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Direction of Changes in the Settlements for Prosumers of Photovoltaic Micro-Installations: The Example of Poland as the Economy in Transition in the European Union

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Abstract: The implemented climate policy and the current geopolitical situation make us pay special attention to energy independence, both in the household and in the national dimension. One way to obtain inexpensive and environmentally friendly energy is the development of photovoltaic micro-installations. For positive changes to occur, correct state regulation and an appropriate set of administrative and economic instruments are necessary. The purpose of this article is to discuss changes in the accounting system for renewable energy prosumers and their consequences for the further development of renewable energy. The financial settlement methods favorable to prosumers were recently replaced with new solutions. According to the authors, this slows down the energy transformation.

Keywords: renewable energy; photovoltaics; prosumers; financial settlement methods; energy transformation

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1. Introduction

Widespread interest in energy development in Poland has been growing for many months. The reasons for the enduring popularity of the issues addressed in this article include growing barriers to obtaining domestic conventional energy carriers [1,2], the EU's consistent energy policy and today's energy crisis.

A natural response for a significant part of the population to emerging energy problems is the desire to acquire photovoltaic micro-installations [3,4]. At the household level, such an investment should reduce energy needs and lower current electricity expenses, primarily in the spring and summer ([5], p. 6). For the electricity system operator, acquiring clean energy provides an opportunity to meet obligations for the share of RESs in the energy balance. With the development of RESs, there will be a reduction in household and industrial energy prices ([6], p. 10) and an improvement in the international competitiveness of the national economy [7].

It also allows for reducing expenses in the purchase of greenhouse gas emission allowances. The environmental, social and political dimensions of RES investment are also important. Increasing the production of clean energy contributes to reducing the demand for fossil energy carriers and becoming independent from imported energy resources.

In the current geopolitical situation, this ties in with improved global security [8]. For there to be an increase in the share of RESs in the energy balance, it is important not only to increase the environmental awareness of society, but it is also necessary to implement an adequate set of administrative and economic instruments. This article discusses changes in the way renewable energy prosumers are billed and the implications of these changes for the further development of RESs in Poland.

Energy transformation means a fundamental change in the structure of primary energy consumption because of the increased use of renewable energy. This includes solar energy, wind energy, hydropower and energy generated from waste. The EU's economic policy in this area from 2019 is referred to as the European Green Deal. The name comes from the Green New Deal concept planned in the UK as part of the fight against the financial crisis in 2008 (President F.D. Roosevelt introduced the New Deal slogan in the 1930s).

The aim of the European Green Deal is to achieve zero greenhouse gas emissions by 2050 ([9], p. 2). An essential step in the decarbonization of the EU economy will be a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 ([9], p. 5). The strategy also calls for a significant reduction in fossil fuel consumption, an increase in the share of RES to 32% [10] and the expansion of smart transmission infrastructure ([9], p. 7). It is also necessary to improve the energy efficiency of economic processes and save energy [11]. The measures taken should contribute to the achievement of the climate goals of the Paris Agreement. This document calls for keeping the global temperature increase below 2 °C. In addition, the temperature increase should be limited to 1.5 °C compared to pre-industrial times ([12], no. 2). A commitment to deepen cooperation in the pursuit of a low-carbon, climate-resilient world was adopted by countries, including Poland, participating in COP24 in Katowice [13].

The problem of excessive human interference with the environment is not new. Already in the past, problems of scarcity and waste of resources such as forests, water and food led to the collapse of earlier civilizations [14]. The scenario described is becoming real again. The scarcity of natural resources and the limited assimilative capacity of the environment could start the catastrophe of the modern globalized society. Increasingly, access to non-renewable resources, especially water and energy carriers, is a source of conflict in the world [1].

In Poland, however, the coal lobby enjoys unwavering support from policymakers. This is reflected in the country's energy policy [15,16]. The maintenance of the dominant position of fossil fuels in the energy mix and the delay in the development of RESs are explained by historical conditions and the need for a just transition. It sets different targets for the energy transition by 2030 than in other EU countries: (a) reducing GHG emissions by 30% compared to 1990; (b) increasing the share of RESs in gross final energy consumption to 23%; and (c) increasing energy efficiency (reducing primary energy consumption) by 23% by 2030 ([17], p. 7). The Strategy for Responsible Development, which is in effect today, corresponds with the presented approach. According to this document, "Poland should remain sovereign in energy supply. Energy generation sources based on domestic energy resources must ensure uninterrupted and competitive energy supply for consumers. Therefore, coal will continue to be an important fuel for the electric power industry in the 2050 horizon" ([18], no. 260) [19].

In Western Europe, the approach to the energy transition differs from that in Poland. Here, coal, like nuclear power, is treated as a transitional solution. For example, the extension of three nuclear power plants in Germany until 15 April 2023 [20] is related to the conflict in Ukraine. This step should fill in the security and reliability of the system for supplying the economy with electricity [21]. There are still legal impediments hindering the development of RES-based energy in Poland [22]. This applies, for example, to the legal rules for building wind power plants. Today, in Poland, the share of RESs in the acquisition and consumption of total primary energy reaches only 14–15%, while in the EU, this indicator is approximately 30%, and in some European countries, it is even 50–75%. High RES participation rates in the EU are due not only to natural conditions (e.g., mountain rivers abundant in water) but also primarily to implementing appropriate economic policies.

2. Review of the Literature on the Transformation to RESs in Poland

The literature on Poland's energy transition is rich. Let us now cite a few review items of high merit. Popczyk outlines a vision for the Polish energy sector until 2050 and

discusses the crisis of large-scale power generation and the potential for reconstruction towards distributed energy (OSG) ([23], p. 195). Rosenkranz states that the end of the era of solid fuels and the beginning of the era of renewable energy is now an accomplished fact. We should consider decentralized energy today as the energy of the future ([24], p. 74). Ehrenhalt discusses the directions for the transformation of the Polish energy industry. He also raises the potential of renewable energy, referring, among others, to the German experience ([25], pp. 88–103). Młynarski [26] points to the links between the energy transition and the EU climate policy. He also assesses the role of RESs in the development of the green economy ([26], pp. 31–44). Ceglarz [27] also addressed the Polish energy policy. This author reviews key information on energy in Poland. In addition, he touches on selected energy policy planning issues, including achieving climate neutrality by 2050 ([27], p. 23).

There are also publications on the problem of the foreseeable electricity deficit. Tokarski et al. [28] analyze three likely scenarios for bridging this deficit in 2031–2040. The authors estimate its amount at 3000 MW of power and 20 billion kWh of electricity production ([28], p. 9). They have also focused on the social dimension of distributed energy development. Worek et al. [29] presented a study on the requirements to be placed on designers and builders of distributed energy facilities. These authors further introduced the concept of "fair energy transition" ([29], pp. 105–119). Tatarkiewicz et al. write about the transformation of the energy sector in Poland and the EU by 2050 [30] They analyze four scenarios: 60% GHG reduction in 1990–2050 (BASE), neutrality (NEU, 90% reduction), neutrality with high fossil fuel prices (NEU_HPRICE) and neutrality with lower potential for offshore wind farm development (NEU_LWIND).

Tatarkiewicz et al. ([30], p. 60) and Ehrenhalt ([31], p. 37) analyzed the transformation of the Polish and EU energy sectors by 2050. The latter also discusses the European development goals in the new economic and climate order. In addition, he touches on new European regulations on energy and heating and discusses Poland's negotiations on climate neutrality. Ehrenhalt devotes considerable attention to the basic assumptions of the Fit for 55 packages (reducing emissions by at least 55% between 1990 and 2030). Graczyk et al. ([32], p. 29) discuss pro-environmental energy attitudes toward RES investments over the past few years. Kurz & Nowak [33] analyze the impact of the level of self-consumption of electricity from a prosumer photovoltaic installation on its profitability. They completed this by considering several energy billing scenarios in Poland. These authors provided their own comments on Polish legislation regarding the use of renewable energy sources. In addition, they analyzed the Polish billing system for electricity produced by individual prosumers ([33], p. 34).

Tomecki [34] reflects on the right strategy for the energy transition. The current shape of the energy market is not suited to the energy transition. Among the most important problems to be solved, he identifies the intermittency and instability of renewable energy generation; the need for investment in renewable energy sources to fill the stability of supply (when the wind is not blowing and the sun is out); the need to recover the fixed costs of investment in renewable energy generation; supporting increasing consumer participation and greater use of the potential of distributed energy resources; improving energy efficiency; and designing a system to support the most vulnerable consumers in energy poverty. Tomecki emphasises that the energy transition process will take several decades [34].

In the review of the Polish literature, it is worth mentioning two collective works on energy transition issues. Nowak et al. [35] discuss topics related to possible energy transition strategies and the energy and climate policy transitions required for this [35]. This work is an important contribution to the discussion on the model and challenges in the transition in the EU and Poland. Całus et al. [36] present a broad spectrum of opportunities and horizons for innovation in the energy sector. The authors address issues such as support schemes in the energy transition, the role of emissions trading schemes, solar energy storage, the future of electric cars and the safety of photovoltaic systems [36].

3. The Research and Its Method

The authors of this article identify the main directions of RES changes that have occurred in the Polish economy. Prosumers and their role in this process were considered. The choice of Poland was based on the fact that its economy is one of the largest (in terms of population and territorial area) among the transforming economies that joined the EU structures in 2004. The analysis of Poland's economy, in the EU policy on energy security and access to diversified energy resources, is therefore fully justified substantively and strategically.

The current stage of Poland's energy transition in terms of decarbonization of the economy reflects significant progress in reducing total greenhouse gas emissions promoted by the EU. Poland has seen a reduction in emissions by over 20% compared to 1990. However, the current dominance of coal in Poland's energy mix is increasing the cost of such a transition. The authors have thus given attention to the desired direction of energy development based on low-carbon or zero-carbon RESs. In addition, this comes with specific problems of energy storage, grid flexibility and distribution or transmission systems.

The basic research method used by the authors was an analysis and critique of the Polish and foreign literature and databases on the subject (Google Scholar, Science Direct, BazEkon, Emerald, Oxford Academic, Scopus, EUR-Lex). The authors completed the following stages in this study:

- Generating information using keywords (renewable energy, photovoltaics, prosumers), and searching scientific databases.
- Collection and selection of information from scientific publications.
- Coding by subject (energy transition, RESs) and time (publication date of articles, monographs and other scientific papers).
- Organizing the information and listing separate research areas within it including (a) the transition to RESs—challenges and dilemmas, (b) the beginnings of the development of photovoltaic micro-installations, and (c) legislative changes regarding RESs in Poland and their significance for the energy transition of the economy.
- Analyzing and drawing conclusions.

Considering the existing typology of scientific research, it is worth emphasizing: (a) the theoretical and cognitive nature of the present research base, among others, on deductive reasoning and methods adopted in empirical sciences and (b) the limitation of the research on energy transition, with particular emphasis on the transition towards RESs.

The adopted research method identified 82 bibliographic items. The authors relate the limitations in this study to the restricted use of the selected databases (so, publications outside these databases were not included). The number of citations of the publications and the recognition of these databases in the scientific community dictated the choice to use them.

We adopted the following research objectives:

- Main objective (MO). Discuss changes in the way of accounting for renewable energy and their consequences for the further development of renewable energy.
- Specific objective (SO1). A literature analysis summarizing the key challenges and dilemmas in the energy transition towards RESs.
- Specific objective (SO2). An indication of the scope and nature of the changes concerning RESs (as an integral component in the energy transition of the economy) in Polish law, with particular emphasis on prosumers.
- Specific objective (SO3). To develop conclusions and recommendations related to the energy transition towards RESs (in terms of ways to account for prosumers).

This study makes the following assumption: new legislative solutions have replaced favorable billing methods for prosumers. This may weaken the interest in investments in photovoltaic micro-installations, slowing down the energy transition in Poland.

The added value of this study lies in (a) a synthetic presentation of the current state of knowledge, challenges and dilemmas related to Poland's energy transition towards RESs and (b) a presentation of conclusions and specific recommendations for the actual implementation of sustainable development in the economy. This is important for reducing the consumption of non-renewable resources.

4. Beginnings of the Dissemination of Photovoltaic Micro-Installations

The dissemination of photovoltaic (PV) micro-installations has been going on since the beginning of the XXI century. Before that, the phenomenon of converting solar energy (light) into electricity was used narrowly, for example, in scientific research or in consumer electronics (e.g., in calculators, where the power requirement rarely exceeded 10–3W). Only state interventionism allowed this innovative and extremely useful technology to come out of the closed circle: "no demand—no mass production—high manufacturing prices—little product innovation—no market".

The first program to support investment in PV micro-installations was implemented in Germany in the early 1990s. The construction of 2200 PV installations was subsidized. They launched a similar program in 1994 in Japan. Between 2000 and 2003, another program was implemented in Germany. It provided for the construction of installations with a total capacity of 300 MW. The program involved supporting investors with an interest-free loan and a 12.5% subsidy [37]. The increase in demand and the scale of production of PV panels resulted in a decrease in the cost of their production, improved efficiency, a decrease in prices and an increased interest in the technology (Figure 1).

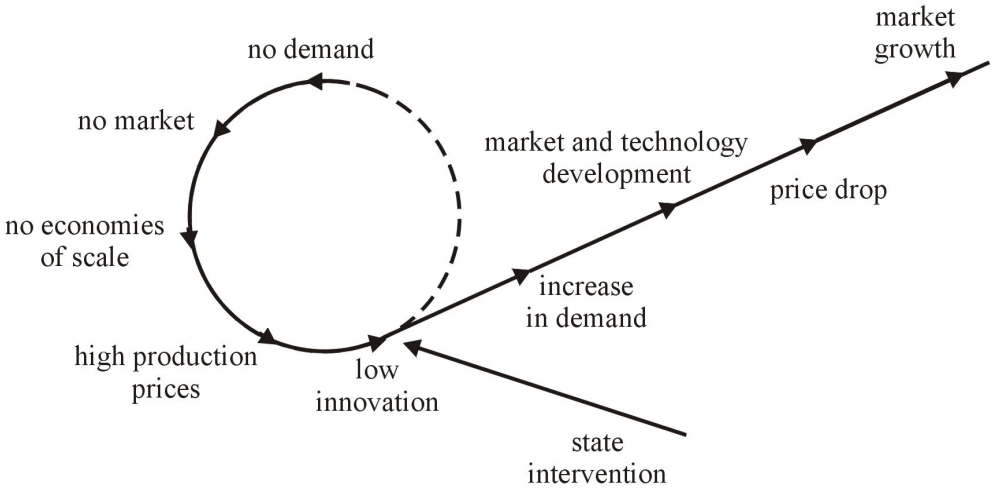

Figure 1. The unreliability of the early photovoltaic market and the effects of state intervention. Source: author's own work.

In Poland, the dissemination of PV micro-installations began later than in the countries mentioned above [38,39]. At the beginning of this century, energy policy here was based on the following pillars [40]:

- State energy, which is not subject to free market rules.
- Energy based on fossil fuels (primarily coal), which is non-innovative and different from the energy preferred in the EU.
- Inexpensive energy offered to state-owned enterprises.
- Overestimation of energy demand and underestimation of energy production and distribution costs.

At the beginning of the second decade of the 21st century, the number of PV micro-installations operating in Poland was negligible. Only a few of them were connected to the grid. As a result, the share of solar energy in the production of electricity from renewable energy carriers between 2010 and 2014 was very low. At the end of 2012, there were

139 installations with an average unit capacity of 3 kW [41]. Legal regulations were an obstacle. They required the prosumer to obtain a license to give energy to the distribution grid. The unfavorable economic calculus associated with the inability to return unused electricity to the state grid [41–43] also compounded difficulties.

5. Positive Legislative Changes in Poland's Energy Transition toward RESs

The situation improved with the gradual implementation of the European Parliament's directive on promoting the use of energy from renewable sources. According to this document, by 2020, the share of energy from RESs in gross energy consumption in Poland was to be 15%, with the EU average at 20% [43]. Another directive introduced a common cap on greenhouse gas emissions in place of national limits. Starting in 2013, it reduced the number of EU allowances issued by 1.74% per year [44]. These changes gave hope for an increased interest in green energy from the commercial power industry.

The RES law passed in 2015 imposed an obligation on the seller to purchase energy from a renewable source for 15 years. This involved hydropower, onshore wind energy and solar energy from micro-installations. In the power range below 3 kW, the price of energy was to be PLN 0.75/kWh. In the 3–10 kW power range—PLN 0.65 [45]. The feed-in tariff (FiT), which was favorable to prosumers, was to be applied for 15 years counting from commissioning the installation, but no longer than until the end of 2035. The financially supported regulations have resulted in an increased interest in photovoltaics in Poland. In 2016, electricity production from PV installations increased (compared to 2014) by almost 18 times (to 123.9 GWh). The share of photovoltaics in the production of electricity from RESs also increased from almost 0% to 0.54% in 2016 and to 6.94% in 2020 (Table 1).

Table 1. Electricity production from RESs between 2011 and 2020 in Poland.

Itemization	Electricity Production from RESs in GWh		Share of Photovoltaics in Production (%)
	Total	Including Photovoltaics	
2011	13,137.00	0	0
2012	16,879.00	1.1	0.01
2013	17,066.50	1.5	0.01
2014	19,841.80	6.9	0.03
2015	22,684.10	56.6	0.25
2016	22,807.40	123.9	0.54
2017	24,122.10	165.5	0.69
2018	21,617.20	300.5	1.39
2019	25,458.80	710.7	2.79
2020	28,226.60	1957.9	6.94

Source: author's work based on Statistics Poland [46–49].

Despite the relatively high rate of development in PV micro-installations, the share of solar energy in obtaining renewable energy in Poland remains significantly lower than in other EU countries (Table 2). As early as 2014, in 30 countries of the world, PV micro-installations allowed generating energy at prices lower than those offered by the public supplier [40]. To maintain the positive trend in building new PV micro-installations, the existing preferential billing of prosumers had to be guaranteed.

Table 2. Structure of solar energy acquisition in EU countries from 2016 to 2019.

Itemization	2016	2017	2018	2019
	%			
Lithuania	0.4	0.4	0.4	0.5
Poland	0.7	0.7	0.7	1.1
Austria	2.8	2.9	3.1	3.2
Czech Republic	4.5	4.6	4.8	4.4
Netherlands	3.4	3.9	6.1	7.8
Germany	9.9	9.6	10.8	10.3
EU-28	6.2	6.4	6.4	6.7

Source: author's work based on Statistics Poland [48,49].

As one can see from the above table, Germany (up from 9.9% in 2016 to 10.8% in 2020) and the Netherlands (from 3.4% in 2016 to 10.8% in 2020) accounted for the largest share of solar energy acquisition in the period under review. Poland's share, compared to the Czech Republic and Slovakia, remains relatively low (up from 0.7% in 2016 to 2.0% in 2020). During the period under review, these three countries, which have relatively recently undergone a systemic transformation, have seen rapid growth in the share of RESs in final energy consumption. While the average increase in the EU over the same period was 1.5 p.p., it was 3.6 p.p. in the Czech Republic, 4.1 p.p. in Poland and 5.4 p.p. in Slovakia.

6. Prosumer Billing for PV Micro-Installations in Poland and Its Impact on RES Development: From Net Metering to Net Billing

The Renewable Energy Act of 2016 repealed favorable regulations. A quantitative system replaced the FiT tariff for settlements between the prosumer and the energy seller (net-metering) [50]. Under this law, the electricity seller was required to settle the electricity introduced by the prosumer into the electricity grid against the amount of electricity taken from the grid in a ratio of 1 to 0.7. However, for micro-installations with a total installed capacity of up to 10 kW, the ratio was 1 to 0.8 [50]. From the point of view of the development of micro-installations, the novelty of the law was the increase in the maximum power of photovoltaic systems covered by preferences to 40 kW.

The Law on Investment in Wind Power Plants has exacerbated problems with the development of RESs in Poland [50]. In particular, regulations on the minimum distances of wind installations from residential buildings raise doubts. According to the law, the distance from residential buildings and from nature conservation sites, where one can build a wind power plant, should not be less than ten times the height of the plant. This refers to the measured height from the ground to its highest point. Similar regulations, because of the dispersed nature of development in Poland, have limited the possibility of locating wind power plants to 2.5% of the entire country's area [51].

Problems with meeting the EU target for the share of RESs in gross final energy consumption were resolved by correcting the method for calculating the number of biofuels. This was primarily about the wood used in fireplaces, cookstoves or stoves. The 2018 figures for household consumption of solid biofuels were revised upward. Despite the poor performance in 2017 (11.06% of the RES share), in the following years, the RES share rate in gross energy consumption reached 16.13% in 2020 [49,52,53]. The stated goal was thus met.

Immediately after implementing net metering, investment in PV micro-installations slowed down. However, rising energy prices caused a resurgence in interest in PV. As of 2018, the rate of growth in solar energy production exceeded even 50% per year. Maintaining the direct subsidy system and the 15-year net metering billing period gives prosumers a sense of stability, even with global energy problems.

7. A Step Backward in the Development of Photovoltaic Micro-Installations

Subsequent amendments to the Renewable Energy Act introduced new solutions for value-based billing of energy produced by the prosumer (net billing) as of 1 April 2022. Existing prosumers and all those who have applied to the Distribution Grid Operator for the connection of a micro-installation to the grid by 31 March 2022 kept the right to net metering billing for 15 years [54].

Settlement according to net metering obliges the prosumer to pay both for the energy taken from the grid and for its distribution, i.e., to pay a fixed and variable transmission fee. The price of energy released to the grid is determined based on quotes from the Day-Ahead Market (TGE). However, energy prices on the TGE are highly volatile daily and monthly. The weighted average prices for individual hours in August 2022 ranged from PLN 910.21 to 2368.54/MWh ([55], p. 4). The lowest prices were during the day when PV energy production was highest. In contrast, the highest energy price applies to the evening peak. We can observe a similar pattern on a monthly basis. The energy produced and returned to the grid in the summer months is much cheaper than that drawn from the grid in the winter months. A prosumer billed according to net billing will pay a higher price for energy than the selling price of the energy he or she produces. The legislator has provided for three stages in introducing the new billing method ([54], art. 1, no. 4 and 5):

- From 1 April to 30 June 2022, the government will bill prosumers according to net-metering rules.
- From 1 July 2022 to 30 June 2024, for producing energy billed according to net metering, the previous month's weighted average prices determined in the Day-Ahead Market will apply.
- As of 1 July 2024, the value of energy returned to the grid will be determined based on hourly rates.

Introducing transition periods has a significant impact on the cost-effectiveness of PV micro-installation production, primarily in Phase II of implementation. The adoption of monthly weighted average prices mitigates the daily variability observed in the TGE. As a result, the price of energy fed into the grid is higher than it would be based on hourly rates. The weighted average price of energy in August 2022 was PLN 1245.46/MWh ([55], p. 4). In addition, under the conditions of periodic operation in the "anti-inflation shields" and officially set prices, electricity rates plus distribution fees are often lower for households than in the exchange. The latter are the prices at which the prosumer resells the energy produced.

Full implementation of *net billing* and billing the prosumer according to hourly rates will reverse the observed phenomenon. In special cases (in exceptionally favorable weather, when RES production is high, on holidays or non-working days, when demand for energy is lower) the prosumer will give energy to the grid without compensation or at a price close to zero. The purchase of energy will be performed based on applicable tariffs. The described scenario, which even the legislature has recognized [54], will have a significant impact on the profitability of investments in PV micro-installations. Anti-crisis measures taken and the prevailing preferences in energy purchases are unlikely to last for the long term. Governments will eventually have to take care of budget revenues and abandon central control of energy prices. Thus, unless the current way prosumers are billed is changed, the profitability of photovoltaic investments in Poland could be slashed.

The unfavorable regulatory changes described above immediately resulted in a weakened interest in photovoltaics. As recently as April 2022, a record 93.6 thousand installations were connected to the grid. By May 2022, it was only 23.4 thousand installations. A similar trend was observed in the following months (Figure 2). It is worth noting that in June and July 2022, projects were being completed, which had already been notified before the change in legislation, and for which the more favorable net metering will still apply. Thus, a further decrease in the rate of connection of new PV micro-installations to the grid can be expected in the coming months.

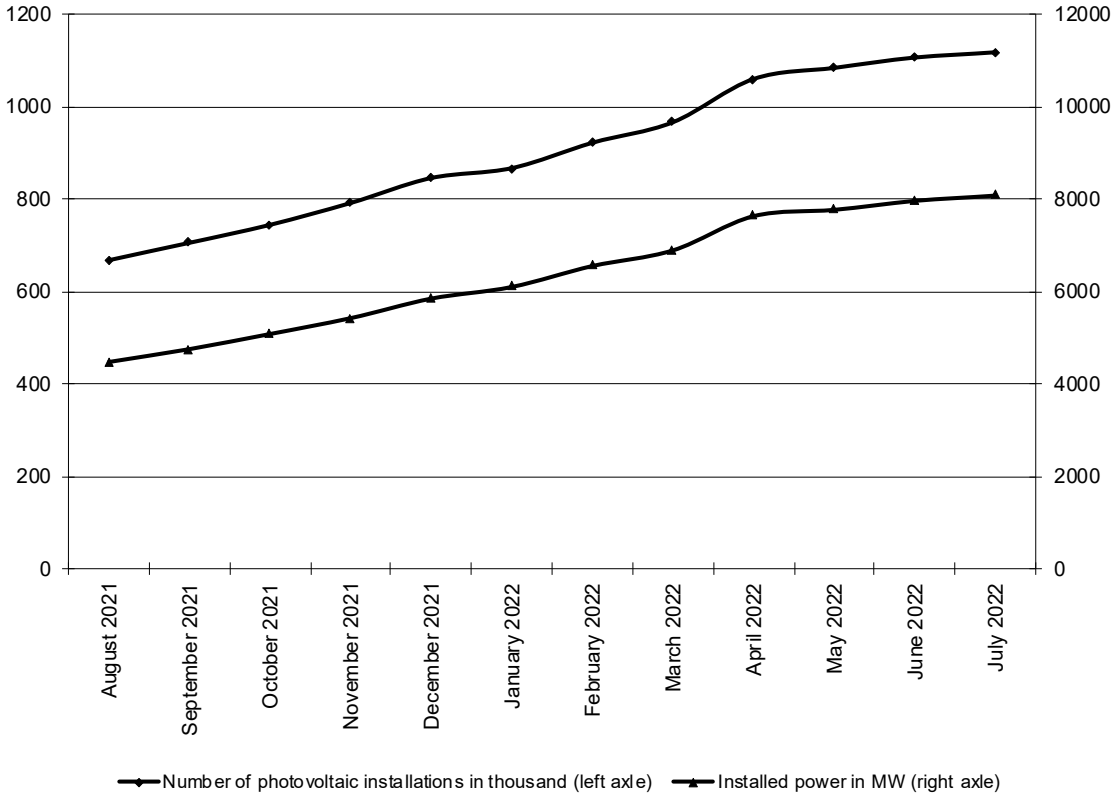

Figure 2. Number (thsnd) of photovoltaic installations in Poland and their capacity from August 2021 to July 2022. Source: author's work based on Energy Market Agency [56,57].

The decline in interest in photovoltaics is also confirmed by the number of people (entities) applying for subsidies to the National Fund for Environmental Protection and Water Management. In the 3rd edition of the Mój Prąd (*Eng.* My Current) Program, the Fund accepted up to 4000 applications per day. After a month from the start of the call, the number of submitted documents exceeded 85,000 [58]. In contrast, during the 4th edition of the Program, which was launched after the legislative changes, only 821 applications were accepted in the first month [59]. In addition, photovoltaics has not been included in the smart development specializations of Polish regions, which results in much more difficult access to ERDF co-financing through operational programs at the regional level [60]. The lack of co-financing of RES-smart specializations weakens the innovation potential of the Polish energy sector, especially related to improving the efficiency and effectiveness of renewable energy generation [61].

8. Conclusions and Indications

For several years, there has been renewed discussion in Poland about the need to reduce the role of conventional power generation. Despite appeals from environmentalists, engineers and economists, the expected modification to regulations on the construction of wind power plants has not occurred [50]. Instead, the way prosumers who generate electricity in PV micro-installations are billed has been changed to their disadvantage. There are proposed amendments to the program for the construction of a nuclear power plant in Poland and the development of offshore wind energy (OWE). However, neither of the two initiatives mentioned has been implemented as of today. The OWE project, which should serve as an alternative to onshore wind power, received a critical assessment in a report by Poland's Najwyższa Izba Kontroli (*Eng.* Supreme Audit Office) (the country's supreme and independent state audit body). The document indicated, among others, the lack of procedures that would accelerate the development of the OWE sector, delays in indicating the location for the construction of the installation terminal and risks associated with

financing the investment. The authors of the report concluded that "it seems unrealistic at present to realize the strategic project assumption that the first offshore wind farm will be included in the electricity balance around 2024/2025" [52].

The optimization of the institutional in the economy, in particular in the energy sector, is currently acquiring importance in Poland [62]. An essential element of governance in supporting RES development is the state energy policy. Poland's energy policy today does not provide for a significant increase in onshore wind capacity by 2040 ([63], item 264). Instead of the desired development in RESs today, the strategy for promoting conventional energy is being implemented. In response to the increase in the price of fossil energy carriers, a system of subsidies for the purchase of coal was introduced [64]. Laws freezing electricity and gas prices for selected households were prepared as part of the "solidarity shield" (*Pol.* tarcza solidarnościowa). Faced with the cessation of coal imports from Russia, suppliers of the raw material are being sought in Colombia, Mozambique, South Africa and Australia. By the end of 2022, the Narodowa Agencja Bezpieczeństwa Energetycznego (*Eng.* National Energy Security Agency) (NABE) will take over coal assets from energy groups ([65], p. 43). The planned transformation is essentially a bailout of the coal-based energy sector with public money.

One argument against the development of RESs (including photovoltaics) is the negative impact of the increasing number of micro-installations on the operation of transmission networks. As studies confirm, photovoltaic farms randomly affect the parameters of electricity in the grid. This is because it is difficult to match weather with the economy's energy demand, which can negatively affect the operator's power balancing ([66], p. 332). However, one should keep in mind the positive aspects of PV micro-installation operation. These include a reduction in power and energy losses in the grid, a decrease in currents in cable lines and a reduction in voltage drops at substations ([66], p. 332). Moreover, to reduce the undesirable impact of photovoltaics on the grid, it is unnecessary to block its further development. An effective solution would be to modernize the transmission infrastructure, such as increasing transformer power and line conductor cross sections ([67], p. 39). Improvements in grid quality parameters can also be implemented on the prosumer side. This is actually happening. To prevent an excessive increase in grid voltage, the inverter automatically shuts down. The device will turn on again when the grid parameters return to normal, i.e., to a voltage below 253 V [68]. It is also possible to install energy storage facilities that store the surplus energy produced [69].

Is it possible to modernize the grid and control the operation of inverters (generators) in such a way to increase the share of photovoltaics in the balance of electricity in Poland? The German experience shows that this is quite possible. In 2021, PV power plants generated 51 TWh of energy in that country. This represents a 9.1% share of Germany's gross energy demand. In 2021, the types of RESs had a 42.4% share ([70], p. 6). By the end of 2030, the share of RESs is expected to reach as much as 80% in meeting electricity demand. In order for the aim to be achieved, solar-based energy should be further developed ([71], pp. 4–7). In Poland, the situation is different. The share of photovoltaics in electricity production in 2021 was 2.14% (3.8 TWh) and in RESs was 16.9% (30.4 TWh) ([54], pp. 16–17). A comparison of Poland's and Germany's achievements clearly shows that the dynamic development in RESs, including PV power plants, is still possible in Poland.

Even a simplified economic and environmental calculation confirms that the development of photovoltaics is the proper answer to the problems in the Polish power industry. Let us assume a calorific value for hard coal of 21.24 MJ/kg ([72], p. 5), a net efficiency in electricity generation ηn = 40% and the number of losses resulting from the transmission and distribution of electricity $\Delta E\%$ = 5.5% ([73], p. 22). Here, from 1 kg of hard coal consumed at the power plant, the end consumer will receive 2.23 kWh of electricity. Doubling the existing photovoltaic electricity production (an additional 3.8 TWh) ([57], p. 14) would mean reducing the consumption of scarce hard coal in power plants by about 1.7 million tons. It is worth mentioning that the average price of CIF ARA coal was about EUR 330/t

in the first half of September 2022, so the direct savings would amount to EUR 561 million per year (the CIF ARA index determines the price of thermal coal with a calorific value of about 25 MJ/kg, a sulfur content of only 1% and an ash content of only 16%, under the terms: Cost, Insurance and Freight at the ports of Amsterdam–Rotterdam–Antwerp). If one assumes a CO_2 emission rate from hard coal of 93.54 kg/GJ ([72], p. 5), then burning 1.7 million tons of coal means emitting 3.38 million CO_2. Here, power plants will incur EU ETS fee of EUR 271.4 million (the weighted average transaction price in July 2022 was EUR 80.29/EUA ([74], p. 1)). Reducing coal combustion will reduce emissions of SO_x, NO_x, CO, PM10 and PM2.5 particulate matter, which will significantly improve the surrounding environment.

Because of the decrease in the supply of fossil energy carriers, their price will decrease. The availability of raw materials in the domestic market will increase. Thus, the country's balance of payments will improve. It will also be easier to meet the obligations to implement the EU climate policy. Among others, it calls for reducing greenhouse gas emissions by at least 55% (compared to 1990) by 2030 [75,76] and increasing the share of RESs in the energy balance to 32% [10]. According to recent proposals, this figure could rise to 45% ([5], p. 6). As research shows, the development of photovoltaics is essential for the EU's stated goals to be met [77]. In addition, the reduction in the cost of building photovoltaic plants observed in the last decade makes solar-based energy cheaper than new coal and gas-fired power plants [78,79]. Therefore, the solution to the problem of access to cheap energy in Poland should be sought in the development of renewable energy sources, including photovoltaics. Official regulations of fossil fuel prices and ad hoc subsidies for coal-based energy can stabilize the energy market only in the short term. Unfortunately, in the long term, state intervention will be a source of market disruptions ([80], pp. 39–40), delays in the development of environmentally friendly energy and weakening of the international competitiveness of the Polish economy.

9. Recommendations

The scarcity of natural resources is one of the significant barriers to the civilizational development ([81], p. 14231) [82]. It is becoming a key concern for modern economic and political systems. The lack of adequate solutions in the field of environmental protection and ensuring the sustainability of resource use will contribute to the growth of crisis phenomena.

Therefore, special attention should be paid to providing stable, low-cost, environmentally friendly and widely available energy sources globally. Diversified RESs adequately met the aforementioned criteria. These include, foremost, onshore and offshore wind energy, photovoltaics and hydropower. The development of a mix of different RESs will help mitigate diurnal and seasonal fluctuations in energy production and facilitate a shift away from fossil fuels.

The postulate of energy transformation is also topical for Poland. In changing the structure of consumption of energy carriers, micro-photovoltaic installations occupy a special place. Because of the short lead time for the construction of PV micro-installations (even a few days), they can play a key role in quickly replenishing the shortage and influencing the reduction in electricity prices. The benefits of PV development should be clear as early as the upcoming spring–summer season when the production of the sun's energy is the highest. Today, it is necessary to provide rapid institutional support for photovoltaics. This can be completed by introducing favorable financial regulations for prosumers at the level of individual EU countries. Implementing a similar goal will allow:

- Increased energy security for countries and entire regions of the EU. This is important under conditions of the ongoing war.
- Improve the resilience to economic crises of countries and regions in transition today.
- Optimization of the state's participation in the economy (institutional governance) and also in the energy sector. This will improve the stability of this sector in the long term.

- Sustainable and balanced development of the energy sector (in the super-long term) for Poland and Europe as a whole.
- Smart specialization of regional economies in the improvement of RES technical infrastructure.
- Increased innovation in the energy sector, including improving the efficiency and effectiveness of RES generation. According to the concept of a knowledge-based economy, increased innovation can serve as a driver for the entire economy. This will facilitate the transition of the European and global economies from a depressed phase to a growth phase.

The European Parliament's Directive on the use of energy from renewable sources required the achievement of a 15% share of energy from RESs in gross energy consumption in Poland. Introducing a feed-in tariff (FiT) favorable to prosumers served this purpose. However, excessive state interference in the matter of renewable energy sources distorts the market. It makes sense to return to the net metering billing method. It is beneficial for both prosumers and utilities. The former will acquire access to virtual energy storage (distribution grid). The latter will meet their RES share obligations without costly investments.

The rapid growth in PV micro-installations evidenced the attractiveness of net metering for prosumers when this method of billing was in force. However, introducing net billing has led to the increased skepticism of prosumers toward PV micro-installations. The profitability of such an investment in the medium term becomes questionable. The proposed subsidies (cf. Mój Prąd Programme) do not compensate for the expenses incurred. In an unfavorable scenario for prosumers, they will sell energy cheaply in the summer season, above all during hours of greatest insolation, and buy it much more expensively in the winter season. The situation of prosumers being billed according to net billing will not be improved even by small-scale energy storage. Today's available technologies allow for the storage of up to several kWh of energy, which in practice will cover several days of electricity demand. Net metering will allow up to 80% of the energy produced to be virtually stored. Thus, a prosumer with a 10 kW micro-installation can draw up to 8000 kWh of energy from the grid.

Under the current legal and technical conditions, the development of micro-installations is a promising strategy for the energy transition. However, electricity generation in large photovoltaic farms (above 50 kW) requires the relevant licenses. Moreover, an adequate change in transmission lines is necessary. The construction of large-scale installations is usually a months-long process, while the installation of micro-installations takes a few days.

Today, wind turbines are not an alternative to PV micro-installations in Poland. The 2016 amendment to the RESs Act ruled out the construction of new wind installations onshore. Work is currently underway to relax the regulations on permissible distances for such construction. However, it is difficult to predict when and to what extent the changes will occur. An obstacle to the construction of offshore wind farms is the difficulty of obtaining external sources of financing and the low profitability of this type of investment. It is hoped that the identified difficulties will be quickly eliminated as the diversification in RESs will give the energy transition the expected dynamic.

The high share of fossil fuels in Poland's energy mix means that soon countries, sourcing RESs more intensively than Poland, will have cheaper energy. It is hoped that severe shortages in energy resources will prompt decision-makers to abandon the recent changes in RES development. Halting the development of RESs, presumably in the coming years already, will exacerbate shortages in energy carriers. This will lead to price increases and even disruptions in the availability of these carriers. To effectively develop RESs in Poland, it is necessary to revise the country's existing energy policy. The current national energy transition plans do not correspond to the targets set by the European Commission. Proper changes will not only give a boost to RES development, but they will also decide the shape of the Polish economy and allow for lower energy prices. The identified discrepancies cannot be explained by the need for a fair energy transition. It is necessary for all EU

countries to cooperate in pro-environmental activities, to which the countries taking part in subsequent climate summits have already committed themselves.

Regardless of the recommendations stated above, it is also necessary to seek other innovative and environmentally friendly ways to obtain energy. We recommend deepening the cooperation of scientific centers, not only within the Polish or European economy but also on a global scale.

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