, and areas with high nature value were situated further away from the plants. Analysis of project charters revealed that around 90% of the sites had been approved in the administrative procedure and were awaiting development. The remaining applications were rejected because the proposed PV installations could not be connected to the grid. In these cases, the procedure of applying for grid connection requirements would have to be reinstated. Most of the examined sites were located in Polish regions where energy is distributed by ENEA (48 solar farm projects) or TAURON (26 solar farm projects). These groups are planning to increase their hosting capacity, but energy demand is highly likely to exceed the planned values.

Most PV systems were planned on leased land. The majority of investors signed long-term lease contracts covering a period of 29 years. Land purchases were far less
frequent. In 2019–2020, the average solar land rent was EUR 2000–2500/ha. Land rents have increased significantly in recent years and presently reach EUR 3000–3500/ha.

The distance from a medium-voltage line was considered in the analyzed locations. There are no large industrial plants in the vicinity that can purchase electricity from the planned farms; therefore, the generated power has to be fed to the power grid. The distance to a medium-voltage line exceeded 500 m in 39 of the analyzed cases. This leads to additional costs at the planning stage (around EUR 15,000), but above all, it prolongs the formal process of acquiring a construction permit. Solar exposure was also evaluated at each site, and only 19 of the analyzed sites were located in Polish regions with moderate insolation (above 1000 kWh/m²) [48].

Only five potential investments (three locations) had not yet initiated formal legal procedures for the construction of a photovoltaic farm. This is confirmed by the fact that consulting and engineering companies, as well as investors, choose locations where PV farms can be built and connected to the grid in line with the existing legal regulations. The neighborhood also plays an important role in the process of choosing the location of a PV farm. Only some of the analyzed sites were located in the proximity of built-up areas. According to Polish law, PV farms can be developed in the vicinity of residential areas. However, investors tend to avoid residential areas due to the need to obtain additional environmental impact assessments and the risk of local protests at the stage of environmental proceedings, which could substantially prolong the planning process.

4. Discussion

According to the Council of European Energy Regulators and network operators, the hosting capacity (HC) quantifies the future performance of the power network [30,49]. In addition to other renewable energy sources (RES), photovoltaics (PV) represent a mature and economical option gaining widespread recognition [50]. Although the PV market is policy-driven, the penetration of PVs continues to increase. Low-voltage (LV) networks have been facing operational issues such as overvoltage and imbalance due to increased rooftop solar PV integration. Thus, the maximum PV penetration that does not exceed operational and performance constraints (PV HC) must be thoroughly understood and measured [51]. The definition of an acceptable limit can help determine how much solar PV can be connected to a grid without additional investments [52,53]. This, in turn, plays an important role in planning and decision-making for future grid reinforcements or expansions [37,53,54]. Most of the analyzed investments were located in the Wielkopolskie and West Pomerania voivodships, where there are currently the largest amounts of hosting capacity (Figure 4).

According to Kaygusuz et al. [55], solar electricity is a success story. Over the past five years, the global solar power sector has been growing at an annual rate of 30–40%. In 2002, the PV sector in Europe registered a 33% growth. Germany has introduced numerous programs to mobilize investments in renewable energy projects [12], and it is presently the largest renewable power producer in Europe with more than an 80% share of the European market [56]. The involvement of France, Italy and Spain in renewables' development is difficult to assess [55]. Switzerland is attempting to find the optimal mix of wind power, solar energy and hydropower in its energy balance [57]. Poland has a similar solar energy capacity to Germany [15,17], but its potential has not been fully utilized to date. In the last 15 years, the average annual insolation for Poland was estimated at 900–1100 kWh/m² [46]. According to estimates, Poland is unlikely to achieve its 15% renewables target by 2030, but it is the European leader in terms of the annual growth rate of solar energy systems [36]. According to Pacelis et al. [58], the renewable heat market in Poland is less developed due to limited resources or underdeveloped technologies. The rapid development of the Polish solar market can also be attributed to the introduction in 2016 of strict requirements concerning the location of wind farms. The distance between wind farms, buildings and protected areas was increased to at least ten times the height of the turbine [59]. The
localization requirements and legal regulations applicable to wind farms, in particular large-scale sites, differ across countries, subject to local environmental conditions [60].

Support policies and the adaptation of energy laws to national circumstances play an important role [61–64]. Many countries have implemented policies to disseminate energy storage systems (ESSs) [65]. According to Narodzonek [66], growth in the popularity of PV installations in Poland was fueled by the introduction of renewable energy auctions. The winning company is guaranteed a fixed price on the energy generated over a period of 15 years. In the EU, tariff guarantees are the main mechanism supporting renewable energy development, and they continue to be applied by many Member States [67]. In Poland, only licensed solar farm operators can participate in auctions, and a license is granted only to investors who have a legal title to the land occupied by the PV installation. Most investors conclude land lease contracts that entitle them to use the land for business operations and reap the associated benefits, in this case, solar energy [66]. An analysis of the examined project charters indicates that the majority of Polish PV solar plants have been developed on leased land. A solar land lease is also an attractive option for landowners as a long-term and stable source of income.

Environmental considerations also play an important role in solar energy development. Research has demonstrated that PV power plants have a relatively low environmental impact in comparison with other renewable energy generation sites (wind farms, biogas plants and others) [68]. Considerable research has been done into solar farms’ environmental impact at every stage of their life cycle [69]. New technologies are also being developed to minimize the adverse environmental effects of PV power plants [12,33] and enhance energy efficiency [70]. Moreover, APV can represent a valuable technical approach to achieving more sustainable agriculture, which helps meet the current and prospective needs for energy and food production while sparing land resources [34].

In Poland, the development of the solar power sector is hindered mainly by the absence of support mechanisms and dedicated legislative solutions, rather than environmental obstacles. As demonstrated by numerous examples from Poland and other countries (Walmart, Amazon and Google operate their own solar farms), PV power plants deliver a range of benefits, both environmental (lower carbon footprint) and economic (cheap energy, limitless energy source).

5. Conclusions

The interest in renewable energy has been spurred on by rapid economic growth, which has increased the demand for energy and led to the depletion of traditional energy sources from fossil fuels. Solar radiation is one of the most promising sources of renewable energy, where sunlight is converted into electrical energy through photovoltaic cells. The development of smarter and more efficient energy technology over the past decades has been spectacular. Technologies have improved and costs have fallen dramatically. Examples of wind and solar photovoltaic (PV) are striking. For solar PV cells, which were stimulated initially by the space program, unit costs have fallen by a factor of 10 in the past 15 years. The results of the present study clearly indicate that insufficient grid hosting capacity is the key obstacle to the development of PV power plants in Poland. Location factors, such as landform, adequate sun exposure, plot shape and the availability of medium-voltage power lines, pose considerable challenges in the process of planning solar investments. The presence of a main transformer station in the vicinity of the planned solar development is the most important consideration. Planning requirements, meanwhile, appear to be less problematic for investors. Solar power plants can be built in areas that are zoned for industrial purposes or are directly intended for renewable energy projects. Most administrative decisions approving the location of solar farms are issued based on individual planning permits specifying building regulations and land management requirements, provided that they do not violate local spatial planning policies. Environmental constraints are eliminated at the stage of selecting a potential site; therefore, they do not pose a serious obstacle in the process of applying for administrative decisions. In conclusion, it should be stressed that
insufficient grid hosting capacity is the main barrier to renewable energy development in Poland. Hence, the expansion and modernization of the national power grid should be the top priority of Poland’s energy policy.

This study’s main aim was to analyze prospective locations of PV farms and present the formal legal requirements for obtaining a PV construction permit in Poland. According to the surveyed engineering consulting firm, around 90% of the evaluated locations have been approved, which implies that these projects are currently underway or will be launched in the near future. Yet, recent changes in material prices, subcontractor fees and technical problems at different stages of the construction process were not analyzed in this study. Looking ahead, the initiated projects will be monitored to identify barriers at each stage of the construction process and the subsequent operation of PV farms.

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