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Comparison of Support Programs for the Development of Photovoltaics in Poland: My Electricity Program and the RES Auction System

Jarosław Kulpa [1,*], Piotr Olczak [1], Tomasz Surma [2,3] and Dominika Matuszewska [4]

1 Mineral and Energy Economy Research Institute, Polish Academy of Sciences, 7A Wybickiego St., 31-261 Cracow, Poland; olczak@min-pan.krakow.pl
2 Faculty of Electrical Engineering, Warsaw University of Technology, 1 Politechniki Sq., 00-661 Warsaw, Poland; tsurma@o2.pl or tomasz.surma@veolia.com
3 Veolia Energia Polska S.A., 2 Puławska St., 02-556 Warsaw, Poland
4 Department of Thermal and Fluid Flow Machines, Faculty of Energy and Fuels, AGH University of Science and Technology, 30 Mickiewicza Ave., 30-059 Cracow, Poland; dommat@agh.edu.pl
* Correspondence: kulpa@min-pan.krakow.pl

Abstract: Poland has great potential for the development of renewable energy sources. The implementation of support systems dedicated to renewable sources has resulted in the installation of over 10,500 MW of installed capacity. At present, with high electricity prices, stimulated by the costs of CO_2 emissions and the costs of fuel purchase, renewable energy sources are of particular importance in the transformation of the Polish power industry. The RES auction system and the My Electricity Program contributed to the growth of entrepreneurship and the development of the economy. Energy consumers, from passive ones, have become active market participants—prosumers. The RES auction system alone contributed to the creation of approx. 5 GWp of installed capacity of photovoltaics (PV) sources in 2016–2021, while the My Electricity Program contributed to the creation of approx. 2 GWp of installed capacity in PV installations in 2019–2021. The aim of the study is to compare the economic and social costs of two photovoltaic development programs, My Electricity and the RES auction system, from the point of view of the country (in support distribution costs—subsidies) and investors, renewable energy installations operators and prosumers to which these programs are targeted, namely, individuals and enterprises.

Keywords: My Electricity Program; RES auction system; feed-in tariff; incentives; renewable energy; photovoltaic; renewable energy transition; Poland

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1. Introduction

The increased demand for electricity, along with the growing awareness of the negative impact of fossil fuels on the environment, forces the use of clean energy sources. Growing awareness of the potential consequences of climate change has led to an increase in the share of renewable energy sources (RES), such as photovoltaics (PV), as an alternative to conventional ones. As a result, greenhouse gas emissions are reduced [1]. At the same time, the number of photovoltaic installations has increased in recent years, making it one of the main renewable energy sources [2]. At this point, the installed capacity in PV is the largest compared to other renewable energy sources, including water and wind energy [3]. It is believed that photovoltaic modules from other distributed energy sources (DER) have become the most common because they are not location-specific, which cannot be said about biogas, wind, or geothermal energy [4,5]. The fact that photovoltaics can be installed in practically every household to meet its own energy needs (while selling excess energy to the grid) makes it so attractive compared to other renewable energy technologies. The use of photovoltaic modules on households can not only reduce the owner's bills but also support the local generation [6]. Therefore, it is one of the most developed renewable energy technologies, especially in countries that are looking for ways to increase their energy independence because they are dependent on imported fossil resources [7]. In order to increase the popularity of RES, many countries have introduced various types of support systems aimed at accelerating this type of investment [8–11]. In addition, the European Union implements specific greenhouse gas emission reduction targets (a significant reduction in emissions by 2050) as part of the EU2030 climate and energy policy. It is believed that achieving these goals is possible with a significant increase in the share of energy production from renewable sources. Therefore, the key factor seems to be supporting such investments [12]. Also in Poland, various types of support mechanisms for RES have been introduced:

—direct grants and other financial instruments supported by the EU/governments, including: European funds, i.e., under the Operational Program "Infrastructure and Environment"; Iceland's, Lichtenstein's, and Norway's financial support (subsidies and loans); Green Investment Scheme (connected to the EU Emissions Trading System); Green Certificates (certificates of origin); auction mechanism (replaced the Green Certificate); net-metering (replaced the feed-in tariff (FiT) before it came into force); My Electricity Program (subsidy program funded through the Green Investment Scheme); and tax relief scheme,

—market-based mechanisms: private funds and investments (e.g., "collective prosumers", "virtual prosumers"); preferential bank loans; crowdfunding; green bonds, etc. [13]. To show the evolution of renewable energy subsidies and financing in Poland, Figure 1 is shown.

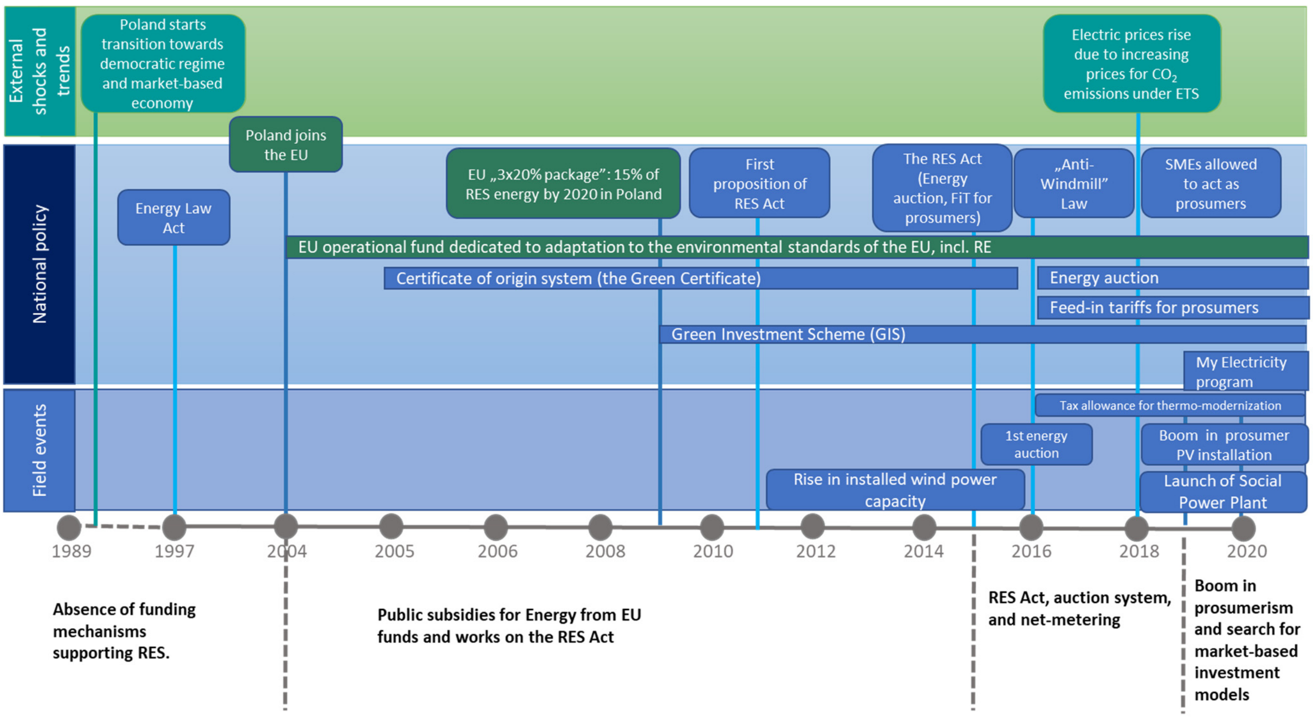

Figure 1. Subsidies and financing of renewable energy sources in Poland in the years 1989–2020. Reproduced from [13], Iskandarova M. et al., 2021.

In 1989, the process of political transformation began in Poland which unfortunately lacked actions for energy transformation and decarbonization of the country. At that time, coal-fired units were almost the only source of electricity (plans to build a nuclear power plant were abandoned after the Chernobyl accident). In the years 1989–2004, the focus was on the problem of Poland's energy dependence (including gas imports from Russia), but no mechanisms were introduced for renewable energy sources. After Poland joined the EU in 2004, the issues of environmental and climate protection slowly grew in importance; in

2005–2015, public subsidies for energy efficiency appeared from the EU, and there were talks of an act on renewable energy sources. The National Fund for Environmental Protection and Water Management was responsible for the management and distribution of public funds for renewable energy projects and those related to energy efficiency (responsible, i.e., for the organization of the Green Investment Scheme (GIS), a derivative of the Emissions Trading System (ETS)) [13]. The RES Act was finally adopted in 2015, introducing several new financing mechanisms: the Green Certificates system was replaced by the RES auction system [14], and the act also enabled prosumerism [15,16]. It originally introduced the feed-in tariff system, but it never came into effect, as this policy measure was withdrawn by the new government and replaced by net-metering. Although the renewable energy policy opened new opportunities for prosumers, government regulations on wind farms practically froze the industries. In 2019, the Program of the Ministry of Energy and Environment "My Electricity" was launched, which co-financed photovoltaic installations (2–10 kW) for households with a subsidy of up to PLN 5000 (~EUR 1200) [13,17,18]. Another important mechanism for financing renewable energy is quite traditional mechanisms, e.g., bank loans and some market-based ones, such as EPC (Energy Performance Contract), ESCO (Energy Service Companies), and innovative instruments, e.g., green bonds [19] and local investment cooperatives [20]. Additionally, Poland introduced the capacity market in 2018. However, since renewable power generation units have limited opportunities to participate in this support instrument [21,22], it is neglected in this study.

As noted by Schmidt [23], renewable energy sources require a much larger financial support, which is why it is so important in their case to study the dynamics of financial instruments and subsidy flows and to assess their effectiveness. On the other hand, Hagspiel V. et al. [24] showed, in the example of FiT subsidies for investments in renewable energy capacity, that withdrawal from the support scheme has a serious impact on investors' decisions. Sendstad L.H. et al. [25] showed the influence of the stability of the political environment on encouraging investments in renewable energy; they showed that the ex post subsidy adjustments reduce the investment rate in photovoltaics by about 45%. Abolhosseini and Heshmati [26] compared FiT, tax incentives, and tradable green certificates as support systems for the development of renewable energy, suggesting that the policies of individual support mechanisms should be redefined from a financial point of view, due to technological progress and reduction of production costs. Dijkgraaf et al. [27] checked whether the FiT was an effective tool for encouraging the development of photovoltaic solar energy (PV). At the same time, they paid special attention to the potential impact of a well-designed FiT, which can be seven times greater. Dong et al. [28] analyzed China's zoned solar FiT policy, showing that an increase in subsidies of ~$0.014/kWh adds about 18 GW/year of installed capacity to the domestic PV market. In contrast, the cost of reducing carbon dioxide through FiT was estimated at ~$ 17 per ton of CO_2.

The aim of the study is to compare the economic and social costs of two photovoltaic development programs, My Electricity (2019–2021) and the RES auction system (2016–2021), from the point of view of the government (in support distribution costs—subsidies). From the point of view of individual investors (companies or households), the My Electricity program and auction system seem incomparable. On the other hand, from the point of view of running programs aimed at leading to the development of photovoltaics in the country at the lowest cost, such a comparison is absolutely justified and can serve as a source of recommendations for decision-makers. Nobody in the literature has compared the different support programs in terms of their different costs and benefits while considering the fulfilment of the incentive effect. Therefore, the authors decided to compare these programs on one of the most growing photovoltaic markets in the European Union, i.e., in Poland. Two key programs were selected for this purpose that have made a significant contribution to this growth: the My Electricity Program and the RES auction system. For the fulfilled incentive effect, we assume the full use of funds or capacity available in each support program, which can be analyzed in the case of these two programs, due to the fact that their assumed effects have been achieved. The above is the main novelty, i.e., the comparison of this effectiveness while meeting the incentive effect.

2. My Electricity Program, RES Auction System, and Energy Market Data

2.1. The State of Development of Photovoltaics in Poland

The development of sources using solar radiation depends, e.g., on the conditions of sunlight in a given area. Due to its geographical location, Poland has moderate sun exposure. Average insolation by voivodeship ranges from 1063 kWh/m^2/year, for the Pomeranian voivodeship, to 1138 kWh/m^2/year, for the Lower Silesian voivodeship, and so it is closely related to the latitude and the state of cloud cover characteristics for a specific area of Poland (Figure 2) [29].

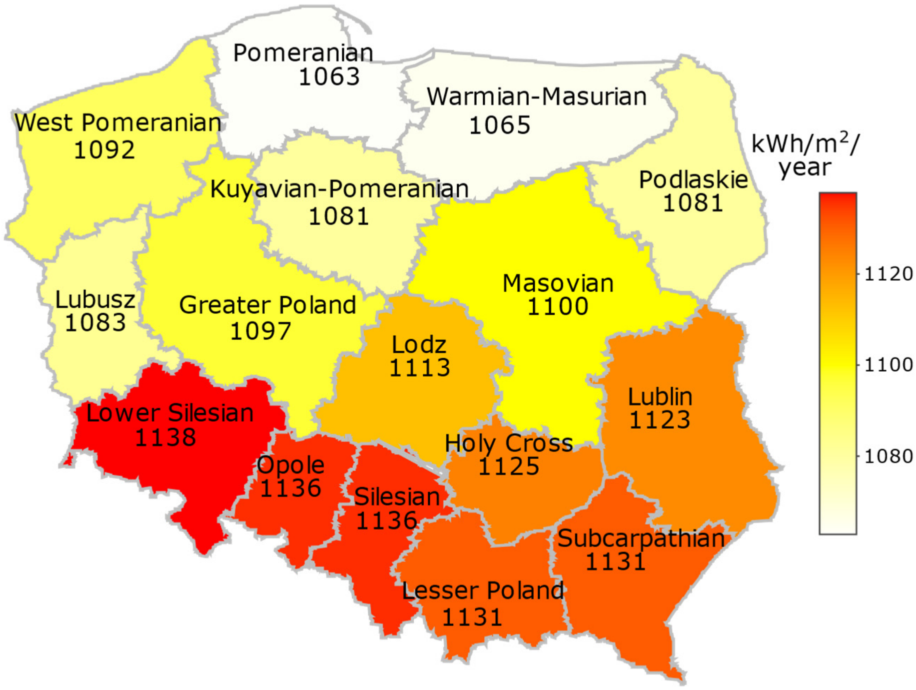

Figure 2. Poland's sun exposure (insolation) conditions averaged for individual provinces. Source: own study based on [29].

From 2019, a dynamic increase in installed capacity in photovoltaic (PV) installations has been observed in Poland. According to the plans presented in the Polish Energy Policy until 2040 (PEP), in 2030 the total installed PV capacity will be in the range of 5 to 7 GWp. However, the development of PV sources is much more dynamic than assumed by PEP, and, as of 31 August 2021, the installed PV capacity reached 5.97 GWp [30]. The lion's share of this capacity is made up of micro-installations, in which, as of September 2021, the installed capacity was over 4.9 GWp, with over 700,000 installations (Figure 3) [30].

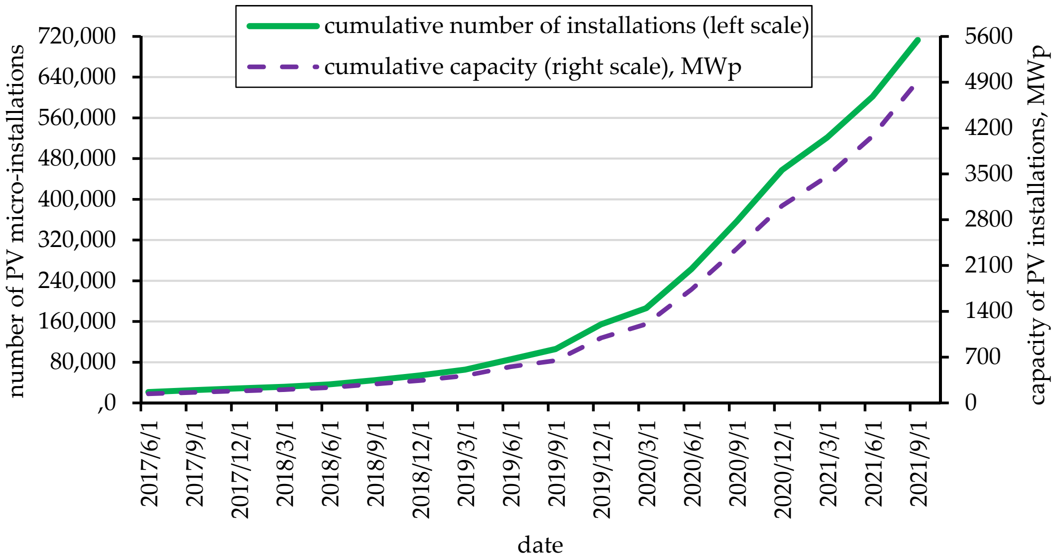

Figure 3. Number of PV micro-installations and PV installed capacity in Poland. Source: own study based on [30].

The intensive growth of new RES capacities is influenced, among others, by the reduction of unit capital expenditure LCOE (Levelized Cost of Electricity, Figure 4), which at the same time makes these technologies competitive in relation to other generation sources. According to [31], in the last decade the investment costs of PV sources, as well as wind farms, recorded a several-fold decrease in investment costs per volume of electricity produced. On the other hand, other renewable sources, in particular those using geothermal resources or water energy, require higher investment outlays today compared to 2010. Figure 4 shows the LCOE of selected technologies of sources using renewable resources. Today, in Polish conditions, PV sources, apart from wind energy, are the cheapest energy generation technologies. In addition, with the recently dynamically growing costs of carbon dioxide emission allowances, which are borne by the conventional energy sector—about 70% of electricity generated in Poland is based on hard coal and lignite—these technologies are even more competitive compared to those burdened with cost issues [32].

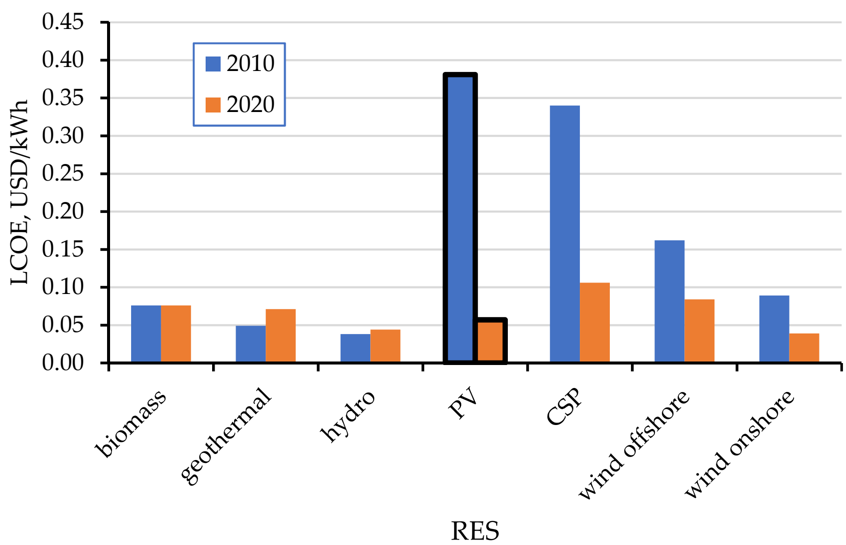

Figure 4. Trends in unit investment in RES technologies (CSP—concentrated solar power, hydro—hydroelectric power station). Source: own study based on [31].

2.2. My Electricity Program

My Electricity is a program aimed at increasing electricity production from photovoltaic micro-installations (from 2 kWp to 10 kWp) [17,33], mainly to cover electricity demand in households. The program is addressed to natural persons producing electricity for their own needs, and its task is to create new micro-installations (projects consisting in increasing the capacity of existing installations are not eligible for co-financing). The total budget of the program in 2019 and 2020 was approx. 260 million EUR, which translates into support in the form of subsidies up to 50% of the eligible costs of micro-installations, with the total amount of support not exceeding EUR 1100 for one project [17]. In 2021, the maximum amount of the subsidy was EUR 650 [34].

The dependence of the installation capacity on the amount of subsidy under the My Electricity Program (Figure 5) depends on the maximum value (EUR 1100) provided by the legislator for one project. However, from the chart we can also see projects in which the amount of subsidy was less than 50% of eligible costs (points under the curve).

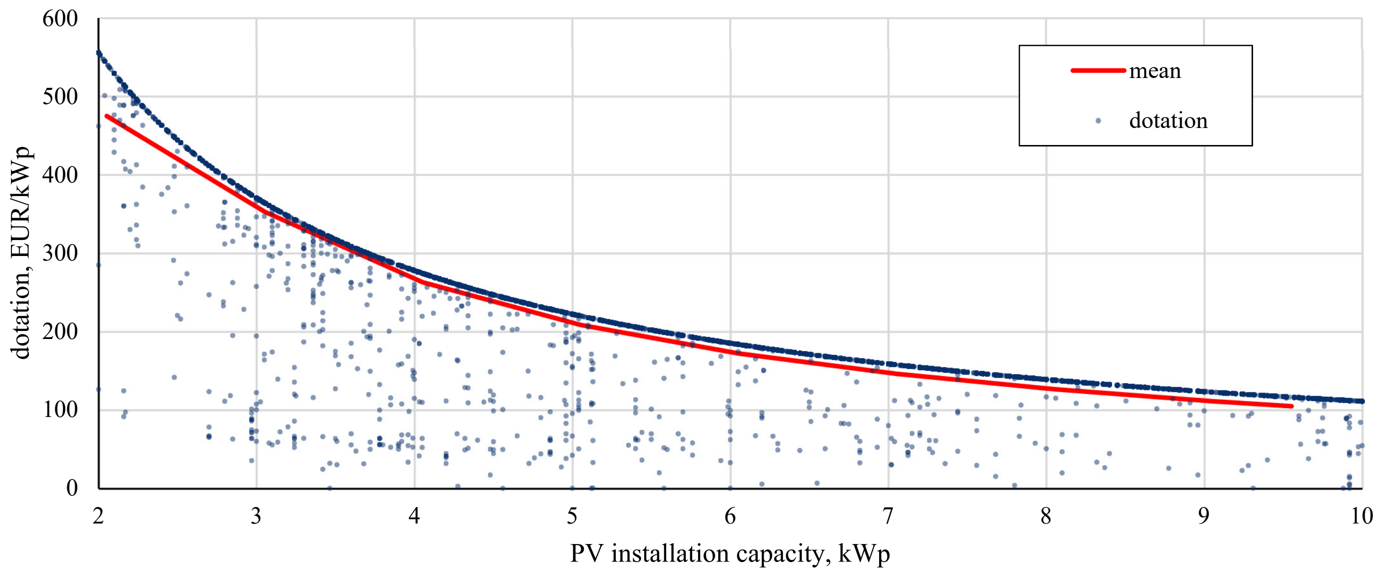

Figure 5. Dependence of the power of the installation on the amount of the subsidy. Source: own study based on [34].

By voivodeship, the greatest beneficiaries of the program are the inhabitants of the Silesian, Greater Poland, Masovian, and Lesser Poland voivodeships (EUR 30.0, 29.5, 28.0, and 27.6 million—Figure 6). This is largely due to the number of inhabitants and, thus, the number of households (especially in single-family houses) that could benefit from this program. In unit terms, per population, the most effective voivodeship is the Subcarpathian (EUR 10.5/inhabitant), before Greater Poland (EUR 8.5/inhabitant) and Lesser Poland (EUR 8.2/inhabitant). At the other extreme, there are the following voivodeships: West Pomeranian (EUR 4.2/inhabitant), Podlaskie (EUR 4.5/inhabitant), and Warmian-Masurian (EUR 5.1/inhabitant).

The launch of the My Electricity Program engaged existing energy consumers, households, to actively participate in the energy market. The program stimulated the entrepreneurship of Polish households that use the possibility of installing individual production sources at home. At the same time, small initiatives of micro-installations collected as a whole will contribute to a significant transformation of the energy sector in Poland, and their total power already has an impact on easing price peaks on the electricity market, which is presented later in this paper.

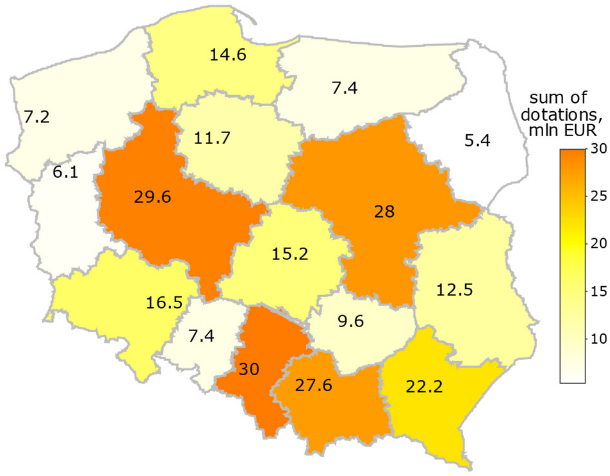

Figure 6. Total subsidies granted under the My Electricity Program. Source: own study based on [34].

2.3. RES Auction System

The Act on renewable energy sources and RES of 2015 [35] introduced a new support system for the development of renewable energy sources. The previous system, based on the certificate formula, was replaced by the new one, based on the formula of competitive auctions. The act also introduced a different support system for small sources and micro-installations. The RES auction system, unlike the My Electricity Program, is dedicated to larger sources connected to the distribution and transmission networks of the power system.

The new auction support system provides for the organization of separate auctions for sources with a capacity of up to 1 MW and above 1 MW, as well as separately for the technologies specified. Auctions are held at least once a year by the President of the Energy Regulatory Office. Before the auction, investors are required to prove the maturity of the development of investment projects in the qualification procedure so as to ensure their implementation after winning the auction.

The Ministry of Climate and Energy, which is responsible for energy regulations, annually announces the volume and budget to be distributed in the RES auction system, with a breakdown for individual auction baskets. The auction is for the total revenue from the sale of electricity and surcharges, above the selling price of this energy. It is a formula for a contract for difference in which the operator can count on an additional payment and compensation of the negative balance to the level of the winning bid, but when the price of electricity on the market exceeds the result of the won auction, the investor returns additional income as a positive balance of the settlement of this contract for difference. The bidders who submit the cheapest bids for the contract for difference (the sum of the electricity price—market price and surcharges) win in the auction, until the auction budget is exhausted [36].

The Ministry of Climate and Energy presents, in a dedicated regulation, the reference prices for individual installations of sources using renewable resources, which are the maximum values to be presented in the auction bids. Sources using solar radiation (PV) take part in the auction by competing with wind farms, both in baskets with a capacity of up to 1 MW and above 1 MW separately [36].

In the auctions conducted at the beginning of the RES auction system (2016–2017), the winning participants were those who offered the lowest selling price, until the amount or value of this energy specified in the auction announcement was exhausted. The amendment to the Act of 2018 introduced the so-called rule of forcing competition, according to which "the auction is won by the participants who offered the lowest selling price of electricity from renewable energy sources, less the amount of tax on goods and services, and whose offers in total did not exceed 100% of the value or quantity of electricity from renewable energy sources specified in the auction notice and 80% of the electricity volume covered by all bids" [36]. This rule forced competition in baskets in which the volume and budget intended for the auction had not been allocated. In principle, this rule is intended to counteract inflating prices in such auction baskets, where the project population is small and, thus, competition may be distorted. This rule is a result of the regulations of the European Union.

In 2016–2020 (Figure 7), most installations and installed capacity under the RES auction system were built in the Greater Poland voivodeship—392 installations, with a total installed capacity of 696 MWp. At the lower end of the spectrum, there was the Silesian voivodeship, with only 41 installations with a total installed capacity of 38 MWp.

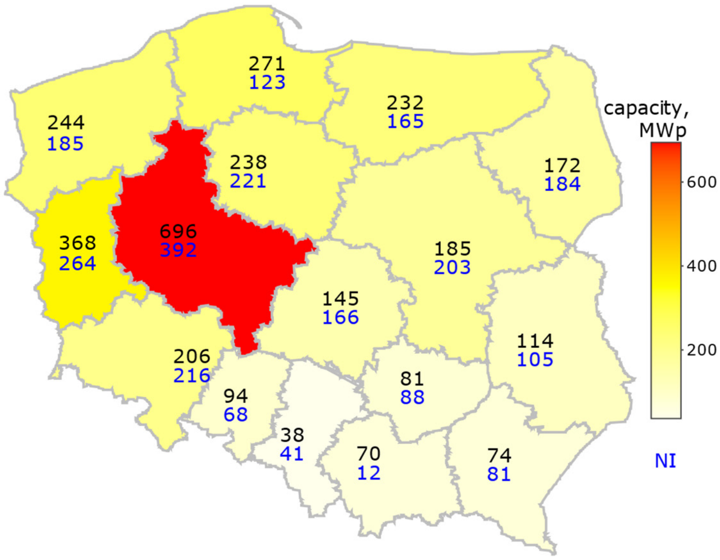

Figure 7. Capacity and number (NI) of PV installations created under the RES auction system in 2016–2020. Source: own study based on [36].

Figure 8 shows the price results of auctions conducted in 2016–2021 for PV sources and wind farms. According to the diagram below (Figure 8), the average price of energy produced in PV installations among all renewable sources is the only one characterized by a downward trend in the subsequent years of the RES auction system operation, and in 2021 it reached the level of EUR 50/MWh, which made it the most competitive (especially for capacity up to 1 MWp).

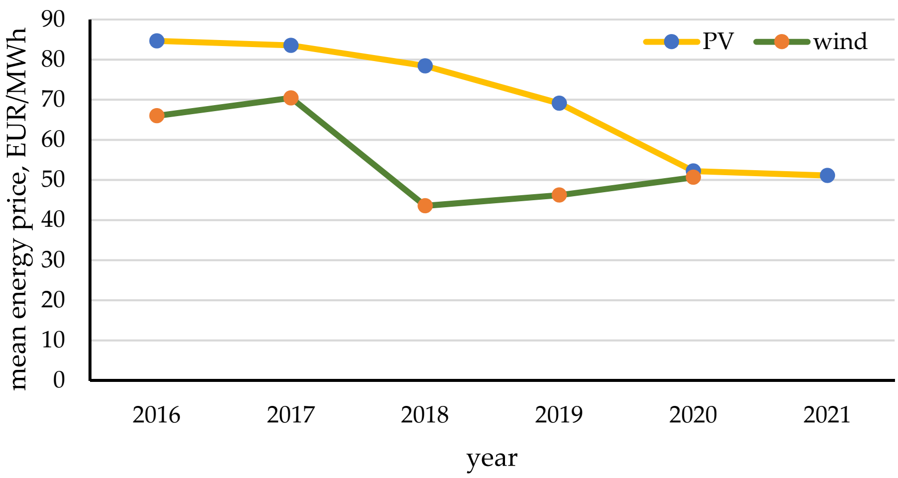

Figure 8. Average energy prices (weighted by the number of installations and energy volume) at the RES auction system (PV: 2017–2021 and wind: 2016–2020) auctions. Source: own study based on [36].

2.4. Renewable Energy Sources on the Energy Market

In recent years, we have observed a systematic increase in electricity prices related to, inter alia, an increase in the prices of CO_2 emission allowances and fuel purchase costs. In the Polish power system, largely based on conventional energy (mainly using lignite and hard coal as fuel [37]), it translates directly into an increase in the average price of energy on the commodity power exchange (TGE Base—Figure 9). In 2016, the cost of purchasing emission allowances in the price of energy oscillated around 10–20%, while now (2021), this share often exceeds 50% of the total electricity price on the wholesale market.

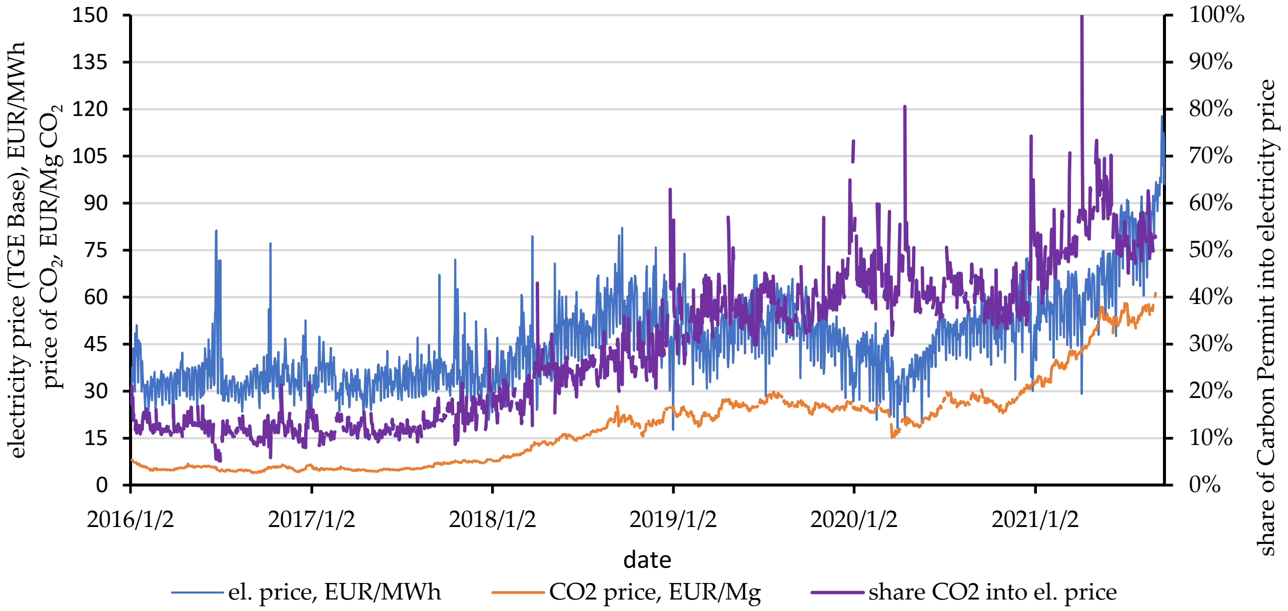

Figure 9. Electricity prices according to Polish Power Exchange (TGE Base index)—instead of price share, share of purchase costs. Source: own study based on [38,39].

The dynamic increase in the prices of CO_2 emission allowances and, consequently, the average price of electricity led to a situation where the prices of RES auctions from photovoltaic (PV) sources in 2021 were significantly lower than the TGE Base index (Figure 10).

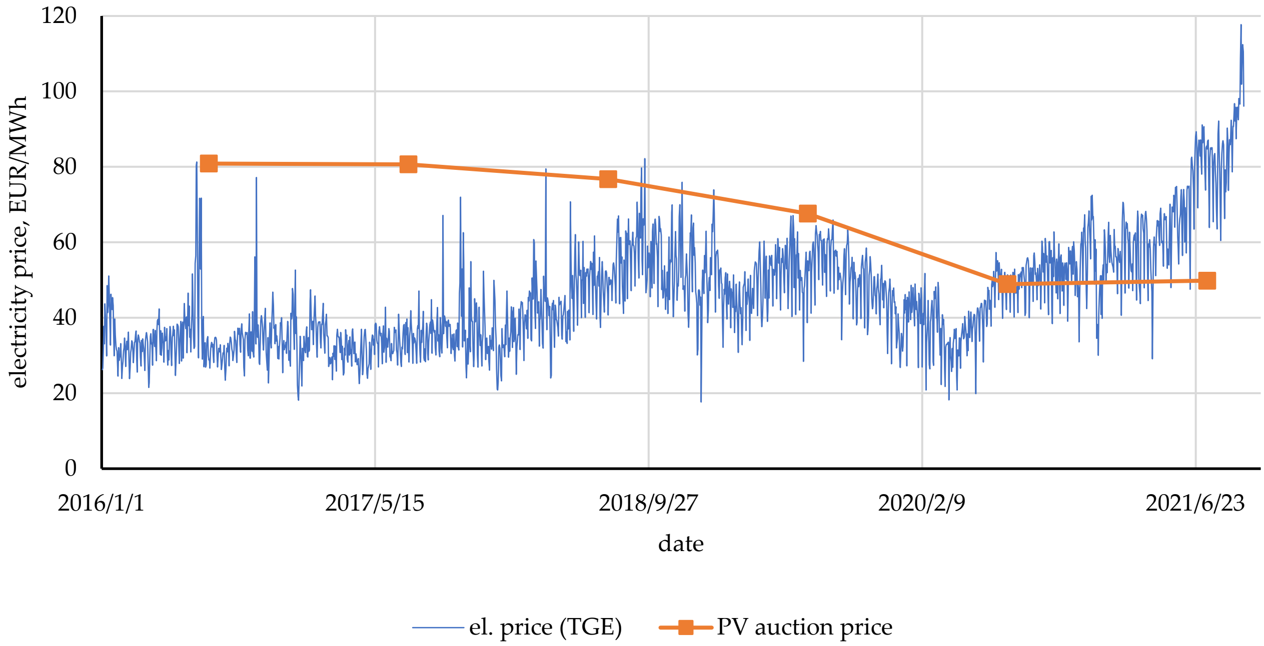

Figure 10. RES (PV) auction prices compared to the electricity price (TGE Base). Source: own study based on [38].

2.5. Comparison of the My Electricity Program and the RES Auction System

Support systems for the development of renewable energy sources, such as the My Electricity Program and the auction support system, differ mainly in the group to which they are addressed. The My Electricity Program was aimed at individual prosumers, with a focus on the implementation of small installations, usually on the rooves of residential buildings. The RES auction system was addressed to enterprises dealing with the energy sector in a professional manner, energy enterprises, with a focus on the implementation of larger investments in energy generation sources working in the power system.

Total new installed capacity in PV systems created with the support of the above-mentioned systems is shown in Figure 11.

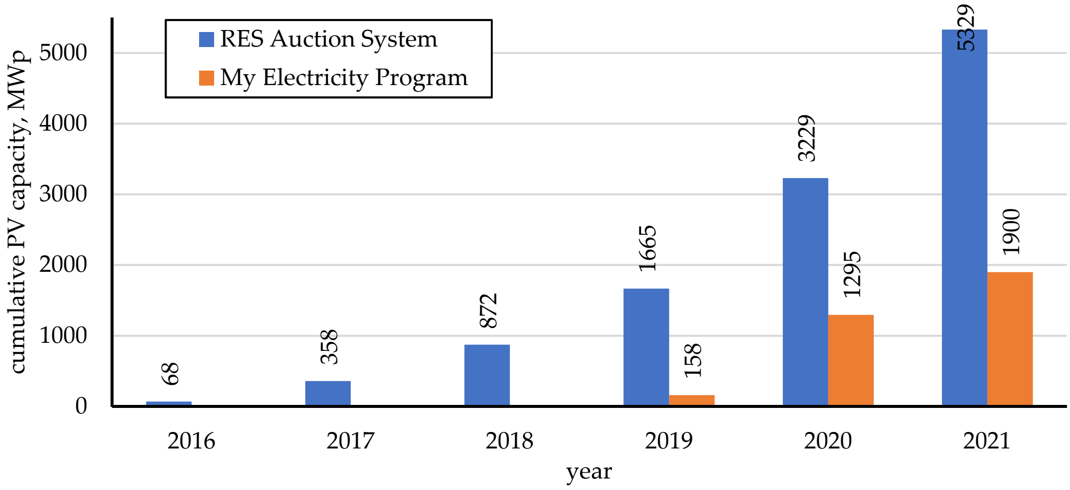

Figure 11. Comparison of the My Electricity Program and the RES auction system—installed capacity cumulatively. Source: own study based on [36].

In the My Electricity Program:

- co-financing amounted to:
- 2019–2020: approx. EUR 195/kWp, i.e., the cost of the subsidy: EUR 6.5/MWh (calculated over 30 years),
- 2021: EUR 130/kWp, which translates to EUR 4.3/MWh for 30 years,
- additionally, tax breaks for investors (households),
- uncertainty of the program's effects in the form of quantitative electricity production
- funds issued by the National Fund for Environmental Protection and Water Management up to six months after the investment,
- support for households—fighting energy poverty.

In the RES auction system:

- the current prices of TGE Base are much higher than the auction prices, which allows the Settlement Administrator to generate additional revenues as a positive balance coverage and, thus, to perform the contract for difference,
- funds settled based on the energy sold,
- the advantage of the system is cheap energy, but it does not bring direct benefits to the recipients, because it goes to the country's power system.

3. Methodology

The implementation or operation of MEP and RAS are related to their costs—assistance for final beneficiaries (the work does not include the costs of operating support programs). MEP is for investment financial assistance in PV and RAS for financial assistance in the sale of electricity in the form of a price guarantee. From the point of view of running programs aimed at leading to the development of photovoltaics in the country at the cheapest cost, MEP and RAS comparison is absolutely justified and can serve as a source of recommendations for decision-makers.

Mainly from the point of view of the government, and in particular the Ministry of Climate and Energy, the current answer to the question of what type of financial aid should be offered for renewable energy (including the PV considered in this paper) will contribute to achieving the objectives of RES participation in the production of energy in the country (which was presented in a broader context in the introduction). This commitment to an appropriate share in the energy produced can be expressed as the cost of the subsidy to energy produced from a given RES source (SDE, EUR/MWh). This was also the adopted economic criterion for comparing both support systems. The years of operation of the support for the auction system, i.e., 15, are assumed as the settlement period. The estimated operating time of the PV installation is longer (about 25–30 years). However, if in both cases (MEP and RAS) we assume that the amount of aid is settled for the same period, it is comparable in this respect. In such a calculation, in both cases (MEP and RAS) the installations will work (produce energy) without financial support after 15 years of operation. In the case of MEP, from the beginning of its existence, there is no control over the amount of energy produced, and in the case of RAS, such control is up to the 15th year of the installation's existence.

The second criterion was the level of financial support for the amount of installed capacity (SDC, million EUR/GWp), calculated with similar assumptions as in the case of SDE.

The auction system is based on a contract for difference in which winning an auction guarantees income at the level of the winning bid for 15 years, indexed annually with the inflation rate.

The market price of electricity sold to the grid, settled in a differential contract, is the average daily electricity price, which is the arithmetic average calculated from the volume-weighted average of trading session electricity prices for all hours of the electricity delivery day (TGE Base), concluded on the market where the exchange session transactions are concluded with the delivery of electricity on the next day and two days after the conclusion of the exchange session transactions.

The payment of the negative balance is made by the Settlement Administrator as the difference between this stock exchange index and the bid for the winning auction. In a situation where the bid of the winning auction is above this ratio, the negative balance is covered and funds flow from the Settlement Administrator to the owner of the renewable energy source installation. In this process, the due state support is paid out.

As mentioned earlier, the essence of this mechanism is based on a contract for difference, in which, when the owner of a renewable energy source sells electricity at the price of the above-described exchange price index, he must return the revenue obtained above the price from the winning auction to the Settlement Administrator. In this process, a positive balance is returned, with the value of the product of the price of energy sold to the grid and the amount of electricity produced and fed into the grid. In this process, the implementation of the contract for difference consists in the payment for the renewable energy source from the operator of the installation to the state, which in this case is represented by the Settlement Administrator. Negative and positive balance settlements are made in the three-year periods of the support system.

The calculation was made considering the weighted average of the results of the auction for PV sources, including the correction for the inflation index, over the period of 15 years of operation of the installation in the support system. The main variable in the simulation, and at the same time the unknown, is the future energy settlement price (TGEB15). The calculation was performed using the following equations:

$$\text{SDE(MEP)} = \frac{\text{sum of dotations, euro}}{\text{MEPE, MWh}} \tag{1}$$

where:

SDE(MEP)—sum of dotations per produced energy for MEP
sum of dotations—Figure 6
MEPE—total energy produced from MEP based on MEP capacity (1900 MWp, Figure 11) and 991 kWh/kWp/year for 30 years from Table 2, Olczak et al. [40]

$$\mathrm{SDE(RAS)} = (\mathrm{RASp} - \mathrm{TGEB15}) \tag{2}$$

where:
SDE(RAS)—sum of dotations per produced energy for MEP
RASp—the mean value of won auctions (EUR 63/MWh) [36]
TGEB15—mean value TGE Base electricity price for 15 years (simulated value), EUR/MWh

$$\mathrm{SDC(MEP)} = \frac{\text{sum of dotations, mln euro}}{\text{total capacity MEP, GWp}} \tag{3}$$

where:
SDC(MEP)—sum of dotations per capacity for MEP
sum of dotations—Figure 6
total capacity MEP—Figure 11.

$$\mathrm{SDC(RAS)} = \frac{(\mathrm{RASp} - \mathrm{TGEB15}) * \mathrm{RASE}}{\text{RAS capacity}} \tag{4}$$

where:
SDC(RAS)—sum of dotations per capacity for RAS
RASp—the weighted mean value of won auctions (EUR 63/MWh) [36]
TGEB15—mean value TGE Base electricity price for 15 years (simulated value), EUR/MWh
RASE—sum of contracted PV energy for 15 years (based on RAS capacity, [36])
RAS capacity—Figures 7 and 11.

In terms of SDE (MEP), a sensitivity analysis was also carried out, as the amount of energy produced in home PV installations is not certain and is not controllable, unlike RAS (settlements for actually produced and delivered energy).

$$\mathrm{SDE}'(\mathrm{MEP}) = \frac{\text{sum of dotations, euro}}{\text{MEPE}\cdot\text{SAI, MWh}} \tag{5}$$

where:
SDE'(MEP)—sum of dotations per produced energy for MEP in sensitivity analyses
sum of dotations—Figure 6
MEPE—total energy produced from MEP based on MEP capacity (1900 MWp, Figure 11) and 991 kWh/kWp/year for 30 years from Table 2, Olczak et al. [40]
SAI = 0.9 (for −10% MEPE) or 1.1 (for +10% MEPE)

Additionally, an analysis of the installed capacity concentration in each province was carried out under both support systems (in 2016–2020). The power density was calculated according to the following formula:

$$\mathrm{PIP(province)} = \frac{\text{total capacity, kWp}}{\text{province surface, km}^2} \tag{6}$$

where:
total capacity—Figure 7 for RAS, Figure 5 from Olczak et al. [40],
province surface—from Table 1—Central Statistical Office [41].

4. Results of Calculations

Considering the above dependencies of the implementation of the contract for difference and the results of the won auction for PV sources and electricity exchange prices, a simulation was carried out, based on which the equilibrium curve between the negative and positive balance presented in Figure 12 was created. This figure shows the equilibrium curve between the negative and positive balance in the RES auction system and also results for MEP (not dependent on electricity price). It indicates, with the value of won auctions, that at the exchange price in the range up to EUR 63/MWh (RASp), a payment of a negative balance will take place. Thus, support will be paid to the owner of the installation. With the exchange price of electricity above EUR 63/MWh (RASp), it will be necessary to return to the Settlement Administrator the revenues obtained above the winning bid. There will, therefore, be a refund of the positive balance.

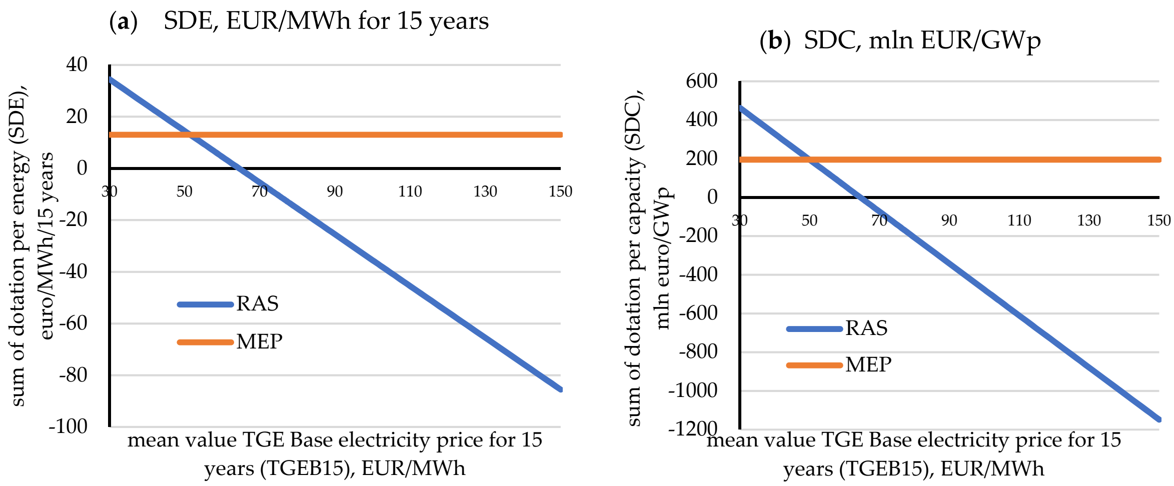

Figure 12. The balance curve between the negative and positive balance (RAS) compared to the My Electricity Program: (**a**) converted into the amount of energy produced for 15 years—SDE, (**b**) converted into installed capacity (GWp)—SDC.

Although the MEP is not price dependent, it was advisable to plot the results (in the form of SDE and SDC) for the MEP to show the intersection between the MEP and RAS curves, i.e., at a price of around EUR 51.8/MWh.

$$\text{SDE(RAS)} = 0 \text{ for TGEB15} = \text{RASp} = \text{EUR } 63/\text{MWh}.$$

$$\text{SDC(RAS)} = 0 \text{ for TGEB15} = \text{RASp} = \text{EUR } 63/\text{MWh}.$$

As part of the sensitivity analysis, a different productivity of the installations created under the MEP was calculated: the cases of reduced productivity, with respect to the assumed, by 10% and increased by 10% were considered (Figure 13a,b). As a result of this simulation, the level of SDE′ subsidy was obtained in the range of EUR 11.8–14.4/MWh/15 years. The point of intersection between the RAS and MEP lines is EUR 50/MWh and EUR 53/MWh, respectively.

The implementation of these support programs also resulted in various developments in the geographical areas of Poland, which are presented in the figure below (Figure 14) as the installation capacity density broken down by voivodeships. In the My Electricity Program, the leaders are in the Silesian and Lesser Poland voivodeships, while in the auction support system the enterprises in the Lubusz and Greater Poland voivodeships are the most active.

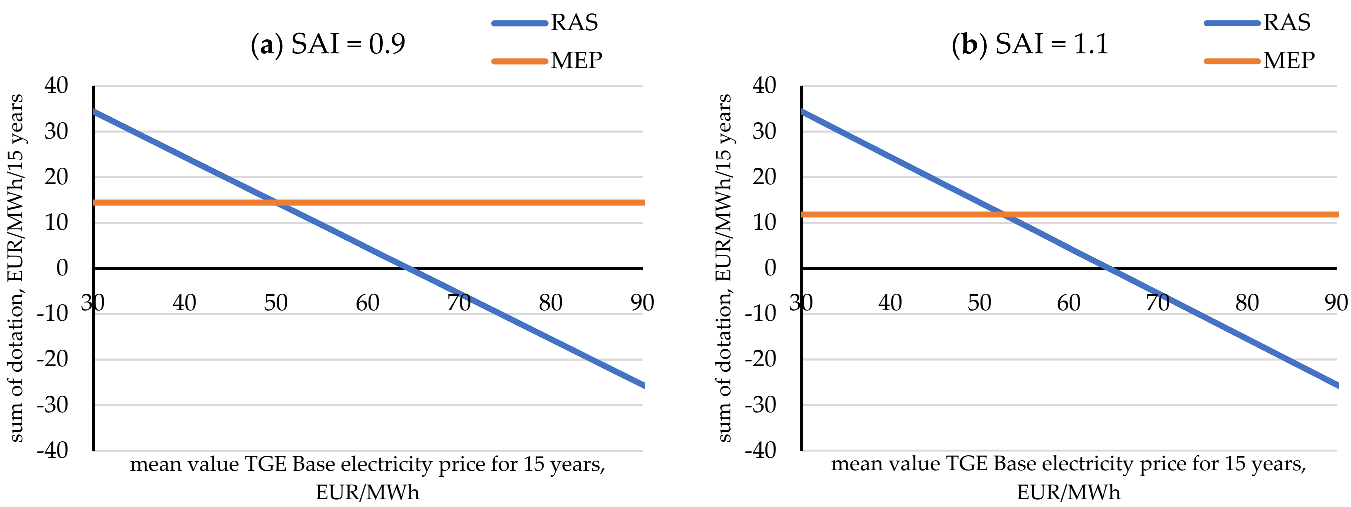

Figure 13. The balance curve between the negative and positive balance (RAS) compared to the My Electricity Program—sensitivity analyses for SDE: (**a**) SAI = 0.9: MEPE −10%; (**b**) SAI = 1.1: MEPE +10%.

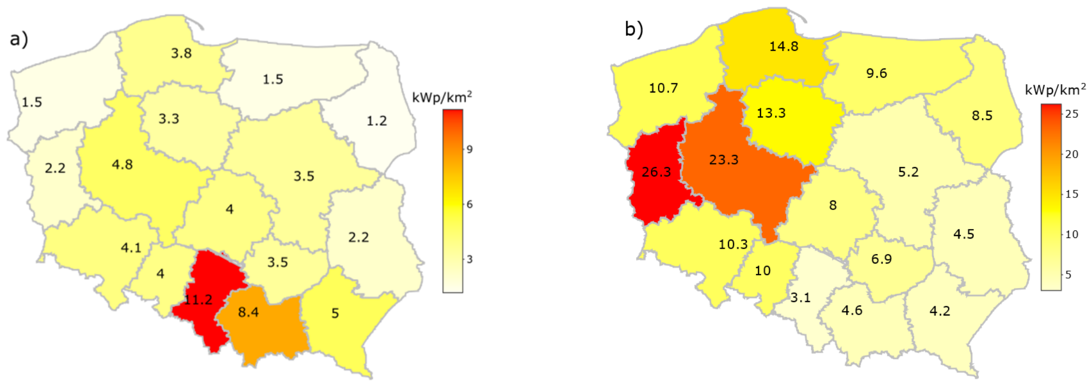

Figure 14. Concentration of PV installation capacity (PIP, kWp/km^2) presented by provinces: (**a**) My Electricity Program; (**b**) RES auction system.

5. Conclusions

Poland has great potential for the development of renewable energy sources. The implementation of support systems dedicated to renewable sources to date has led to the installation of over 10,500 MW of installed capacity, as of 30 June 2021. These sources generate about 20 TWh of electricity per year. The PV sources alone have over 6000 MW of installed capacity today.

At present, with high electricity prices, stimulated by the costs of carbon dioxide emissions and the costs of fuel purchase, renewable energy sources are of particular importance in the transformation of the Polish power industry. Additionally, the decreasing LCOE costs of PV technology have a particular impact on the position of these sources in the energy mix.

The RES auction system contributed to the creation of approx. 5 GWp of installed capacity of PV sources in 2016–2021. Many investments, distributed in the RES auction system, especially in recent years, are still under implementation. It should be mentioned that the investor in the RES auction system has two years to install and sell electricity to the grid for the first time. The power values presented in this study are based on data as of October 2021.

In the RES auction system, due to the price relations of TGE Base and the prices from the won auctions, a payment of a positive balance may take place and the settlement of the contract for difference. These pricing relationships and these rules may make the Settlement Manager the biggest beneficiary of this system.

Investors in the auction system, by winning, are guaranteed a certain stable income at the level of the winning bid, corrected by the inflation rate. This was often an important condition when financing an investment. However, the RES auction system prevents them from using the additional revenues generated today by the price of electricity on the market above the winning bid.

The price relations of the energy market and the level of won auctions lead today to the development of new business models for the construction of new PV source installations. Perhaps in the near future, the current popularity of the RES auction system will change in favor of the PPA—Purchase Power Agreement formula.

The My Electricity Program contributed to the creation of approx. 2 GWp of installed capacity in PV installations in 2019–2021. The total cost of the program on the part of the state is approx. EUR 390 million in direct subsidies and additional tax breaks for prosumers. The unit value of the subsidy to the My Electricity Program is EUR 195 million for 1 GWp, which, at the current energy prices on the POLPX, stands in opposition to the negative value of the subsidy for the RES auction system (i.e., potential program beneficiaries pay for participation in the auction system instead of receiving support).

In terms of the main criterion considered in this paper, i.e., economic (the lowest cost of state budget support) at the current energy prices (over EUR 150/MWh), the auction system is undoubtedly the best support program. Only a decrease in the energy price below EUR 52/MWh will bring the costs of both programs into line with the current prices. Currently, the operation of RAS (in the field of PV) amounts to approximately EUR 100/MWh of revenues to the state budget from RES support (the state benefits from RES energy production instead of subsidizing it). The main reason for this is the difference between the current energy prices and the prices of won auctions, based on the current LCOE values for PV.

In terms of fighting energy poverty, the MEP is a much better solution for support programs.

The My Electricity Program contributed to the incentive of individual energy consumers in the process of generating electricity in PV installations. Households (natural persons) were the largest beneficiaries of the program.

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