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Decarbonization Obstacles in the Context of the Photovoltaic Market Development in Poland From the Social (Prosumers') Perspective

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Abstract: **Background:** Decarbonization of economies is a key development priority of the European Union. As nonrenewable fuels prevail in Poland's energy balance, the country has faced serious problems regarding priority implementation for many years.
Research objectives: Given the said circumstances, the objective of this article is to identify obstacles to using renewable energy sources (solar energy) from the prosumers' perspective.
Research design and methods: During the research, I used the results of surveys conducted on a representative sample of 754 Polish prosumers. The results underwent an analysis based on descriptive statistics and nonparametric statistical tests, including Kruskal-Wallis test and Mann-Whitney U test.
Results: The major obstacles to the development of photovoltaics in Poland from the prosumers' perspective include financial difficulties, mainly the costs of photovoltaic system installation and insufficient state subsidies for such products.
Conclusions: Hence, the state activities aimed at promoting decarbonization must consider extending the financial support for photovoltaics, simplifying the procedures to apply for RES funding, and stabilizing the conditions of transaction cost settlements on the photovoltaic market.
Keywords: decarbonization; photovoltaic market in social research; prosumers' decisions and behavior; renewable energy sources
JEL Codes: E71; E21; F64; G50

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Introduction

Contemporary economies, including but not limited to the European Union ones, must face the challenge of decarbonization. The effectiveness of this process is crucial not only for the quality of life of today's and future generations, but also for the state's economic image and standing internationally.

Decarbonization means the need to reduce greenhouse gas emissions by systematically lowering the consumption of fossil fuels (Galvin, 2020). Therefore, it applies to both industry and households using such energy sources (Businge & Mazzoleni, 2023). Decarbonization

poses a particularly difficult problem for emerging and developing economies, where the use of nonrenewable energy sources still dominates.

Systematic decarbonization is one of the key conditions for sustainable development. Progress in its implementation affects not only the climate, but also, above all, the future societies' quality of life (Liao et al., 2023). For these reasons, striving for a zero-emission economy is important both on a macro scale and at the level of regional and local communities formed by economic entities. Without grassroots social initiatives building understanding and acceptance of the decarbonization idea, effective and quick implementation of decarbonization goals will not be possible.

Currently, the literature is paying increasing attention to the bottom-up approach to promoting decarbonization, emphasizing the role of local communication, partnership, and synergy in the use of renewable energy sources (Rodin & Moser, 2022; van der Horst, 2008). The overall effect of decarbonization depends on the acceptance, attitudes, and behavior of individual energy consumers (Véliz et al., 2023), which decision makers often forget when creating holistic energy policies. In this context, the role of local social entrepreneurship is systematically growing: the phenomenon serves as a catalyst for local low-emission energy transformation (Wronka-Pośpiech, 2023). Social enterprises belong to the third sector and have a unique ability to combine economic and social benefits. One can successfully use this ability to shape more sustainable attitudes and behaviors. This, in turn, can significantly support the green transformation and decarbonization (Hillman et al., 2018).

In emerging and developing economies, green energy transformation encounters numerous obstacles. Those include macroeconomic difficulties, which refer to the inaccessibility of technology and funds for energy sector modification and modernization (Deka et al., 2023; Isah et al., 2023; Kumar & Majid, 2020; Raza et al., 2020; Yousaf et al., 2021; Bratnicka-Myśliwiec et al., 2019) or the unstable energy policy (Amoah et al., 2020; Uddin et al., 2010). They may also refer to low environmental awareness and education (Asif et al., 2023; Štreimikienė & Baležentis, 2015).

Other obstacles are microeconomic: they concern business entities and households, which need not only to accept the changes in the energy balance, but also to participate in the decarbonization costs, modify the energy habits, and modernize the systems supplying energy and heat (Pavlowsky et al., 2023; Higueras-Castillo et al., 2019; Süsser & Kannen, 2017).

In societies with low or average residual income, this poses a truly serious challenge which is difficult to face without any state subsidies. For these subsidies to be effective, the state must identify the expectations of end users of renewable energy sources (RES) and draft a profile of their typical characteristics. This enables one to effectively design and implement initiatives for the green transformation and decarbonization of economy.

Given the said circumstances, the objective of this article is to identify obstacles to using RES (solar energy) from the prosumers' perspective in the Polish economy. To achieve this objective, I present the results of a survey conducted on a representative sample of 754 Polish prosumers. They enable one to address the following research problems:

1. What are the obstacles which hinder the prosumers' decision to install a photovoltaic system and what is their priority order?

2. Are there any differences in perceiving obstacles to photovoltaic system development between groups of prosumers? If so, what are they?

Answering the above questions makes it possible to fill in the research gap relating to the assessment of the social and behavioral aspects of decarbonization. What is more, it provides

grounds for a precise adaptation of the government subsidies for RES development to prosumers' needs, which is important for green transformation effectiveness.

Further on, I discuss literature studies of decarbonization aspects in emerging and developing economies as well as the existing results of prosumers' behavior research. Next, I describe the research methodology, considering the rules of survey questionnaire design and the statistical methods of results analysis. Later, I present and discuss the research findings, and then offer recommendations toward increased efficiency of Polish economy decarbonization. Finally, I formulate the most important conclusions and describe study limitations and directions for further research.

Literature Review

The socioeconomic trend of research on the solar energy use by prosumers includes many publications on photovoltaic market functioning. This stems from the specific nature of the peer-to-peer (P2P) market model which can be used to settle distributed transactions. Nonetheless, the majority of existing studies concerns optimization and settlement mechanisms (Fernandez et al., 2023; Zeng et al., 2023; Forcan & Forcan, 2023).

In this trend, scholars also analyze the financial benefits of photovoltaics use. Those may refer to individual prosumers, as mentioned by Moghadam and Javidi (2022) and Mensin et al. (2022). They may also apply to the entire local communities, as described by Umer et al. (2023) and Espadinha et al. (2023). Economists study the prices and the demand-supply alignment on the photovoltaic market; for these aspects, see An et al. (2022), Huang et al. (2022), and Li et al. (2020).

This means that researchers focus primarily on the macroeconomic aspects of the photovoltaic market mechanism connected with RES and the green transformation. Few works tackle the problems of the macroeconomic perspective referring to individual prosumers, even though certain authors stress the need to carry out such research (Xiang et al., 2023).

Prosumers' opinion polls usually take place in the context of incentives encouraging households or entrepreneurs to install photovoltaic systems. They produce the following conclusions:

1. Prosumers' decisions are most strongly and frequently affected by financial incentives, i.e., the opportunity to reduce energy costs. Prosumers in emerging and developing economies experience incentives to a greater extent (Jonek-Kowalska, 2023; Zdonek et al., 2023; Mularczyk et al., 2023).

2. Beside the financial incentives, photovoltaic systems are used because of the need for economic self-sufficiency (Ecker et al., 2017; Korcaj et al., 2015; Römer et al., 2015), willingness to protect the climate (Georgarakis et al., 2020), and the opportunity to reduce energy poverty (Paudel et al., 2019, Tushar et al., 2019).

3. Prosumers' opinions highly differ in the international and national context (Bruine de Bruin et al., 2007). The opinions change over time as photovoltaic systems develop. This implies a continuous and individualized necessity to identify prosumers' needs.

The analysis of obstacles to photovoltaics development which form the subject of this article appears in the literature mainly from the macro perspective. In this context, the aspects of designing and modifying energy strategies to increase RES use are analyzed primarily in developing and emerging economies.

Thus, Osorio-Aravena et al. (2021), who studied the Chilean economy, notice that the major obstacle to photovoltaics development is low income and the high cost of photovoltaic system

installation. According to the authors, decarbonization and RES development in Chile would not be possible at all without state incentives.

Similar conclusions result from the research by Sotnyk et al. (2023), who studied Ukraine. The authors stress the role of financial obstacles and pay attention to the energy storage aspects. In both cases, they believe that the solution to the financial problems can be state initiatives, which is similar to Botelho et al. (2022), who analyzed photovoltaic development in the Brazilian economy.

One should add that, in practice, prosumers do not possess any tools which would enable them to analyze the costs and benefits of photovoltaic systems. Hence, they find it difficult to assess the long-term profitability of such investments, and this may discourage them from using RES – as described by Yang and Zou (2016).

Another problem in photovoltaics development is the distrust toward the state and the institutions who organize energy trading in the grid. This reduces the prosumers' agency and increases the risk accompanying RES investments – a phenomenon discussed by Patterson-Hann and Watson (2022).

In this context, one should add that Poland has been building the society's trust in the state in free-market economy conditions for less than three decades, which certainly hampers photovoltaics development. Moreover, the energy policy is highly unstable and there are no clear directions of low-emission energy source development (Skjærseth, 2018; Lis & Stankiewicz, 2017). Following a period of developing wind energy systems, the state reoriented its support toward solar energy (Solorio & Jörgens, 2020). Moreover, significant efforts regarding nuclear energy commenced only two years ago. The changing energy conditions increase the risk of both macro- and microeconomic RES investments (Wronka-Pośpiech et al., 2016), which is likely to discourage people from any decarbonization efforts.

The literature review indicates that the photovoltaic market has been analyzed from a relatively unilateral perspective which focuses on the macroeconomic approach. There is no research oriented toward social aspects to a higher degree, or considering the micro perspective of individual prosumers. However, such an approach is important and valuable as the development of RES in the entire economy results from attitudes and behaviors of individual business entities. This means that there is a research gap concerning the identification and assessment of obstacles to using solar energy from the prosumers' perspective. This article attempts at filling the gap in question.

Research Method and Material

As already mentioned, I used a survey questionnaire for the research. The questionnaire contained four groups of questions concerning obstacles which hinder the use of photovoltaic systems or discourage people from such use. Given the above literature review, the question groups referred to the following obstacles:

- financial – most frequently mentioned in the discussions concerning RES;
- legal, which determine the photovoltaic market frameworks;
- administrative, which translate into the complexity of formal measures required from prosumers to get subsidies;
- technical, which concern the conditions of photovoltaic system installation and guarantee.

The list of survey questions is presented in Table 1.

Table 1. Groups of Survey Questions About the Obstacles to Photovoltaics Development in Poland

Question group	Question
financial	cost of photovoltaic system installation
	insufficient state subsidies
legal	legal amendments regarding subsidies for photovoltaic investments
	legal amendments regarding the settlement of photovoltaic energy production and consumption costs
administrative	complexity of procedures to obtain state subsidies
technical	necessity to fulfill the technical requirements for solar panel installation
	limitations of the guarantee for photovoltaic system installation and use

Source: own elaboration.

The respondents assessed the obstacles in Table 1 using a five-point Likert scale, defining their inconvenience as follows:

1 – very low;
2 – low;
3 – medium;
4 – high;
5 – very high.

The sample size was determined based on the following assumptions:

– fraction size: 0.5;
– 4% maximum error defining the scale of difference between the results obtained in the sample and the population;
– 97% confidence percentage that determines the certainty of the results obtained.

The research was conducted in early 2023.

I used descriptive statistics to analyze the results at the first stage of the research. This enabled me to answer the first research problem, namely: What are the obstacles which hinder the prosumers' decision to install a photovoltaic system and what is their priority order? In this respect, I used central tendency measures, including arithmetic mean, mode, and median value, as well as variation measures, including standard deviation and the coefficient of variation. Moreover, I calculated skewness and kurtosis to illustrate the distribution of responses when compared to normal distribution.

The second stage of research included nonparametric statistical tests to assess the differentiation of the studied groups which enabled me to answer the second research problem, namely: Are there any differences in perceiving obstacles to photovoltaic system development between groups of prosumers? If so, what are they? The analysis considered the property owners' age and place of residence (as defined in the particulars). The identification of the prosumers' behavior typology in those groups produced more accurate recommendations to make decarbonization more effective. The results analysis entailed the following nonparametric statistical tests comparing the distributions of several variables:

– Mann-Whitney U test for two unrelated samples comparing the median value of distributions – used for the place of residence, i.e., village/city;
– Kruskal-Wallis test for more than two unrelated samples comparing the variance of distributions – used for the age of the surveyed property owners.

Results and Discussion

At the first stage of research, I identified the intensity of obstacles to photovoltaics development of Poland using descriptive statistics. The results of this step are shown in Table 2. According to the information presented, the financial obstacles – more specifically, the costs of photovoltaic system construction and insufficient state subsidies – are the most important for prosumers. The responses have the highest arithmetic mean and median value, and the respondents are consistent in their assessment, as confirmed by the lowest values of the coefficient of variation and standard deviation.

The prosumers' responses point not only to financial difficulties, but also to the high score awarded to the complexity of procedures to obtain state subsidies. This may be an important obstacle to RES development in Poland and may slow down the decarbonization process.

Among the other obstacles – including technical, organizational, and legal ones – the respondents indicated the significance of legal amendments regarding the settlement of photovoltaic energy production and consumption costs. Those are rated as more burdensome than legal amendments regarding subsidies for photovoltaic investments. This means that Polish prosumers are able to accept the initial cost of photovoltaic investments but fear the risk connected with their use and the unforeseeable rules of transaction settlements with the energy grid operator.

According to the respondents, the technical obstacles are less inconvenient than the financial or regulatory – that is, organizational and legal – difficulties described above, as proved by the lower average assessment and median value. However, in this case, the prosumers are less consistent than for the financial aspects: the responses yield lower coefficients of variation and lower standard deviation.

The obtained priority order of obstacles to RES development in Poland points to insufficient state subsidies for photovoltaic development. The prosumers' reservations refer primarily to financial and regulatory – that is, legal and organizational – aspects. The research reveals that the respondents would expect higher subsidies for photovoltaic systems and simpler procedures to obtain them. The prosumers' fears refer not only to the conditions of making the decision to invest in photovoltaics, but also to future rules of the energy market, such as transaction settlement costs. Moreover, the variability of those conditions in the last decade has resulted in negative experience of both existing and prospective prosumers, encumbering the investment in photovoltaics with a higher risk. This may reduce their willingness to opt for RES and slow down the decarbonization pace in Poland.

At the subsequent research stage, I focused on assessing the variability of the responses provided by the studied groups based on their place of residence and age. The aim of such an approach was to adapt the aid instruments better to the prosumers' expectations in case any significant differences in the obstacles' perception were found.

Hence, Table 3 presents the results of Mann-Whitney U test for the interdependency between obstacle assessment and the prosumers' place of residence (village/city). Table 4 contains group descriptive statistics for the analyzed variables. The analysis covered solely the obstacles where statistically significant differences were found ($p < 0.05$).

Table 2. Descriptive Statistics to Assess the Obstacles to Photovoltaics Use by Households

Obstacles	Statistical measures									
	Average	Median	Mode	Mode size	Minimum	Maximum	Standard deviation	Coefficient of variation	Skewness	Kurtosis
cost of photovoltaic system installation	3.5995	4.0000	3.0000	254	1.0000	5.0000	1.0378	28.833	−0.3633	−0.3635
insufficient state subsidies	3.5676	4.0000	3.0000	254	1.0000	5.0000	1.0442	29.269	−0.3416	−0.4025
legal amendments regarding subsidies for photovoltaic investments	3.1300	3.0000	3.0000	304	1.0000	5.0000	1.0781	34.445	−0.2220	−0.3768
legal amendments regarding the settlement of photovoltaic energy production and consumption costs	3.2533	3.0000	3.0000	303	1.0000	5.0000	1.0221	31.417	−0.2981	−0.1817
complexity of procedures to obtain state subsidies	3.3289	3.0000	3.0000	275	1.0000	5.0000	1.0959	32.922	−0.2481	−0.4688
necessity to fulfill the technical requirements for solar panel installation	3.1817	3.0000	3.0000	302	1.0000	5.0000	1.0550	33.158	−0.2249	−0.3275
limitations of the guarantee for photovoltaic system installation and use	3.2095	3.0000	3.0000	312	1.0000	5.0000	1.0377	32.333	−0.1557	−0.3034

Source: own elaboration.

Table 3. Results of the Mann-Whitney U Test for Obstacle Assessment Depending on Place of Residence

Variable	Rank sum for the city	Rank sum for the village	Z	*p*
legal amendments regarding subsidies for photovoltaic investments	164,038.5	120,596.5	2.2265	0.0259*
necessity to fulfill the technical requirements for solar panel installation	164,301.0	120,334.0	2.3147	0.0206*
limitations of the guarantee for photovoltaic system installation and use	164,089.5	120,545.5	2.2436	0.0248*

*$p < 0.05$

Source: own elaboration.

Table 4. Descriptive Statistics for the Obstacles to Photovoltaics Development in Villages and Cities

Group	Average	Median	Mode	Mode size	Standard deviation	Coefficient of variation
Legal amendments regarding subsidies for photovoltaic investments						
all	3.1299	3.0000	3.0000	304	1.0781	34.44%
city	3.2110	3.0000	3.0000	182	0.9944	30.97%
village	3.0296	3.0000	3.0000	122	1.1671	38.52%
Necessity to fulfill the technical requirements for solar panel installation						
all	3.1816	3.0000	3.0000	302	1.0550	33.15%
city	3.2661	3.0000	3.0000	171	1.0017	30.67%
village	3.0771	3.0000	3.0000	131	1.1100	36.07%
Limitations of the guarantee for photovoltaic system installation and use						
all	3.2095	3.0000	3.0000	312	1.0377	32.33%
city	3.2925	3.0000	3.0000	175	0.9858	29.94%
village	3.1068	3.0000	3.0000	137	1.0913	35.12%

Source: own elaboration.

According to the data presented in Tables 3 and 4, the differences between the assessment by the residents of cities and villages refer to three obstacles: one financial and two technical. The city residents considered the legal amendments regarding subsidies for photovoltaic investments more burdensome than did the village residents, which is quite surprising as the income levels in Polish cities are higher than in Polish villages. This assessment difference may stem from the more critical attitudes to the Polish government of the time – the one formed by Prawo i Sprawiedliwość (PiS) – in urban areas. This context may explain why amendments to energy policy received less favorable assessment from this group.

The city residents perceive the technical burdens relating to photovoltaic systems as more difficult as well, including the necessity to fulfill the technical requirements for solar panel installation and the limitations of the guarantee for photovoltaic system installation and use. The first of these two differences naturally stems from the shortage of space where photo-

voltaic systems can be installed in urban areas. The second may arise from the need to meet higher technical requirements when installing solar panels. In both cases, the identified differences seem reasonable and justified by the different conditions of installation in the village and urban areas.

One should add that the city residents offered less differentiated assessments of the obstacles to photovoltaics development than did the village residents. This may make it more difficult to adapt any incentives and subsidy programs to the latter group's needs.

At subsequent stages of the research, I analyzed the interdependency between obstacle assessment and the age of the property owner where the photovoltaic system is used. Table 5 shows the results of the Kruskal-Wallis test for statistically significant interdependencies, whereas Table 6 includes descriptive statistics for the age groups.

Table 5. Obstacle Assessment Depending on the Property Owner's Age (Kruskal-Wallis Test)

Means of promotion	Kruskal-Wallis test	*p*-value
cost of photovoltaic system construction	7.8943	0.0139*
complexity of procedures to obtain state subsidies	7.9054	0.0396*
limitations of the guarantee for photovoltaic system installation and use	7.2287	0.0269*

$p < 0.05$*

Source: own elaboration.

Table 6. Descriptive Statistics for Obstacle Assessment Depending on the Property Owner's Age

Age group	Average	Median	Mode	Mode size	Standard deviation	Coefficient of variation
Cost of photovoltaic system construction						
up to 30 years	3.5098	4.0000	4.0000	16	1.1202	31.91%
from 31 to 50 years	3.5337	3.0000	3.0000	171	0.9903	28.02%
over 51 years	3.7297	4.0000	4.0000	80	1.0909	29.25%
Complexity of procedures to obtain state subsidies						
up to 30 years	3.3529	3.0000	3.0000	22	0.9343	27.86%
from 31 to 50 years	3.1058	3.0000	3.0000	188	1.0560	34.00%
over 51 years	3.2779	3.0000	3.0000	92	1.0674	32.56%
Limitations of the guarantee for photovoltaic system installation and use						
up to 30 years	3.4117	3.0000	3.0000	24	0.9203	26.97%
from 31 to 50 years	3.1396	3.0000	3.0000	194	1.0293	32.78%
over 51 years	3.2895	3.0000	3.0000	94	1.0661	32.41%

Source: own elaboration.

The analysis revealed three obstacles displaying statistical sensitivity to the respondents' age:

– financial: cost of photovoltaic system construction;
– organizational: complexity of procedures to obtain state subsidies;
– technical: limitations of the guarantee for photovoltaic system installation and use.

Hence, the oldest respondents experience the photovoltaic system cost the most acutely, as proved by the highest average, median, and mode for their assessment. This cost is also highly burdensome for the youngest prosumers (the highest median and mode). Such a distribution of responses in age groups most probably stems from income differences. For middle-aged owners, at the height of their career development, the photovoltaic system cost may be relatively lower when compared to the income than for those starting or ending their careers.

The complexity of procedures to obtain state subsidies hampers access to photovoltaics the most for the youngest prosumers, which may stem from their short experience and aversion to bureaucracy. For the other age groups, this factor is less burdensome.

For the youngest group of prosumers, the limitations of the guarantee for photovoltaic system installation and use are more difficult to overcome than for the other age groups. This technical difficulty is the least important for respondents aged 31–50.

The results permit a claim that prosumers aged 31–50 have lower financial, organizational, and technical expectations than the other two age groups – i.e., the youngest and oldest prosumers. The major problem for the oldest age group is the financial costs of the photovoltaic system. On the other hand, the youngest respondents expect simplified administrative procedures and more favorable conditions of photovoltaic system installation and use. Thus, the middle-aged group seems to best accept the existing organizational, legal, and financial conditions.

Further Discussion

The research results confirm the weight of economic priorities in prosumers' decisions to use RES (Zdonek et al., 2023; Mularczyk et al., 2023). This is a typical phenomenon in emerging and developing economies, as described, for example, by Osorio-Aravena et al. (2021), Sotnyk et al. (2023), and Botelho et al. (2022). Nonetheless, one should stress that the financial aspects are not equally important for all age groups. According to the research, it is the oldest group of respondents who most strongly experience the economic obstacles to photovoltaics development – a phenomenon certainly supported by the regular development of the Polish economy and increasing wealth of younger generations. This is confirmed by the changeability and variability of prosumers' expectations noticed by Bruine de Bruin et al. (2007).

Polish prosumers are significantly affected by intensely experienced effects of unstable energy policy (Skjærseth, 2018; Lis & Stankiewicz, 2017). The changing legal conditions of settling the transactions in the energy grid discourage them from investments in photovoltaics. The complexity of administrative procedures accompanying the process of applying for photovoltaic system subsidies is another factor which hinders their decisions.

In Poland, the development of nonrenewable energy sources is progressing very slowly. So far, the state has not taken advantage of the opportunity to develop nuclear energy. As a result, the decarbonation efficiency remains very low. Therefore, it is worth using the obtained results to create favorable conditions for solar energy development. This primarily means providing financial support and enabling satisfactory settlement of the energy produced. The stabiliza-

tion of energy policy and certainty of the conditions for the functioning of prosumerism is also important for its participants.

Responses of the surveyed prosumers clearly point to the state's leading role in RES development and economy decarbonization (Patterson-Hann & Watson, 2022). The state is obliged to provide subsidies for the green transformation and organize the administrative and legal conditions required for the solar energy market operations. Even though one cannot expect or require increased capital to subsidize RES investments because of the insufficient Polish national income, the simplification of procedures and stabilization of legal conditions presents a feasible task for a modern state.

As emphasized in the introduction, local and regional initiatives in the form of social entrepreneurship play an increasingly important role in today's energy transformation (Rodin & Moser, 2022; van der Horst, 2008). Thus, it is certainly worth using them in two directions. The first is to disseminate the importance of decarbonization and ecological education (Véliz et al., 2023). The second, more immediate, concerns the use of social enterprises and energy cooperatives to improve transactions on local energy markets. The sharing and synergy effect achieved through such activities can encourage the use of RES and demonstrate their efficiency and climate friendliness (Wronka-Pośpiech, 2023; Hillman et al., 2018).

This means that the research can form a basis for recommendations fostering the development of photovoltaics in Poland and accelerating the decarbonization of Polish economy:

- stabilized energy policy of the state;
- reduced risk related to the changing conditions of RES energy settlements;
- minimized procedures required to obtain funds for photovoltaic systems and/or organized administrative help for those applying for such funds;
- development of photovoltaics investment support forms;
- provision of tools to calculate the benefits and costs of long-term solar energy use.

Conclusions

The major objective of this article was to identify the obstacles to photovoltaics development in Poland from the social (prosumers') perspective. Those obstacles hinder and slow down the Polish economy decarbonization process. According to the findings, the major obstacle to RES use by prosumers is the cost of photovoltaic system installation and insufficient state subsidies for such investments. Moreover, complex procedures of applying for funds and legal amendments to the rules of energy settlement with the grid operator present a significant burden. Technical obstacles concerning the conditions of photovoltaic system installation and use are not as important for the prosumers as the above-mentioned financial, organizational, and legal difficulties. However, one should emphasize that residents of urban areas perceive the technical obstacles as more painful than do village residents, which stems from the natural shortages of urban space.

When analyzing the research findings in terms of the need to adapt the solutions supporting RES development to the needs of prosumer age groups, one can claim that the youngest prosumers (up to 30 years) expect simplified administrative procedures of obtaining the subsidies for photovoltaics. The oldest group of respondents (over 51 years) believes that photovoltaic system cost reduction is the most important. The medium age group (from 31 to 50 years) seems to accept the existing financial, organizational, and technical conditions.

The main limitation of the research is narrowing down the analysis scope to Polish prosumers. Nonetheless, such an approach ensures a focused assessment of needs and an improved adaptation of the RES support policy to the Polish economy's needs, which is a highly important and topical task given the slow progress of its decarbonization.

The future research of prosumers' behaviors should investigate their assessment and attitude toward the individual RES support instruments. It would also be interesting to learn the incentives which encourage prosumers to modify their energy consumption behaviors oriented toward energy market optimization (balancing).

Bearing in mind the role of social entrepreneurship in decarbonization, it is also worth deepening the research regarding its impact on accelerating the low-emission transformation on a regional and local scale. In this trend, an important research direction is the identification of barriers and opportunities for including social enterprises in local prosumer initiatives. Another interesting topic would be to assess the role of energy cooperatives in shaping sustainable energy consumption.

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