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DETERMINANTS OF THE INVESTMENTS IN PHOTOVOLTAIC MICRO-INSTALLATIONS BY INDIVIDUAL USERS IN POLAND

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ABSTRACT

Aim: The paper's objective is to determine the behavior and attitudes of Polish investors and users towards photovoltaic installations in Poland. **Methods:** The survey was carried out by ARC Rynek i Opinia (the Institute of Opinion and Market Research), commissioned by the company Alians-OZE, which, as part of the cooperation between business practice and science, made the results of the research available to the authors of this paper. The study was carried out in April 2021 using the CAWI technique. **Results:** The most important advantage of using photovoltaic micro-installations included factors such as using a source of free energy and independence from electricity price increases. The most important disadvantages were the high price of installation and the period of return on investment. **Conclusions:** The individual users of photovoltaic micro-installations, due to their activities in the green energy market as prosumers, not only increased the amount of renewable energy available, but also increased the social awareness of the benefits of such solutions. Therefore, it is important to promote as part of the pro-ecological policy, as well as the measures aimed at promoting this renewable energy source among individual users.

Key words: renewable energy, residential solar photovoltaics, market behavior, prosumer
JEL codes: Q2, Q5 D12

INTRODUCTION

The introduction of green energy is important to mitigate environmental and climatic conditions. In addition to the need to access energy, the issue of raw materials for production is growing. The modern world is powered by fossil fuels. Coal is responsible for about 40% of the world's CO_2 emissions, which makes reducing its emissions crucial for our planet. Limiting the increase in average temperature to 1.5°C, compared to preindustrial times, requires emissions to be zeroed in the 2050s, and in the case of the 2°C thresholds, it must take place in the 2070s. By 2030, emissions for the 1.5°C target should drop by 45% and for the 2°C target by 25% compared to 2010. Unfortunately, emissions have not decreased since 2010, but on the contrary, they have increased. Among European Union (EU) countries, the leaders in the field of renewable energy are the Scandinavian countries, where a sustainable lifestyle is developing the fastest. It is important to note that Norway has a chance to give up fossil fuels by 2050 [MM Magazyn Przemysłowy Online 2021].

Under the United Nations Framework Convention on Climate Change from 1992, all countries are required to act to "avoid dangerous climate change"

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and find ways to reduce greenhouse gas emissions fairly. The Conference of Parties (COP), held since the 1990s, aims at developing a global response to the climate crisis. It is clear from the operation of the first European Renewable Energy Directive (2009–2020) that only solar and wind energy have the potential required to meet the targets adopted during this period, namely 20% of energy consumption in the EU needs to come from renewable energy sources (RES) [Jäger-Waldau et al. 2011]. The new European Renewable Energy Directive envisages 32% of EU energy consumption by 2030 to be generated from renewable sources such as wind, solar, hydroelectric, ocean energy, geothermal energy, biomass and biofuels. In July 2021, the EU proposed to the co-legislators a change consisting of setting the target at the level of 40% by 2030 [Directive EU 2018/2001, Directive 2009/28/EC][2]. The European Parliament voted in September 2022 to increase the RES target. Renewables are to account for 45% of the energy mix by 2030. This represents a 5% increase in share compared to the RED II Directive adopted in 2018 [Parlament Europejski 2022]. However, the EU needs to cope with different energy crises or market and political causes [Fracastoro 2014]. Russia's invasion of Ukraine on 24 February 2022 has forced the EU and its Member States to revise their energy transition plans and strengthen energy generation from renewable sources. Thus, political actions are enforced to promote the production of RES. The Fit for 55 package is considered for an update according to the new geopolitical situation. This includes both revising the deadlines of withdrawing fossil fuels and shifting investments towards a larger share of RES in the European energy mix. In response to the Russian invasion of Ukraine, many European Union countries undertook actions aimed at reducing their dependence on Russian natural gas imports [Jos et al. 2022]. The European Commission (EC) enforced the EU Solar Energy Strategy as part of the REPowerEU plan. This strategy aims to bring online over 320 GW of solar photovoltaic capacity by 2025 (more than doubling compared to 2020) and almost 600 GW by 2031. The additional PV capacities are seen to displace the consumption of 9 bcm of natural gas annually by 2027. In the strategy, the EC also assumed the promotion of quick and massive PV deployment via the European Solar Rooftops Initiative for rooftop solar on commercial and public buildings by 2027, and for new residential buildings by 2029, highlighting the role of individual users [European Commission 2022].

The International Energy Agency (IEA) [2022] reports significant growth in solar photovoltaic energy production in the European Union, which is due to a faster rate of implementation of the installation, with an accelerating policy role. The policy-driven growth is visible in Germany, the Netherlands, Poland, Italy and France. It is expected that the impact of new and adjusted European energy policies will be limited by 2023. However, in the next periods, the growth in PV installations on residential and commercial installations will enable consumers to reduce their electricity bills through self-consumption [International Energy 2022].

Moreover, the global demographic trend related to the aging of society and lifestyle changes is becoming more and more noticeable. As a result, the number of one-person households and individuals who are single is growing [Dąbrowska et al. 2019]. Piekut [2020, 2021] identified the satisfaction of needs in terms of maintaining proper thermal comfort in one-person households and in households run by people aged 60 and older. Based on the results of the study, the author claims that perceiving energy poverty only through the prism of income indicators may lead to excluding some individuals from the group of energy-poor people. In some one-person households, despite a low share of energy expenditure in disposable income and a relatively favorable income situation, people reported a high degree of unsatisfied needs related to thermal comfort in the apartment.

The authors, noticing the relationship between meeting energy needs and the health of the society and the healthcare sector, refer to the seventh objective of the UN Sustainable Development Goals. The objective concerns ensuring "access to affordable, reliable, sustainable and modern energy for all", while emphasizing that according to UN data, the global electrification rate reached 89% in 2017, but 840 million people

[2] Directive 2009/28/EC of the European Parliament and of the Council has been substantially amended several times. From the need for further amendments, the directive had to be recast for the sake of clarity

worldwide do not have access to electricity [Kirshner and Broto 2020]. WHO reports that the declining costs of renewable energy technologies are becoming more accessible to healthcare facilities. This is especially true of solar photovoltaic energy [Porcaro et al. 2017].

Currently, the problem of energy is frequently raised during the COVID-19 pandemic. Energy in pandemic conditions plays a key role, as it allows households to function without disruptions. The latter is particularly important in the case of remote learning and remote work taking place at home. Modern electricity is a key factor in improving health systems. It is also an important determinant of human health and, consequently, the achievement of sustainable development goals for health [Chen et al. 2019].

Therefore, the paper's objective is to determine the behavior and attitudes of Polish investors and users towards photovoltaic installations in Poland. The research problems analyzed in this study concerned the following issues: willingness to undertake investments or expand the existing installation; factors influencing the decision to invest; perceived profitability and overall rating of respondents' satisfaction with photovoltaic installations; an indication of sources of information on photovoltaic installations.

MATERIALS AND METHODS

To examine and discuss the determinants of investing in photovoltaic micro-installations by individual users in Poland, the authors carried out a desk study based on a systematic review of the literature. The review following the guidelines by Xiao and Watson [2019] was executed through the search of the scientific databases: Web of Science, Scopus, Ebsco, and Google Scholar using the main keywords: photovoltaic, energy, individual user, renewables, Poland. The selection process consisted of exclusion criteria related to the year – the perspective from 2004 was applied, and for the empirical status of presented results – only solid empirical studies were considered.

The results also include quantitative studies based on survey questionnaires. The survey was carried out by ARC Rynek i Opinia, the Institute of Opinion and Market Research. The empirical study was commissioned by the company Alians-OZE, which, as part of the cooperation between business practice and science, made the results of the research available to the authors of this paper. The study was carried out in April 2021 using the CAWI (Computer-Assisted Web Interview) technique. The researchers used epanel.pl, a research panel administered by ARC Rynek i Opinia, which has about 60,000 registered users. The respondents in the study were individuals who lived in detached, terraced or semi-detached houses. The study was carried out on a sample of 802 people living in their own homes, including 197 respondents who have photovoltaic installations (this group constituted a research sample for the current research). The selection was the case of quota sampling, consistent with the structure of the nationwide population. The structure of the sample was representative of the population of Poles aged 18–65 in terms of gender, age, and the size of the place of residence. After collecting the data, it was weighted twice.

The majority of people who have photovoltaic installations are individuals with higher or secondary education (51.5 and 43.0%, respectively). Most often, people who indicated that they had assessed their financial situation as average responded: "We live on an average level – we have enough money to support ourselves every day, but we have to save for high-value purchases" (52.5%), and those declaring that "We live well – we have enough money for many things without the need to save"(32.5%). Depending on the age group of the respondents, it was noted that the owners of these types of installations most frequently came from two age groups: 35–44 years and 25–34 years (31.5 and 29.5%, respectively). When the place of residence was a differentiating factor, rural residents (44.0%) declared owning photovoltaic installations most frequently. Table 1 presents the characteristics of the respondents' using photovoltaics.

The key issue in shaping the respondents" opinions on renewable sources was the question of whether the photovoltaic installation met their expectations. It was a case of a closed question with a five-point Likert scale. In this question, a rating of 1 represented "definitely not", and a rating of 5 referred to "definitely yes". This scale was also used

Table 1. Respondents' characteristics

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Education			
Primary	2.0	2.8	1.1
Basic vocational	3.5	0.9	6.5
Secondary	43.0	43.0	43.0
Higher	51.5	53.3	49.5
Age groups			
18–24 years	14.5	22.4	5.4
25–34 years	29.5	31.8	26.9
35–44 years	31.5	28.0	35.5
45–54 years	15.0	10.3	20.4
55+ years	9.5	7.5	11.8
Subjective assessment of the financial situation in the household			
We live very poorly – we do not even have enough money to cover our basic needs	1.5	1.9	1.1
We live modestly – we must carefully manage our money	8.5	6.5	10.8
We live on an average level – we have enough money every day, but we have to save for high-value purchases	52.5	57.9	46.2
We live well – we have enough money without the need to save	32.5	29.9	35.5
We live very well - we can afford certain luxuries	5.0	3.7	6.5
Place of residence			
Country	44.0	47.7	39.8
Town up to 19,000 residents	10.5	15.0	5.4
City from 20,000 to 49,000 residents	11.5	6.5	17.2
City from 50,000 up to 99,000 thousand residents	9.5	10.3	8.6
City from 100,000 up to 199,000 thousand residents	7.5	6.5	8.6
City from 200,000 up to 599,000 thousand residents	9.5	7.5	11.8
City with a population of 500+ thousand residents	6.5	8.6	7.5

Source: own elaboration based on data provided by Alliance RES.

in the question regarding the respondents' opinions on the profitability of the photovoltaic installation. In this case, rating 1 represented the response of "markedly low profitability", and rating 5 was used to describe "very high profitability".

In turn, a scale from 0 to 10 was used in the question concerning the respondents' declarations regarding the recommendation to friends or family to invest in photovoltaic installations. "0" meant that the respondent "would not recommend investing in photovoltaic installations to friends or family at all" and "10" that the respondent would "definitely recommend investing in solar installations to friends or family".

Statistical analysis was performed using the IBM SPSS Statistics version 27.0 package. For the analysis of quantitative data, selected methods of descriptive statistics were used first. Pearson's chi-square test was applied to examine the relation between the above-listed matters and the characteristics of respondents.

The distribution of quantitative variables, assessed on the Likert scale, was investigated using non-parametric tests – the Mann-Whitney U test and the Kruskal-Wallis H test. However, statistical significance was not demonstrated.

The authors also examined the relationship between the opinion of the respondents on whether the photovoltaic installation met their expectations and the profitability of the photovoltaic installation and recommended investment in photovoltaic installations to friends or family of the respondents (using Spearman's correlation).

The analysis of the data collected during the survey was additionally broken down into responses given by men and women. This is related not only to the fact that, as indicated by the IRENA [2019], there is a growing role of women in renewable energy decision-making globally but also to the role of women in Polish households' decision-making. Cecelski [2020] confirmed that women have contributed to the design of household energy technologies and projects. Also, other authors [Accelerating 2018, Lamas et al. 2021] emphasize the role of gender in expanding RES development. It needs to be stressed that when it comes to electricity consumption in Poland, awareness is a key aspect. Electricity use can be automatic, as it accompanies daily habits, e.g., cooking and cleaning. Internal factors, such as pro-environmental attitudes, values, and personal and social norms, cause consumers to monitor their e.e. consumption levels and try to use them more efficiently [Gołębiowska 2020]. In addition, as Frączek's research [2012] indicates, among the factors influencing decisions in this area in Polish households, psychological factors related to security come to the forefront. These are more important for women than for men. Fatuła [2015] argues that concerning gender issues, the differences that occur indicate the specificity of the financial decisions of the household.

THEORETICAL FRAMEWORK

Although the slowdown of the solar thermal market in the EU since 2018 and the more remarkable decrease of new installations in 2020 compared to 2019 by 15.3%, which mostly were caused by the Covid pandemic, the sector is back on track for growth [EurObserv'ER 2021]. The European Union photovoltaic market situation in 2021 has improved with a growth trend, despite challenging conditions mainly related to difficulties in the supply chains of photovoltaic system components [EurObserv'ER 2022]. In this respect, the data presented by the Renewable Energy Institute indicate that in 2020, Poland maintained the 5th position in the EU in terms of the increase of new PV capacities, behind Germany, Spain, the Netherlands and France [Wiśniewski 2020]. The analysis of the European development trends clearly indicates that the changes that will be implemented towards sustainable development in the energy market will depend not only on the decisions and policies of the government but largely on the awareness of household members and their activities as well as the market factors such incentives, prices and energy availability [MM Magazyn Przemysłowy Online 2021].

Concerning Poland, under the Act on Renewable Energy Sources [Dz.U. 2019 poz. 1524], in Poland, the term renewable energy prosumer represents a final customer producing electricity exclusively from renewable energy sources for their own needs in a micro-installation, provided that in the case of a final customer who is not a household electricity user, the latter is not the object of the predominant economic activity determined under the provisions of public statistics regulations.

Prosumer is a combination of the terms producer and consumer, defined as a consumer, in this case, co-creating electricity and supporting such a solution [Gwiazda 2016]. The term is thus understood as an individual or entity that simultaneously consumes and produces electricity for their own needs using a micro-installation, and their predominant economic activity is not related to the production of electricity. The basis for a financial settlement, in this case, is a comprehensive agreement.

The interest in prosumer energy among Poles is relatively high. Installing devices enabling the use of renewable energy sources in their home or farm building in the next 2-3 years was considered by a total of 22% of respondents, and 7% of survey participants indicated that they would "definitely" take such an

opportunity into account. These people were primarily interested in generating energy for their own needs: 72% of them were interested in producing heat energy for their own use, and 46% of the sample indicated their interest in producing electricity. Only less than one in ten people interested in prosumer energy (9%) declared their intention to sell electricity to the grid at a fair price [Gwiazda 2016].

As Kazimierska [2021] emphasizes, the most important advantages of being a prosumer involve three key aspects:

- energy independence – i.e., independence from price increases is one of the most important benefits of prosumer activity. Developing the solutions available to prosumers allows us to predict that from year to year, it will be an increasingly profitable undertaking;
- concern for natural resources – under the conditions of the current climate change and increasing air pollution in Poland, the use of renewable energy sources is the best course of action concerning one's own contribution to environmental protection;
- profitability of the investment – there is probably no other form of investment, such as a solar farm or a small wind farm, that would ensure continuous profit, which is significant for the budget. Investing in renewable energy RES micro-installations is certainly one of the most reliable ways of investing capital nowadays.

According to the average expectations, RES should be the main source of electricity in 2050, supplying nearly half of its production [Derski 2021]. The CBOS research shows that Poles expect a significant decrease in energy coming from coal to 32.7% in 2035 and 15.4% in 2050, and in the next dozen or so years, they expect the development of renewable energy sources (33.8% in 2035 and 47.1% in 2050). The declarations show some reserve in the approach to the development of nuclear energy in Poland (in the perspective of 2035, 8% of electricity should be generated from nuclear energy, and by 2050, the desirable share is estimated at 12.4%). Natural gas has a permanent place in the energy generation system (21.4% in 2035 and 20.6% in 2050). The way of thinking about the future of the energy sector in Poland is differentiated based on socio-demographic characteristics. The analyses show that the development of nuclear energy is one of the most controversial current issues, and the use of renewable energy sources causes discrepancies, to say the least. A share of coal that is slightly higher than average is assumed by elderly people (aged 65+), rural residents, respondents with primary education, and respondents with low or average income per capita. Similarly, older, less educated and less well-off respondents favor the use of natural gas to a slightly greater extent than average. The development of nuclear energy is more often supported by men, residents of the largest cities, respondents with a higher socio-economic status, as well as young people. Women, slightly more often than the average, young people, but also middle-aged people aged 45-64, inhabitants of small towns and medium-sized and the largest cities, people with secondary and higher education, as well as relatively well-off individuals foresee and hope for the development of renewable energy sources [CBOS 2021].

Comparing studies from 2009 and 2016, opinions concerning renewable energy sources have changed significantly in Poland. In the opinion of the vast majority of respondents, renewable energy sources do not emit carbon dioxide at all. The respondents perceive solar, wind, hydro and geothermal energy as climate-friendly, not emitting carbon dioxide (87, 85, 83 and 75% of responses) [Badora 2016].

Energy consumption in Poland is also related to the level and quality of life. Generally speaking, the standard of living is the overall quality of the living conditions and the degree to which important needs such as living comfortably, satisfaction and pleasure in life are met. In this perspective, it is a synonym of broadly perceived living conditions [Piasny 1993]. Quality of life consists not only of the overall objective conditions in which a person lives but also the subjective quality of life experienced by individuals, also referred to as subjective well-being [GUS 2017]. Well-being is very often associated with consumerism, i.e., buying and using excessive amounts of durable goods that consume energy in people's households. In 2020, Polish households recorded purchasing additional household equipment such as a printer (by 17.1%), a dishwasher (by 14.0%), a smartphone (by 9.6%), a device with Internet access (by 6.1%), a car (by 5.3%) and a per-

sonal computer (by 5.2%). The differences in terms of equipment, including these devices, between the city and the countryside are decreasing [GUS 2021a].

Analyzing the situation in Poland for the period 2000–2020, expenses related to the use of a flat or house and energy carriers accounted for 17.9–18.8% of overall household expenditure (Table 1). In hous--holds' budgets, energy carriers include electricity and gas (charges for electricity consumption for lighting and heating purposes, charges for natural gas consumption and for filling gas cylinders for household needs); thermal energy (central heating and hot water) and fuel (liquid fuels <heating oils, kerosene>; hard coal, coke, firewood, other fuel products <lignite, peat, sawdust>) and other fuels [GUS 2021b]. The expenditure on energy carriers in 2000–2020 in Poland accounted for 9.7––10.3% of the structure of total expenditure (Table 2).

The average monthly expenditures per capita in households in relation to the use of a flat or house and energy carriers amounted to 18.8% in the structure of total expenditure in 2020. In individual quintile groups, this value ranged from 17.2% in the highest 5th quintile group and 18.8% in the 1st quintile group to approx. 20% in the 3rd and 4th quintile groups (Table 3) [GUS 2021b].

The lowest expenses in this regard were recorded in rural areas (17.1%), and the highest expenditure was observed in cities with 20–499 thousand residents (from 20.2 to 20% – Table 4), [GUS 2021b].

Table 2. Average monthly expenditures on housing, water, electricity, gas and other fuels per capita in Polish households in 2000–2020

Specification	Years									
	2000	2005	2010	2014	2015	2016	2017	2018	2019	2020
	(PLN)									
Expenditures* on	599.49	690.30	991.44	1078.74	1091.19	1131.64	1176.44	1186.86	1251.73	1209.58
housing, water, electricity, gas and other fuels	107.21	135.64	199.88	216.73	219.48	221.35	229.92	217.44	224.93	227.37
of which electricity, gas and other fuels	58.19	75.83	118.18	123.65	124.38	121.84	125.48	122.54	122.54	124.03
	% share in overall expenditure									
housing, water, electricity, gas and other fuels	17.9	19.6	20.2	20.1	20.1	19.6	19.5	18.3	18.0	18.8
of which electricity, gas and other fuels	9.7	11.0	11.9	11.5	11.4	10.8	10.7	10.3	9.8	10.3

*Since 2013, including expenditures for life insurance.

Source: own elaboration based on [GUS 2021b].

Table 3. Expenditures on housing, water, electricity, gas and other fuels per capita in Polish households by quintile groups

Specification	Grand total	Quintile group				
		I	II	III	IV	V
Expenditures (PLN)	1209.58	845.86	889.11	1064.52	1320.86	1931.42
housing, water, electricity, gas and other fuels (PLN)	227.37	159.13	178	214.11	254.62	331.55
The % share of expenditure related to housing, water, electricity, gas and other fuels in overall expenditure (%)	18.8	18.8	20.0	20.1	19.3	17.2

Source: own elaboration based on [GUS 2021b].

Table 4. Expenditures on housing, water, electricity, gas and other fuels per capita in Polish households by place of residence

Specification	Grand total	Urban							Rural
		total	town/city by size in thousands						
						100–499			
			less than 20	20–99	total	100–199	200–499	500 and more	
Expenditures (PLN)	1209.58	1346.85	1211.65	1200.09	1363.81	1324.85	1398.15	1665.51	994.97
housing, water, electricity, gas and other fuels (PLN)	227.37	264.16	231.18	242.62	273.05	265.61	279.61	315.89	169.84
The % share of expenditures related to housing, water, electricity, gas and other fuels in overall expenditure (%)	18.8	19.6	19.1	20.2	20.0	20.0	20.0	19.0	17.1

Source: own elaboration based on [GUS 2021b].

The construction of micro-photovoltaic systems is becoming more widespread in Poland. This interest has been developing since 2015, when the relevant law came into force. There has been a noticeable increase in the number of installed micro-installations in recent years. Very often, people who are initially skeptical about this type of investment after a certain period of time are convinced to install a photovoltaic micro-installation on their farm [Klepacka and Zalewska 2016]. The main task of a photovoltaic micro-installation is to supply a household with enough electricity so that the electricity produced fully covers the household's needs [Marciniak 2021]. Admittedly, a photovoltaic installation for an individual household is a large investment. However, investors in a photovoltaic micro-installation can reduce the cost of their investment with funds from programs that support the development of photovoltaics, as well as the available rebates. These programs significantly affect the efficiency of the investment, making it profitable from an individual point of view. As reported by Rakowska and Ozimek [2021], in Poland, as in other countries, public aid is significantly triggering, especially local authorities' renewable energy initiatives. It increases the number and scope of renewable energy investments as well as cooperation with other municipalities and participation in these programs of public organizations and private households. The average payback of the installation depends on the productivity effect of a given photovoltaic micro-installation and on the amount of own capital contribution to this investment [Olczak 2021]. Most often, it is about 8-10 years [Gryko 2020, Iwaszczuk and Trela 2021].The most popular support measure – 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 [Kulpa et al. 2022]. Gręposz-Krawczyk et al. [2021] study showed that households in Poland can pay for high quality, environmental protection, and future savings. Additionally, the various types of publicly funded programs supporting such investments also address the solutions to solve the problem of energy poverty [Biernat-Jarka et al. 2021]. Regional governments are especially focused on increasing the living conditions for the citizens by promoting programs investing in RES [Batyk et al. 2022]. However, will this favorable outlook on the development of photovoltaics be confirmed? Probably only time will tell. The adopted draft amendment to the RES Act assumes less profitable settlements with electricity suppliers for prosumers. Experts say that the boom in investments in photovoltaic panels will continue in 2021. This would probably be aided by government programs such as "Mój Prąd" (My Electricity). From 2022, however, when the changes proposed by the government come into force, the number of people interested in less profitable micro-installations will probably decrease [Czechowicz 2021].

RESULTS

The study tried to identify how long the respondents used the photovoltaic installation. This factor could have been important for further evaluations and the expressed attitudes. The results of the study are presented in Table 5. The respondents most often declared having photovoltaic installations for less than a year (41.1%) or 1 to 2 years (39.4%). Therefore, it emerges that the majority of respondents (80%) did not have a long experience in the use of photovoltaic installations. Women more frequently than men (44.4% and 37.9%, respectively) declared owning photovoltaic installations for less than a year. In the case of having photovoltaic installations for a period from 1 year to 2 years, the opposite situation was observed. Men more often than women had photovoltaic installations for 1 to 2 years (43.2 and 35.6%, respectively). Only a few respondents indicated that they have photovoltaic installations for 5 years or more (3%). The place of residence of the respondents differentiated the opinions of the respondents in a statistically significant way χ^2 (24) = 42.98, p <05. It is worth noting that the history of photovoltaics in Poland dates back to the beginning of the second decade of the 21st century [Rataj et al. 2021]. However, it was only in 2019 that co-financing for photovoltaics was introduced through the government program "Mój Prąd" (My Electricity).

More than half of the respondents indicated that the biggest incentive for them to install photovoltaic solu-

Table 5. Declarations of respondents regarding the time of owning photovoltaic installations (%)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Less than a year	41.1	44.4	37.9
1–2 years	39.4	35.6	43.2
3–5 years	16.5	16.7	16.3
5–10 years	2.6	2.5	2.6
More than 10 years	0.4	0.8	0.0

Source: own elaboration based on data provided by Alliance RES.

Table 6. Respondents' opinions on what prompted them to invest in photovoltaic installations (% responses)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Free source of energy	61.9	56.4	67.2
Co-financing of installation	50.3	56.3	44.3
Independence from increases in electricity prices	47.8	45.5	50.0
Ecological aspect – the use of renewable energy sources	45.8	49.2	42.4
Guarantee of energy security (independence from external power suppliers)	25.4	22.0	28.7
Property value increase	21.7	19.1	24.2
Reliability of the photovoltaic installation	21.0	21.3	20.8
Tax relief	20.8	16.0	25.6
Other	0.5	0.0	1.0
I don't know / hard to say	1.8	2.8	0.9

Source: own elaboration based on data provided by Alliance RES.

tions was a free energy source (61.9%) and installation subsidies (50.3%). Less than half of the respondents indicated independence from increases in electricity prices and the environmental aspect, i.e., the use of renewable energy sources. (Table 6).

Almost 1/3 of the users of the photovoltaic installation declared that the installation "definitely" met their expectations, and about 52% of the sample pointed to the "rather yes" answer (Table 7). Women indicated slightly more often than men that the photovoltaic installation "definitely" met their expectations (37.5 and 26.3%, respectively). Men, on the other hand, expressed opinions that the photovoltaic installation "rather" met their expectations more often than women (57.4 and 45.8%, respectively). Gender significantly differentiated the opinions of the respondents in this respect in a statistically significant manner (Table 7).

Among the survey participants, 2/3 of the respondents were convinced that the profitability of the photovoltaic installation is high or rather high (including about 18% of the responses that it is definitely high). However, almost a quarter of the respondents could not unequivocally answer this question, selecting the answer of "neither low nor high" (Table 8). It is worth noting that the lifetime of the photovoltaic installation (the time of use) in the case of 41% of respondents did not exceed 1 year, and in the case of 39%, it did not exceed 2 years.

Among the most important advantages and benefits of using photovoltaic installations, the respondents indicated two factors: free energy source (86.3%) and independence from increases in electricity price (78.5%). Over 2/3 of the respondents indicated the ecological aspect, i.e., the use of renewable energy sources (Table 9).

The most important disadvantages related to the use of photovoltaic installations that were most of-

Table 7. Opinions of the respondents about whether the photovoltaic installation met their expectations (%)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Definitely not	3.6	2.9	4.3
Rather not	3.0	2.6	3.4
Neither yes nor no	9.8	11.2	8.5
Rather yes	51.6	45.8	57.4
Definitely yes	31.8	37.5	26.3

Source: own elaboration based on data provided by Alliance RES.

Table 8. Opinions of the respondents on the profitability of a photovoltaic installation (%)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Definitely low	2.3	0.6	4.0
Rather low	7.2	8.4	6.0
Neither low nor high	23.6	21.2	25.9
Rather high	49.0	51.1	47.0
Definitely high	17.9	18.7	17.1

Source: own elaboration based on data provided by Alliance

ten indicated by the survey participants included the high price of the installation and the period of return on investment (77.4 and 71.2%, respectively). Women (83.8%) indicated the high price of the installation more often than men (71.1%). This can be explained by the fact that women are frequently responsible for household budgets. Less than 2/3 of the respondents indicated a decrease in the efficiency of the installation under unfavorable weather conditions. Nearly half of the respondents pointed to procedures related to grants and legal regulations as important disadvantages of using photovoltaic installations (Table 10).

The problems that may occur during the purchase or installation of photovoltaic installations were an important issue raised in the study. More than 2/5 of the respondents did not encounter such problems. This may be interpreted as the confirmation of the high quality of the devices and related services. The problem indicated most frequently was the issue related to obtaining a subsidy or obtaining a source of financing (24.1 and 19.5%, respectively). These problems were mentioned more often by men than by women (Table 11).

Investing in installations producing energy from renewable sources requires significant financial outlays from the outset. When investing in photovoltaic installations, respondents most often used their own resources (67.4%) and co-financing (or subsidies) (46.7%). Women used the subsidies more often than men (52.7 and 40.7%, respectively) (Table 12).

Table 9. The most important advantages and benefits of using photovoltaic installations indicated by the respondents (% of responses)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
Free source of energy	86.3	89.2	83.4
Independence from increases in electricity prices	78.5	74.6	82.4
Ecological aspect – the use of renewable energy sources	69.3	71.1	67.5
The increase in property value	33.4	37.4	29.5
Reliability of the photovoltaic installation	32.5	27.6	37.2

Source: own elaboration based on data provided by Alliance RES.

Table 10. The most important disadvantages related to the use of photovoltaic installations indicated by the respondents (% of responses)

Specification	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
High installation cost	77.4	83.8	71.1
ROI (payback) period	71.2	70.2	72.3
The decrease in installation efficiency in unfavorable weather conditions	62.1	62.4	61.8
Procedures related to grants and legal regulation	49.2	45.2	53.2
The need to clean the photovoltaic installation	40.0	38.4	41.7

Source: own elaboration based on data provided by Alliance RES.

Table 11. Problems indicated by the respondents which occurred during the purchase or assembly of photovoltaic installations (% of responses)

Specification	% of All [N = 197]	Gender	
		% of women [N = 98]	% of men [N = 99]
Problems with obtaining a subsidy	24.1	22.5	25.7
Problems with obtaining a source of financing	19.5	16.6	22.4
No possibility to eliminate shading (and the related decrease in system efficiency)	13.7	10.9	16.5
Improper installation	10.6	6.4	14.7
Others	1.1	0.8	1.4
I don't know/hard to say	12.6	21.3	4.0
I have not encountered any problems	43.0	43.8	42.2

Source: own elaboration based on data provided by Alliance RES.

Table 12. Sources of financing used by the respondents when making investments in photovoltaic installations (% of responses)

Specification	% of All [N = 197]	Gender	
		% of women [N = 98]	% of men [N = 99]
Own funds	67.4	68.0	66.7
Co-financing / subsidies	46.7	52.7	40.7
Credit	13.4	10.1	16.5
Bank loan	14.1	13.7	14.4
Leasing	1.9	3.2	0.6
Other	1.1	2.2	0.0
I don't know/hard to say	3.3	5.0	1.7

Source: own elaboration based on data provided by Alliance RES.

The respondents most often declared that when deciding to install photovoltaic devices, they benefited from the subsidies: "Mój prąd" (My Electricity) (16.2%) "Czyste Powietrze" (Clean Air) – 16.2%, "Ulga podatkowa związana z termomodernizacją" (Tax relief related to thermal modernization)–- 14.7% and "Program regionalny" (Regional Program) (e.g., Poznań – Program Słoneczne Dachy/Sunny Roofs Program) – 8.6%.

The purpose of the study was also to gain knowledge of whether photovoltaic installation users would recommend these solutions to their friends or family. Respondents were asked to respond to this question using a scale from 0 to 10. In the question, the score "0" meant that the respondent "would not recommend investing in photovoltaic installations to friends or family at all" and "10" would be assigned to the response related to the situation where the respondent "would definitely recommend investing in photovoltaic installations to friends or family"). The vast majority of respondents would recommend investments in photovoltaic installations to their friends or family (the share of 6% and more ratings was 95.1% – Table 13). This means that there is potential for the growth and development of clean energy production.

Descriptive statistics for selected assessments of photovoltaic installations by the respondents are presented in Table 14.

The authors examined the relationship between the respondents' opinions on whether the photovoltaic installation met their expectations. The other aspects as-

Table 13. Declarations of the respondents regarding the recommendation to invest in photovoltaic installations to friends or family (%)

Assessment	% of All [*N* = 197]	Gender	
		% of women [*N* = 98]	% of men [*N* = 99]
0	1.3	0.6	2.0
2	0.4	0.0	0.9
3	0.3	0.5	0.0
4	1.0	0.9	1.1
5	1.9	2.2	1.7
6	12.1	11.4	12.8
7	11.2	10.9	11.5
8	26.9	23.0	30.8
9	22.7	30.8	14.7
10	22.2	19.8	24.6

(Rated on a scale from 0 to 10. In this case, '0' means that the respondent would 'not recommend the investment in photovoltaic installations to friends or family at all' and '10' means that the respondent would 'definitely recommend investing in photovoltaic installations to friends or family')

Source: own elaboration based on data provided by Alliance RES

Table 14. Descriptive statistics for selected assessments of photovoltaic installations by the respondents

Description	Gender	*N*	Mean	Std. error	Median	Std. Dev.	Skew–ness	Kurto-sis
the photovoltaic installation met their expectations*	Women	98	4.02	.092	4.00	.951	–1.310	2.134
	Men	99	4.04	.097	4.00	.932	–1.571	3.230
	all	197	4.03	.066	4.00	.940	–1.417	2.520
profitability of the photovoltaic instal-lation**	Women	98	3.69	.089	4.00	.926	–.652	.256
	Men	99	3.70	099	4.00	.953	–.898	1.083
	all	197	3.70	.066	4.00	.936	–.766	.616
recommendation of a photovoltaic installation to friends/family***	Women	98	8.11	.163	8.00	1.690	–1.530	4.336
	Men	99	8.03	.207	8.00	1.992	–1.784	4.757
	all	197	8.08	.130	8.00	1.832	–1.692	4.690

* the evaluation was made on a 5-point scale, where 1 represented the response "definitely not", and 5 – "definitely yes"; ** assessment made on a 5-point scale, where 1 represented "markedly low profitability", and 5 – "very high"; *** assessment made on a scale from 0 to 10, where "0" – means that the respondent "would not recommend investing in photovoltaic installations to friends or family at all", and "10" that the respondent would "definitely recommend investing in photovoltaic installations to friends or family".

Source: own elaboration based on data provided by Alliance RES.

sessed by the study were the profitability of the photovoltaic installation and the respondents' recommendation to invest in photovoltaic installations to their friends or family. It is important to note that the increase in the positive assessment of the respondents of the photovoltaic installation was accompanied by an increase

Table 15. Spearman's rho correlation coefficients

Categories/ Spearman's rho	The photovoltaic installation met their expectations	Profitability of the photovoltaic installation**	Recommendation of the photovoltaic installation to friends/family***
The photovoltaic installation met the respondents' expectations1	X	.558**	.605**
Profitability of the photovoltaic installation2*	.558**	X	.514**
Recommendation of the photovoltaic installation to friends / family3	.605**	.514**	X

**correlation statistically significant at 0.01 (two-tailed) **; 1) the evaluation was made on a 5-point scale, where 1 represented the response "definitely not", and 5 – "definitely yes"; 2) assessment made on a 5-point scale, where 1 represented "markedly low profitability", and 5 – "very high"; 3) assessment made on a scale from 0 to 10, where "0" – means that the respondent "would not recommend investing in photovoltaic installations to friends or family at all", and "10" that the respondent would "definitely recommend investing in photovoltaic installations to friends or family".

Source: own elaboration based on data provided by Alliance RES.

Table 16. Declarations of the respondents regarding plans for further use of their photovoltaic installation (%)

Specification	% of All [N = 197]	Gender	
		% of women [N = 98]	% of men [N = 99]
I plan to use it without introducing any changes or modifications	57.1	64.7	49.7
I am planning to expand my photovoltaic installation	23.7	16.4	30.9
I am planning a new/additional investment in a new location	2.2	1.8	2.5
Other plans, what kind?	0.6	0.0	1.1
I don't know/hard to say	16.4	17.1	15.8

Source: own elaboration based on data provided by Alliance RES.

in both the profitability of the photovoltaic installation (Spearman's rho = 0.558, p <0.01, respectively) and the willingness to recommend the photovoltaic installation to friends/family (Spearman's rho = 0.605. p <0.01). The highest coefficient was noted between the answer to the question about meeting the expectations and the order of the photovoltaic installations (Spearman's rho = 0.605. p <0.01). The lowest coefficient was recorded between the profitability declared by the survey participants and the recommendation of photovoltaic installations (Spearman's rho = 0.514. p <0.01) (Table 15).

More than half of the respondents plan to continue using their photovoltaic installation, and less than a quarter of them plan to expand it (Table 16). Women did not plan to introduce any changes to their installation more often than men. The declarations regarding the expansion of their photovoltaic installations applied to men twice as often as women. Gender significantly differentiated the opinions of the respondents in this regard.

The study participants emphasized that they most often obtain information on photovoltaic installations and renewable energy sources using a search engine on the Internet (46.5%) and from friends and family (43.5%). Additionally, about 1/3 of the respondents pointed to industry websites, information obtained directly from the seller and blogs or internet forums (Table 17). Multi-channel information acquisition allows for more informed decision-making, taking into account the experience of individual

Table 17. The sources of information on photovoltaic installations and renewable energy sources (RES) declared by the respondents (% of responses)

Specification	% of All [N = 197]	Gender	
		% of women [N = 98]	% of men [N = 99]
Search engine (e.g., Google)	46.5	47.7	45.2
Friends/family	43.5	50.5	35.5
Industry websites	37.0	36.4	37.6
Directly from the seller	34.0	30.8	37.6
Blogs and internet forums	33.0	32.7	33.3
Social media (e.g., Facebook)	24.5	31.8	16.1
Offices and institutions (e.g., local governments, municipal offices, town halls or ministries)	23.5	25.2	21.5
Economic and business media	22.5	17.8	28.0
Other	1.5	0.9	2.2
I don't know/hard to say	2.0	2.8	1.1
I do not use any sources of knowledge	1.0	0.0	2.2

Source: own elaboration based on data provided by Alliance RES.

users who have already invested in micro-photovoltaic systems.

DISCUSSION

According to the Institute for Renewable Energy (Instytut Energii Odnawialnej), photovoltaics in Poland, unlike many countries in Europe, currently has a prosumer character. In the CBOS survey from 2016, 50% of 992 respondents indicated that it is necessary to focus on renewable energy sources, i.e., solar radiation, wind, water and biomass. At the same time, only every fifth respondent stressed (including 7% – "definitely yes", and 15% – "rather yes") that they are considering the use of installations enabling the use of renewable energy sources in their home/outbuilding as part of investment plans in the next 2–3 years [Rynek 2021].

In the CBOS study (2016), people considering the independent production of heat energy showed a marked preference for solar collectors (76%). The respondents intended to generate electricity using installations focused primarily on photovoltaic panels (73%). Rural dwellers (26%) more often than city dwellers considered the possibility of installing devices that enable the use of renewable energy sources in their homes or outbuildings. This solution was the most popular among people working on private farms (36%) [Gwiazda 2016].

The study shows that incentives for owning photovoltaic installations are also important. In the proprietary research, more than half of the respondents indicated that a free source of energy (61.9%) and funding for installation (50.3%) were the factors that prompted them to invest in photovoltaic installations. Less than half of the respondents indicated independence from increases in electricity prices. Our study also indicated that energy independence is very important to Polish consumers, similarly to the ecological aspect, i.e., the use of renewable energy sources. These findings are confirmed by the results of other studies, e.g., the SunSol report "Poles and solar farms 2021" commissioned by the Quantify research agency. The survey, which was carried out in June 2021 using an online questionnaire (CAWI) on a representative group of 1,000 respondents [Kurek 2021], pointed to the main motivations for using RES. The main incentive for Poles is the independence from external suppliers associated with using energy

generated by photovoltaic panels. This answer was indicated by 72% of respondents. The remaining answers to the question included a 22% share pointing to "partially", and 6% of the respondents indicated the opposite opinion. In addition, half of the respondents also considered photovoltaic panels to be the best energy solution in terms of ecology.

In the study, the most important disadvantages related to the use of photovoltaic installations most often indicated by the respondents included: the high price of the installation and the period of return on investment (77.4 and 71.2%, respectively). As emphasized by Wolske et al. [2018], households' use of energy-efficient and renewable energy technologies can significantly reduce emissions from electricity generation. However, high installation costs are often an obstacle in deciding to switch to renewable energy, even if the future energy savings can offset the costs. The researchers carried out a series of randomized experiments to establish whether framework strategies based on behavioral economics and psychology can be used to increase the financial attractiveness of such products. The study involving mock advertising for Residential Solar Photovoltaics (PV) revealed that the reformulation of the financial benefits of photovoltaics does not significantly affect the attractiveness of photovoltaics or the likelihood of responding to false advertising. However, it was discovered that the basic motivations and incentives for consumers (i.e., perceived social support, consumer innovation, and personal environmental standards) are the main drivers of interest in the use of solar energy. The study findings suggest that tailoring messages to target consumer segments may be more effective than trying to promote the financial benefits of solar PV to a wider public [Wolske et al. 2018].

It can be learned from the study that the respondents most often learn about photovoltaic installations and renewable energy sources using a search engine on the Internet (almost half of the respondents). Friends and family are the second most popular source of information for them. Also, according to the SunSol report, 41% of the respondents were already interested in the topic and looking for additional information. They paid attention to the price when choosing the company's services (60%). The next important factor was the guarantee and quality of the components used (55 and 46% of survey participants). 44% of the respondents noted the company's qualifications, and a 40% share indicated previous projects. Reviews on Google are important to 28% of respondents, and certificates and awards for 16% of the survey participants [Kurek 2021].

As the findings of the research show, the respondents most often indicated the problem connected with obtaining a subsidy or the problem related to obtaining a source of financing. The respondents most often declared that they benefited from the subsidies for photovoltaic installations. The sources of funding included the subsidies such as "Mój prąd" (My Electricity) – 16.2%, "Czyste Powietrze" (Clean Air) – 16.2%, "Ulga podatkowa związana z termomodernizacją" (Tax relief related to thermal modernization) (14.7%) and "Program regionalny" (the Regional Program) – 8.6%. Other studies also confirm the popularity of these subsidies. According to the SunSol report, Poles are familiar with government programs for financing photovoltaic investments. The aforementioned "Czyste Powietrze" program was indicated by 51% of respondents and "Mój prąd" by 31% of respondents. "Ulga podatkowa związana z termomodernizacją" program, which offers the highest co-financing (annual income deduction), came third in the ranking. 14% of respondents have heard about individual loans and preferential loans, and 5% of respondents have not heard of any co-financing program [Kurek 2021]. It is worth emphasizing that on 6 October 2021, the call for applications for co-financing photovoltaic micro-installations under the "My Electricity 3.0" program for 2021–2023 (started on 1 July 2021) was closed by the National Fund for Environmental Protection and Water Management (NFOŚiGW) due to exhaustion of funds. PLN 534 million was allocated for this purpose, and 178,000 households benefited from subsidies of up to PLN 3,000 [Kołodziejszyk 2021].

Finally, the results indicate different gender perspectives on investments in photovoltaic micro-installations in Poland. For women more than men, the investments were related not only to high profitability despite initial significant installation costs, but also to ecological aspects. On the contrary, for men more than for women, the factors related to independence from energy prices were more important, which led to the declaration that

they would plan to expand the investment. Also, the results of the study by Rosak-Szyrocka and Żywiołek [2022] show that respondents with knowledge about energy behave differently by gender on issues related not only to consumption but also to source and investment in green energy.

CONCLUSIONS

The status of prosumers of green energy is an upper level of consumption and contributes to a higher level of sustainability awareness. The research conducted on the representative research sample of individual users of micro-photovoltaic installations in Poland allows for identifying the determinants of the willingness to invest in such solutions as well as satisfaction with being a prosumer of green energy. It was found that the surveyed respondents mostly used micro-installations for a short period (80.5% for up to 2 years), and generally expressed satisfaction with the investment, assessing it as profitable. The most important advantage of using photovoltaic micro-installations included factors such as using a source of free energy (86.3%) and independence from electricity price increases (78.5%). The most important disadvantages were the high price of installation and the period of return on investment (77.4 and 71.2%, respectively). The vast majority of respondents would recommend investments in photovoltaic micro-installations to other potential users, especially their friends or family (95.1%). The recommendation would be more likely to be given by women than men. The individual users of photovoltaic micro-installations, due to their activities in the green energy market as prosumers, not only increased the amount of renewable energy available but also increased the social awareness of the benefits of such solutions. Therefore, it is important to promote, as part of the pro-ecological policy, investment in photovoltaic micro-installations as well as the adopted measures aimed at promoting this renewable energy source among individual users. The study's main limitation is the lack of regional perspective on the issues discussed. Therefore, further research in this area should primarily take into account this aspect.

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DETERMINANTY INWESTYCJI W MIKROINSTALACJE FOTOWOLTAICZNE PRZEZ UŻYTKOWNIKÓW INDYWIDUALNYCH W POLSCE

STRESZCZENIE

Cel: Celem artykułu jest określenie zachowań i postaw polskich inwestorów i użytkowników wobec instalacji fotowoltaicznych w Polsce. **Metody:** Badanie zostało zrealizowane przez ARC Rynek i Opinia (Instytut Badania Opinii i Rynku) na zlecenie spółki Alians-OZE, która w ramach współpracy praktyki gospodarczej z nauką udostępniła wyniki badania autorom niniejszego opracowania. Badanie zostało przeprowadzone w kwietniu 2021 roku techniką CAWI. **Wyniki:** Do najważniejszych zalet korzystania z mikroinstalacji fotowoltaicznych należały takie czynniki jak korzystanie ze źródła darmowej energii oraz uniezależnienie się od wzrostu cen energii elektrycznej. Najważniejszymi wadami były wysoka cena instalacji oraz okres zwrotu z inwestycji. **Wnioski:** Indywidualni użytkownicy mikroinstalacji fotowoltaicznych, dzięki swojej aktywności na rynku zielonej energii jako prosumenci, nie tylko zwiększyli ilość dostępnej energii odnawialnej, ale także podnieśli świadomość społeczną na temat korzyści płynących z tego typu rozwiązań. Dlatego tak ważne jest promowanie, w ramach polityki proekologicznej, działań mających na celu promocję tego odnawialnego źródła energii wśród indywidualnych użytkowników.

Słowa kluczowe: energia odnawialna, fotowoltaika w budynkach mieszkalnych, zachowania rynkowe, prosument