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Energy Behaviors of Prosumers in Example of Polish Households

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Abstract: This paper explores ways to save energy in households with energy prosumers who generate energy using photovoltaic panels and heat pumps. On the basis of a literature analysis, we formulated a research gap in the case of the energy behaviors of prosumers. This research is important due to the growing demand for energy and the transitions of countries toward renewable energy sources. The role of prosumers in the economy is growing as they ensure energy independence and cost savings. The main purpose of this research is to understand the energy behaviors of prosumers and to examine the differences in energy behaviors between users of photovoltaic systems and heat pumps. A sample of 326 Polish prosumer households was selected using the CAWI method in order to obtain empirical data. The results suggest that prosumers show advanced ecological behaviors, and more than half of the respondents implement pro-ecological behaviors in their homes. Being a prosumer is associated with energy independence, which leads to economic stability and less dependence on traditional energy sources. The results indicate that prosumers show a general inclination toward pro-ecological behavior. Thus, this study recommends promoting prosumers and encouraging the use of pro-ecological energy as a priority for the economy. This initiative will contribute to a reduction in energy consumption in various areas, thus raising ecological awareness and a sense of responsibility for the environment.

Keywords: energy behavior; prosumer; households; responsible consumption; energy sector; Poland

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1. Introduction

The world, and developed countries in particular, is facing the need to diversify energy sources and save energy. It is estimated that by 2050, the share of renewable energy sources (RESs) will account for about 55% of the total energy consumption [1]. Saving electricity is very important in terms of the decarbonization of economies and the sustainability of industries. When companies and consumers conserve electricity, power plants and other energy suppliers do not need to produce as much, thus polluting the environment less (reducing CO_2 emissions). By using less electricity in households, consumers have smaller bills, i.e., they gain savings in their household budget. There are many ways to save electricity, ranging from rational lighting in a home to the correct use of household appliances to economical heating [2]. Environmental responsibility takes on particular importance with the clarification of 'green transition' policies. Consumers and prosumers of energy should be made aware of forms (ways) of saving energy. Energy awareness must become apparent in the practical and cognitive fields of human activity. In the concept of the 'green transition', energy responsibility refers to economies' overarching value of global sustainability. After the COVID-19 pandemic, new assumptions for the development of the

industry, called 'Industry 5.0' (report from 5 Jun. 2021), have emerged in EU documents, in which a return to sustainability is taking place [3]. Contributing to the development of household sustainability are energy prosumers, i.e., people who use renewable energy and heat sources in their households [4,5] and who are aware of the need to save energy and energy resources. Environmental awareness models of households are increasingly based on eco-friendly houses [6,7]. However, in order for there to be more and more such houses (flats), environmentally aware users are needed.

Analyzing how households with renewable energy prosumers can save energy was the subject of our research. The prosumers were producers of energy obtained from photovoltaic panels and heat pumps installed in households. This research was conducted on a sample of 326 households in Poland. Two household segments (Ss) were distinguished among the respondents: (i) photovoltaic (PV) panel users/prosumers (Segment 1, S1) and (ii) heat pump (HP) users/prosumers (Segment 2, S2). The authors investigated ways of saving electricity in the following areas: lighting, electrical appliances, daily habits, and the heating of flats and houses, rating them on a Likert scale from one to five, where one is the lowest grade (respondent negation and a negative prosumer attitude) and five the highest grade (full acceptance and an active prosumer attitude).

The aim of this study was to identify the energy behaviors of Polish prosumers. This topic is particularly important because the demand for energy in the world is constantly growing. According to the report World Energy Outlook 2020, the energy demand will increase by 12% between 2019 and 2030 [8]. In the policies of many countries, there is a strong emphasis on shifting consumer energy consumption from non-renewable sources to renewable energy sources such as solar, hydro, and wind [9–12]. In addition, users are encouraged not only to reduce their household energy consumption but also to generate renewable energy in their home environment and return excess energy to the grid, i.e., becoming prosumers.

Based on a literature analysis, we formulated a research gap in the case of the energy behaviors of prosumers. This topic was not analyzed in a complex way from prosumers' points of view on various behaviors. The new aspects in our paper compared with the previous one are the broach research base and also the deep analysis based on many aspects connected to prosumers. In particular, we did not find in the analyzed papers research on the differences and similarities between the cases of photovoltaic system prosumers and heat pump prosumers.

To achieve the research aim, three research questions (RQs) were formulated:

RQ1: What specific energy behaviors do prosumers exhibit?
RQ2: What disparities in energy behaviors can be identified between users of photovoltaic systems and heat pumps?
RQ3: Are prosumers' claims about saving energy resources reflected in actual behaviors?
RQ4: What energy behaviors related to the reduction in electricity consumption are undertaken by prosumers and with what frequency?
RQ5: What energy behaviors related to saving thermal energy are undertaken by prosumers and with what frequency?

Detailed information about the methodological approach in the research presented in this paper is in Section 3: Materials and Methods.

2. Background for Research

Returning to the history of sustainability, the concept of socio-economic sustainability was defined by the World Commission, the G. Brundtland Commission on Environment and Development, established in 1983. It defines sustainable development as one in which the needs of the present generation can be met without depriving future generations of the ability to meet their needs. After many years, each of us has our own view on the balance between what building sustainability is and what it can be in order to preserve the environment for us and future generations. From the sustainability of industries, especially strong energy-intensive industries, e.g., the steel industry [13–16], one moves

on to the sustainability of households. Household sustainability should be manifested in the behavior of prosumers in particular, i.e., individuals or economic entities that are both consumers and producers of energy. Of particular importance is energy awareness in The European Green Deal [16], which is the new growth strategy for an EU economy that is sustainable, cleaner, safer, and healthier. The document includes a roadmap for a new future by 2050 with net-zero CO_2 emissions and other greenhouse gases via the efficient use of resources in the circular economy, the restoration of biodiversity, and other cuts to pollution. The implementation of each direction requires the involvement of many actors who have specific relationships and dependencies with each other, hence highlighting the growing importance of their environmental responsibilities. One important (key) level of responsibility is energy consciousness, which is built on many economies, such that both individual and collective consumers need to save energy. At the household level, energy behavior manifests itself in various forms of energy conservation in houses and flats.

In recent years, prosumer activity in the broader field of sustainability and environmental protection has been gaining momentum. In the long term, there is has been a noticeable change in the behavior of energy prosumers, including energy conservation and the use of renewable energy sources [16–18]. According to the Cambridge Dictionary, the term is a portmanteau of the words producer and consumer [5]. The word 'prosumer' is made from two words: 'producer' and 'consumer' [4,5]. The term 'prosumer' is used to refer to energy producers and consumers [4]. The initiator of the name prosumer was Alvin Toffler (1980) in his book *The Third Wave* [19]. In this book, Toffler argues that in the future, consumers will produce more goods and services for self-consumption. In [20], the following definitions of a prosumer are presented: (i) 'A prosumer is someone who both produces and consumes energy' [21], (ii) 'Prosumers are individuals who are both able to 'produce' as well as 'consume' products or services' [22], (iii) 'Prosumers in the energy markets are energy consumers who produce or co-produce their energy demand individually or through collective organizations' [22], and (iv) 'Prosuming refers to when energy customers actively manage their own consumption and production of energy' [23]. In many documents, both 'prosumer' [24,25] and 'renewable self-consumer' or 'active customer' [26] appear. Bodo et al. introduced six types of prosumers: DIY prosumers, self-service prosumers, customizing prosumers, collaborative prosumers, monetized prosumers, and economic prosumers [27]. In the field of renewable energy, prosumers are households or organizations that sometimes produce surplus fuel or energy and feed it into the national (or local) distribution grid, while at other times (when their demand for fuel or energy exceeds their own production), they consume the same fuel or energy from the grid. This is commonly undertaken by households using photovoltaic panels on their roofs to generate electricity. Such households can additionally use battery storage to increase the share of self-consumed PV electricity, which is referred to in the literature as presumption [28,29]. The European Union's Nobel Grid project, which is the part of the Horizon 2020 research and innovation program, uses this term to refer to producers and consumers of green energy. In our research, we refer to users of photovoltaics and heat pumps as energy prosumers. Energy prosumers are divided into individual, collective and SMEs, and public organizations [24]. The respondents in our research are individual energy prosumers.

The issue of energy price hikes is not new, and it has been observed that energy consumption bills have increased due to the rising cost of CO_2 emission allowances associated with the environmental policies of the European Union. This has a greater impact on countries that heavily rely on traditional energy production methods, such as Poland. With the added burden of the COVID-19 pandemic and the ongoing economic crisis, the rising cost of electricity puts a strain on the finances of many households and businesses. This highlights the significance of unforeseeable events and their impact on the energy stability of various economies [30].

The complicated situation in the energy market emphasizes the need for action to control the progressive increase in energy prices and their negative consequences. One such

action is to focus on obtaining energy from renewable sources, which requires energy policies at the national level to outline the framework and set conditions for the development of renewable energy sources [31,32].

In recent years, rising markets have had a significant impact on energy prosumers in Poland. The increasing demand for energy, coupled with the rising costs of traditional energy production, has made it challenging for households and businesses to access affordable and reliable energy [33].

One of the major drivers of rising energy markets in Poland is the country's heavy reliance on coal. Coal accounts for more than 80% of Poland's electricity production, making it one of the most coal-dependent countries in Europe. However, the rising costs of coal production, coupled with the increasing costs of carbon emission allowances associated with the European Union's environmental policies, have made it difficult for traditional energy producers to maintain affordable energy prices [34,35].

As a result, many households and businesses in Poland have had to pay higher energy bills, placing a strain on their finances. This is particularly challenging for low-income households and small businesses, which are more vulnerable to rising energy costs. Many of these prosumers have had to cut back on their energy consumption, compromising their quality of life and business operations [36]. Moreover, the impact of rising markets on energy prosumers in Poland has been compounded by the COVID-19 pandemic and the economic crisis it has caused. Many households and businesses have seen a decline in their incomes, making it even more challenging to afford rising energy prices [37,38].

To mitigate the impact of rising markets on energy prosumers in Poland, the government and energy companies have taken several measures. One of these measures is to encourage the use of renewable energy sources, such as wind and solar power. The government has set targets to increase the share of renewable energy in the country's energy mix, and energy companies are investing in renewable energy projects. Another measure is to improve energy efficiency in households and businesses [39,40]. This can be achieved through energy-saving technologies, such as LED lighting and energy-efficient appliances. The government has also launched programs to support energy-efficient renovations of buildings [41].

Many people are looking for solutions on how to save money on home heating and electricity. Some install special devices to save electricity and reduce electricity consumption. Others install photovoltaic panels, heat pumps, and other devices to have their own energy supply. Household investment in renewable energy sources is dictated by the rapidly rising price of traditional energy and overriding policies [42].

Solar energy is the most readily available source of electricity for consumers. The sun is a renewable source of energy and by installing photovoltaic panels, its rays can be converted into electricity, thus reducing the electricity intake from the public grid and providing independence from electricity price increases. Domestic photovoltaic installations are an investment that not only saves energy in an environmentally friendly way but also reduces electricity bills without depleting household budgets [24]. As the International Energy Agency (2021: 15) writes, 'In most markets, solar PVs are the cheapest available source of new electricity generation [26].' On the environmental aspect, it is important to note that PV panels do not generate any direct greenhouse gases during operation and use. The use of energy from PV panels is considered a 'low environmental impact' choice because they use a 'clean' source such as the sun, avoiding the production of greenhouse gases [43]. They exploit energy flows in the environment at zero marginal 'fuel' cost [44]. They have gone through all stages of commercialization, from early pilot development to widespread adoption and commercialization [45]. The technology is continually being improved, and its performance is improving (the efficiency of the panels is increasing). The availability of the technology is increasing in the markets, resulting in lower costs [46,47]. In recent years, photovoltaics has started to become the fastest-growing energy technology in the world. Examples of the development of photovoltaic technology are coming from many countries, including both highly developed—among the EU countries, mainly Germany and the

UK [48–50]—and developing countries [51–54]. Among all PV panels installed worldwide, China has the largest share (31%), followed by the USA (15%) and India (7%) [55,56]. In Poland, at the end of December 2022, the installed capacity of photovoltaic technologies was 12, 189.1 MW. This is 58.7% more than in December of the previous year when 7681.4 MW was recorded. Prosumer PV installations had a capacity of 8773.91 MW. Their number was 1,193,053 units [57]. According to the Institute of Renewable Energy (in Polish, the IOE), the number of users (prosumers) in Poland is approaching one million [58].

In recent years, heat pumps (heat pumps do not emit harmful emissions during operation and mainly use renewable energy sources for their operation) have become an increasingly popular source of (ecological) heating for households, following photovoltaic panels. Heat pumps, like photovoltaic panels, can be used to heat houses and flats and provide hot water for their users. Heat pumps reduce CO2 emissions by an average of 20% (compared with gas boilers) [59]. In 2021, sales of heat pumps increased by 34% in Europe (the European Heat Pump Association (EHPA)) [60 principles in life]. In 21 countries, 2.18 million heat pumps were sold, which is almost 560,000 more than in 2020. This brings the total number of installed heat pumps in the EU to 16.98 million, covering approximately 14% of the heating market (EHPA) [60]. In Poland, based on data from the NFOSIGW, the share of heat pumps in consumer applications under the government's 'Clean Air' program in April 2022 was 49% [61]. According to the EHPA, in 2021, Poland was among the top countries with the strongest relative gains in heat pumps (an increase of 87%). The next places were occupied by Ireland (+69%), Italy (+63%), Slovakia (+42%), Norway and France (+36% each), and Germany (+28%) [62].

In EU countries, fossil fuel energy production technologies are being replaced by renewable energy production technologies, in line with member state policies. Strongly promoted by government institutions, renewable energy technologies create new opportunities for economies, industries, and people, but there are also barriers that can slow down the energy transition. The EEA report [24] details legislative (regulations for individual prosumers are relatively well developed), financial (high transition costs), technological (self-consumption with PV panels usually requires no additional energy infrastructure), and social (social resistance and a lack of knowledge of renewable energy sources, such that, often, households have little specialist knowledge) barriers. Current EU policy pays attention to economic support for transforming households, especially for those with low incomes. High energy prices and low incomes are major causes of energy poverty. When energy-poor households become prosumers, their energy bills will stabilize, and they will be better protected against rising electricity prices. Furthermore, households must not only be consumers of the energy produced (their own energy) but also be producers for others, and this requires an expansion of infrastructure investment [62].

Circular economy strategies are enablers for new sources of energy adoption in households [63]. In the circular economy, the life cycle of equipment, including used renewable energy devices, is being extended. Photovoltaic (PV) panels have an average lifespan of 25–30 years, and their disposal is very important for recovering already used materials and for putting them back into other processing cycles. Forward-thinking prosumers are considering how to solve the problem of recycling PV panels installed in homes in the future. With the initiative of a number of organizations, resource recovery centers are already being set up for end-of-life PV panels. The life cycle of technologies must be closed. Innovative solutions are therefore needed to minimize the emission of pollutants derived from the recycling of photovoltaic panels that no longer work [56].

After the presentation of the market with the key renewable energy sources in which prosumers are investing, it is important to emphasize the importance of prosumer energy awareness for economies. The role of prosumers in the economy is becoming increasingly important as the world transitions towards a more sustainable energy system. In this essay, we will explore the various ways in which prosumers contribute to the economy [64,65]. Prosumers provide an opportunity for energy independence. By generating their own energy, prosumers can reduce their reliance on traditional energy sources, which can be

unstable or subject to price volatility [66]. This provides prosumers with energy independence, which can lead to greater economic stability. They can also save money on energy costs. The cost of renewable energy technologies such as solar panels and wind turbines has fallen significantly in recent years, making them increasingly competitive with traditional energy sources [67,68]. By generating their own energy, prosumers can save money on energy costs, particularly if they use renewable energy sources [69].

Prosumers play an important role in modern society by actively engaging in the production and consumption of energy. The term 'prosumer' is derived from the words 'producer' and 'consumer' and refers to individuals or organizations that generate their own energy through renewable sources while also consuming energy from the grid. They are becoming increasingly popular due to the growing concerns over climate change and the need for sustainable energy sources [70–72]. By producing their own energy, prosumers are reducing their carbon footprint and contributing to the transition towards a low-carbon economy [73]. Additionally, prosumer-based systems can help to increase energy security, reduce dependency on traditional energy sources, and promote local economic development [74,75].

In addition to the environmental and economic benefits, prosumers also play a social role in modern society [76]. By participating in renewable energy production, prosumers are contributing to the development of more sustainable and resilient communities [77,78]. Prosumer-based systems also promote community engagement and participation as individuals and organizations work together to develop and maintain a renewable energy infrastructure [79–81].

Prosumers can help to stabilize the electrical grid. When prosumers generate more energy than they consume, they can provide excess energy back to the grid. This can help to stabilize the grid, particularly during peak demand periods [82,83]. Prosumers can also help to reduce the need for costly grid upgrades by providing local energy sources. The growth of the renewable energy market due to prosumers can lead to job creation [84]. As more households and businesses adopt renewable energy technologies, there will be an increased demand for the installation, maintenance, and manufacturing of these technologies. This can lead to job creation in these areas, contributing to the growth of the green economy [85–87].

Prosumers have the ability to share excess energy with other prosumers, with the goal of increasing the use of renewable energy and reducing the economic impact of energy storage systems (ESSs) and generation costs. However, to further increase the use of renewable energy, there is a need for a more efficient energy trading mechanism. One potential solution is to implement this approach on campuses, which could help to further reduce the operational costs of a system [70].

It is worth pointing out that prosumers can spur innovation in the energy sector. By adopting and investing in new renewable energy technologies, prosumers can create demand for these technologies, which can spur innovation and technological advancements in the energy sector. By reducing their carbon footprints and contributing to the reduction in greenhouse gas emissions, prosumers help to mitigate climate change [88,89]. This has important economic implications, as climate change can have significant economic costs, such as damage to infrastructure and agricultural productivity [90]. Prosumers contribute to energy independence, cost savings, grid stability, job creation, innovation, and environmental benefits. As the world continues to transition toward a more sustainable energy system, the role of prosumers will only become more important [91–94].

Prosumers, or consumers who also produce energy, play an important role in the decarbonization of the economy. One of the main ways in which prosumers contribute to decarbonization is through the use of renewable energy sources, also known as RESs (renewable energy sources) [95]. It can be observed that prosumers can contribute to the growth of RESs. By adopting renewable energy technologies such as solar panels or wind turbines, prosumers create demand for these technologies, which can spur innovation and investment in the RES sector. As more households and businesses adopt RES technologies,

the demand for fossil fuels decreases, which can lead to a reduction in greenhouse gas emissions [96–99].

They also can help to integrate RESs into the energy system. As the share of RESs in the energy system grows, it becomes increasingly important to manage the variability and intermittency of these energy sources [100]. Prosumers can help to integrate RESs into the energy system by providing local energy sources, reducing the need for costly grid upgrades, and providing energy back to the grid when they generate more energy than they consume. By adopting energy-efficient technologies and reducing overall energy consumption, prosumers can reduce the need for energy production, including RESs. This can help to reduce the environmental impact of energy production and contribute to the decarbonization of the economy [101,102].

It can be pointed out that prosumers can contribute to the development of energy communities. Energy communities are groups of individuals or organizations that cooperate to produce, store, and consume energy. By creating energy communities, prosumers can work together to maximize the use of RESs and reduce the environmental impact of energy production. The relationships between prosumers and RESs are crucial for the decarbonization of the economy [103,104]. Prosumers can contribute to the growth of RESs, help to integrate RESs into the energy system, reduce energy consumption, and contribute to the development of energy communities. As the world continues to transition toward a more sustainable energy system, the role of prosumers and RESs will only become more important in achieving the goal of decarbonizing the economy [105,106].

In the context of our publication topic, household (human) awareness is important at the decision-making stage of choosing a renewable energy source, as well as during the use of technology and in the overall functioning of a household (daily habits). Energy awareness, or rather, household energy conservation awareness, has a very broad spectrum of activity, from maximizing the efficacy of all energy-using devices to minimizing their use via various means [107]. According to Culiberg and Rojšek [108], environmental awareness is a predisposition to respond to environmental problems in a certain way. In our work, we narrowed down the object of study to behaviors in everyday life resulting from environmental (energy) awareness. This is because the practical application of energy-saving principles takes place in everyday life (in everyday household activities). Household energy awareness takes place in the specific conditions in which people live their daily lives. Guiding principles related to general attitudes toward the environment, as well as social norms, ecological knowledge, and the values that people adopt, influence human behavior, which is called environmental awareness. We want to structure our research by pointing to examples concerning the behaviors of prosumers in their households. This will, of course, only be an illustration of the broader issue of prosumers' energy awareness and pro-environmental behavior. Knowledge of the motives for sustainable consumption is a prerequisite for proposing measures to change prosumer behavior. Responsible consumer behavior is influenced by individual consumer values and beliefs. Guiding principles in life can influence how prosumers assess the importance of environmental problems and whether or not they decide to take any energy-saving measures [108–111]. Environmental awareness should precede prosumer behavior. However, even if prosumers are environmentally conscious, they may not necessarily behave environmentally in their daily lives. Environmental awareness (including energy conservation) is the first step to becoming a conscious prosumer. A conscious prosumer reduces energy demand. A prosumer uses less energy in his or her household as he or she is sensitive to wasting energy in other places where he or she resides, e.g., in the workplace and public places.

Prosumers, as we have described, are consumers who also produce energy, typically through the use of renewable energy technologies such as solar panels or wind turbines. Prosumers are leading the way in the transition to a more sustainable energy system, reducing their reliance on traditional energy sources and contributing to the growth of renewable energy markets. On the basis of the literature analysis, we can differentiate

many of these behaviors connected to energy. The main, important energy behaviors of prosumers include the following [112–118]:

- Energy generation: prosumers generate their own energy, typically using renewable energy sources, which reduces their reliance on traditional energy sources and lowers their carbon footprint.
- Energy storage: prosumers can also store excess energy they generate using battery systems, allowing them to use that energy when their generation systems are not producing energy.
- Energy efficiency: prosumers can also reduce their energy consumption through energy-efficient practices such as turning off appliances when they are not in use, using LED lighting, and installing energy-efficient appliances.
- Energy management: prosumers can monitor their energy production and consumption to optimize their energy use and even sell excess energy back to the grid.
- Energy sharing: prosumers can share their excess energy with others in their community through peer-to-peer energy sharing systems or community-based energy cooperatives.

Furthermore, prosumers can use many methods to decrease their usage of energy. The most important of these that can be used in households include the following examples [119–126]:

- Energy-efficient appliances: upgrading to energy-efficient appliances can significantly reduce energy consumption. One can look for appliances with the ENERGY STAR label, which indicates that they meet high energy efficiency standards.
- Efficient lighting: switching to LED bulbs can reduce energy consumption, and they last much longer than traditional bulbs. Turning off lights when not in use is also important.
- Insulation: ensuring adequate insulation and the sealing of doors and windows can prevent energy loss and reduce heating and cooling costs.
- Smart thermostats: installing a smart thermostat allows for temperature control and scheduling, helping to reduce energy consumption.
- Unplugging electronics: electronics and appliances still draw power when plugged in, even if they are not in use. Unplugging electronics or using power strips can help reduce energy usage.
- Renewable energy: installing solar panels or wind turbines can provide a household with clean and renewable energy, reducing reliance on traditional energy sources.
- Conservation: one can conserve energy by reducing overall energy use, for example, by using public transport, biking, or walking instead of driving alone.

In our work, we analyze energy prosumers who are already using renewable energy sources (PV and HP). We investigate whether a 'renewable energy prosumer', or 'energy prosumer' for short, is undertaking energy-saving measures in the household and beyond in a broad sense.

3. Materials and Methods

The aim of this study was the identification of the energy behaviors of Polish prosumers. The methodological framework employed for this inquiry is presented in Figure 1.

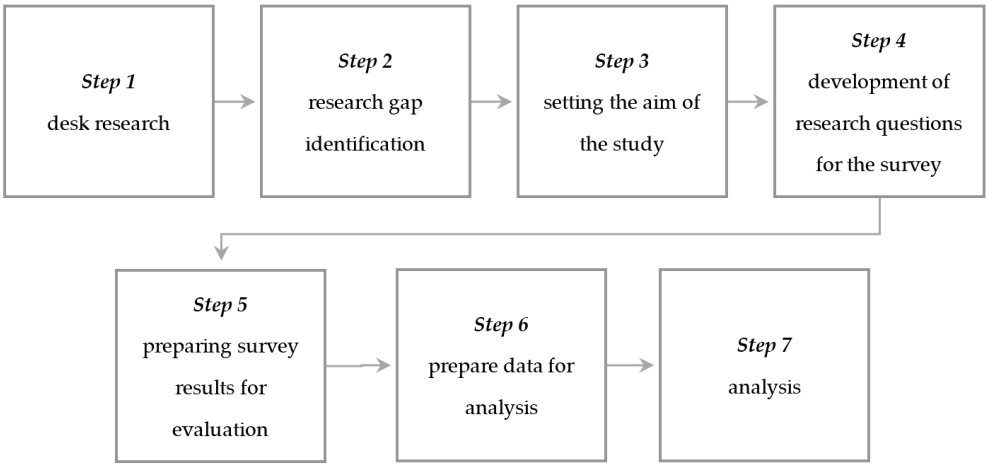

Figure 1. Methodological approach for this research.

The literary basis for this paper was prepared based on a Scopus database analysis. We analyzed the papers published in the last ten years, in the years 2013–2023. We used keywords such as energy behavior, prosumers, and energy household. Firstly, we analyzed the abstracts of the papers. In the second stage, we used the selected papers as the literary basis for our paper.

In our research, the following research questions (RQs) were formulated:

RQ1: What specific energy behaviors do prosumers exhibit?
RQ2: What disparities in energy behaviors can be identified between users of photovoltaic systems and heat pumps?
RQ3: Are prosumers' claims about saving energy resources reflected in their actual behaviors?
RQ4: What energy behaviors related to the reduction in electricity consumption are undertaken by prosumers and with what frequency?
RQ5: What energy behaviors related to saving thermal energy are undertaken by prosumers and with what frequency?

The inquiry pertains to measuring basic constructs, such as the reduction in customer behavior, energy-efficient behavior, the recognition of prosumer behavior, and the demographic attributes of the survey participants, i.e., age, gender, number of household members, education, place of residence, and self-assessment of the material situation. In the questionnaire, the following scales were used: the Curtailment Behavior scale [127] and the Energy Efficiency Behavior scale [128]. A scale was developed based on the results of research conducted by CBOS [129] and RWE Polska [130].

This paper is predicated upon the outcomes of a research study that utilized the CAWI method. CAWI stands for 'Computer Assisted Web Interviewing', which is a method of conducting surveys or collecting data using online tools and technologies. CAWI is a type of online survey that uses a web interface to administer the surveys of respondents who complete a survey using their own computers or mobile devices. The CAWI method has been used in several studies related to digital technology [131], renewable energy platforms [132], the energy-saving behaviors of Polish consumers [133], the generation and consumption of electricity [134], and customer satisfaction with the energy market service in Poland [135]. This research was aimed at recognizing the environment for the implementation of digital technology platforms for renewable energy sources, assessing the factors influencing energy-saving behaviors, broadening the knowledge about the opinions of young people on energy production and consumption, and obtaining opinions on the decarbonization policy related to energy produced using PV micro-installations. The results of this study provide insight into building sustainable energy consumption attitudes and the long-term directions of energy policy in Poland. At the outset of the questionnaire, the participants were provided with a statement regarding anonymity and confidentiality.

Additionally, the focus and purpose of the study were delineated. The personal data and information furnished by the respondents were treated with strict anonymity measures.

The initial questionnaire underwent preliminary investigation. Thirty households were selected for the pre-test. During the process, respondents checked the content and relevance of each item to make sure every question was adequate and accurately understood. The pre-testing process allowed for the development of a comprehensive and refined questionnaire. The survey was conducted between February and March 2022. The link to the questionnaire was disseminated via email to purposefully selected households with photovoltaic (PV) panels or a heat pump (HP).

This research is focused on Polish household inhabitants aged 18 and older. The non-random selection method was used for the selection of respondents for this study. The selected sample consisted of 326 households.

Within this sample, 54.4% of the participants were female and 45.6% were male. The mean age of the households in this sample was approximately 36 years. More than half of the survey participants had completed tertiary education, while almost 40% had completed secondary education, and less than 10% had completed primary or vocational education. Additional social and demographic features of the respondents in the survey, as well as the features of the properties they occupied, are presented in Table 1.

Table 1. Sample characteristics (%).

Characteristic	Item	Households with PV %	Households with HP %
Number of household members	1 person	3.8	3.5
	2 persons	13.7	18.2
	3 persons	14.8	25.9
	4 persons	38.8	30.1
	5 persons	18.8	12.6
	6 persons and more	10.9	9.8
Self-assessment of the material situation	Very bad	0.5	0.7
	Bad	2.2	2.1
	Sufficient	18	28
	Good	60.1	44.1
	Very good	19.1	25.2
Place of residence	Rural area	51.4	30.1
	City, up to 100,000 residents	25.1	32.2
	City, 101,000–500,000 residents	15.3	22.4
	City, over 501,000 residents	8.2	15.4
Property type	Detached house	82	69.2
	Terraced house	13.1	17.5
	Flat in a multi-family building	4.9	13.3
Usable floor space	Minimum	50	40
	Maximum	497	650
	Mean	160.51	167.14
	Median	150	140

Source: own research.

4. Results of this Research

Prosumers are by far the greenest group of Polish households. They are characterized by a high awareness of the need to reduce the consumption of heat and electricity. The vast majority declare full consistency in ecological behaviors such as turning off lights in rooms when they leave; buying energy-efficient light bulbs and household appliances; and using the fridge, dishwasher, and washing machine in a way that limits electricity and water consumption. They also limit the use of electric clothes dryers and consciously do not ask for a daily change of towels in the hotels where they stay (Table 2).

Table 2. Frequency of energy behaviors of prosumers (%).

No.	Item (Q)	1—Never Do This	2	3	4	5—Always Do This
Q1	We leave our electric devices in a state of readiness in my household.	11.9	34.1	24.1	17.5	12.5
Q2	When we are not using them, we unplug chargers for mobile devices such as tablets, phones, and laptops from sockets.	8.6	25.9	18.8	17.6	29.0
Q3	When leaving a room, we switch off the light.	0.6	5.6	11.2	22.1	60.4
Q4	During the winter season, we keep the windows open for extended periods to allow fresh air to circulate.	19.3	44.1	18.0	11.5	7.1
Q5	I would rather take a shower than a bath.	3.1	6,9	17,0	26,7	46.2
Q6	We wait until we have a full load of laundry before doing it.	2.2	4.7	15.0	23.1	55.1
Q7	I wash dirty clothes without prewashing.	4.7	8.5	17.7	23.3	45.7
Q8	I request fresh towels on a daily basis when staying in hotels.	45.2	27.4	14.5	5.3	7.6
Q9	I use a clothes dryer.	50.4	9.6	10.3	16.0	13.8
Q10	In winter, I turn down the heat when I leave my apartment for more than 4 h.	31.7	22.4	16.3	10.9	18.6
Q11	In winter, I keep the heat on so that I do not have to wear a sweater.	19.5	28.9	24.5	13.5	13.5
Q12	We utilize the ECO function of our washing machine/dishwasher.	3.2	13.8	25.7	21.9	35.4
Q13	We boil only the amount of water in the kettle that we need at one time.	6.0	18.2	23.8	22.6	29.5
Q14	We use lids while cooking.	0.6	6.9	22.5	27.5	42.5
Q15	I ensure that any new household appliances or electronic devices I purchase are of the highest energy efficiency rating.	2.2	9.2	19.3	23.4	45.9
Q16	I bought energy-saving light bulbs that were more expensive upfront.	1.3	5.6	14.1	24.8	54.2
Q17	I own energy-efficient household devices.	0.6	13.6	27.4	25.2	33.1
Q18	We only open the refrigerator when it is necessary and ensure to never leave it open for any reason.	0.6	6.3	11.6	16.7	64.8
Q19	I ensure that the refrigerator is cleaned and defrosted on a regular basis.	2.2	18.2	25.2	23.6	30.7
Q20	I follow the manufacturer's recommendations to use the least amount of electricity when placing products in the fridge.	15.8	20.2	21.1	19.6	23.3
Q21	I run the dishwasher only when it is fully loaded.	1.3	4.0	10.4	17.8	66.4

Source: own research.

Figure 2 shows the distribution of the responses in Table 2. The five responses (Q3, Q6, Q16, Q18, and Q21), highlighted in Figure 1, received indications above 50% for a score of 5 (Likert scale). In Table 3, the answers of the respondents are sorted according to the dominance of each question.

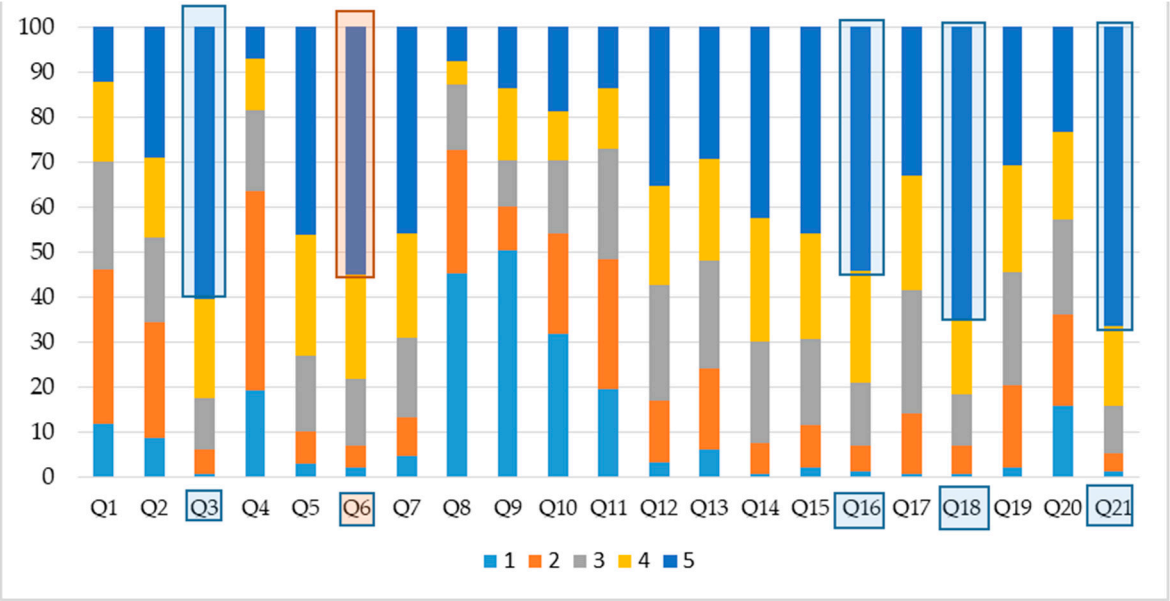

Figure 2. Energy behaviors of prosumers: distribution of responses in Table 2. Source: own research.

Table 3. Prosumer energy behaviors according to the dominance of each question.

No.	Item	Dominance	%
Q9	I use a clothes dryer.	1	50.4
Q8	I request fresh towels on a daily basis when staying in hotels.	1	45.2
Q10	In winter, I turn down the heat when I leave my apartment for more than 4 h.	1	31.7
Q1	We leave our electric devices in a state of readiness in my household.	2	34.1
Q4	During the winter season, we keep the windows open for extended periods to allow fresh air to circulate.	2	44.1
Q11	In winter, I keep the heat on so that I do not have to wear a sweater.	4	28.9
Q20	I follow the manufacturer's recommendations to use the least amount of electricity when placing products in the fridge.	5	23.3
Q2	When we are not using them, we unplug chargers for mobile devices such as tablets, phones, and laptops from sockets.	5	29
Q13	We boil only the amount of water in the kettle that we need at one time.	5	29.5
Q19	I ensure that the refrigerator is cleaned and defrosted on a regular basis.	5	30.7
Q17	I own energy-efficient household devices.	5	33.1
Q12	We utilize the ECO function of our washing machine/dishwasher.	5	35.4
Q14	We use lids while cooking.	5	42.5
Q7	I wash dirty clothes without prewashing.	5	45.7
Q15	I ensure that any new household appliances or electronic devices I purchase are of the highest energy efficiency rating.	5	45.9
Q5	I would rather take a shower than a bath.	5	46.2
Q16	I bought energy-saving light bulbs that were more expensive upfront.	5	54.2
Q6	We wait until we have a full load of laundry before doing it.	5	55.1
Q3	When leaving a room, we switch off the light.	5	60.4
Q18	We only open the refrigerator when it is necessary and ensure to never leave it open for any reason.	5	64.8
Q21	I run the dishwasher only when it is fully loaded.	5	66.4

Source: own research.

Stating the hypothesis (Ho) that prosumers' energy behaviors are differentiated by the type of RESs they own, based on the results obtained and the significance tests carried out, it should be concluded that regardless of whether prosumers produce electricity (by owning photovoltaic panels) or heat (by owning heat pumps), their behaviors do not differ in a statistically significant way. Most of the declared behaviors (19 out of 21 variables) related to conscious energy consumption are undertaken with the same frequency by the prosumers

surveyed. The behaviors of the prosumers of electricity and heat differed statistically significantly (significance level α = 0.05) only in the case of 2 variables: frequency of keeping electrical appliances on standby and starting the washing machine only when it is full (Table 4).

Table 4. Summary hypothesis test (Mann–Whitney U test for independent samples).

Ho	α = 0.05	Decision
The distribution of Q1 is the same for the prosumer category.	**0.014**	**Reject Ho**
The distribution of Q2 is the same for the prosumer category.	0.068	Accept Ho
The distribution of Q3 is the same for the prosumer category.	0.204	Accept Ho
The distribution of Q4 is the same for the prosumer category.	0.173	Accept Ho
The distribution of Q5 is the same for the prosumer category.	0.309	Accept Ho
The distribution of Q6 is the same for the prosumer category.	**0.017**	**Reject Ho**
The distribution of Q7 is the same for the prosumer category.	0.122	Accept Ho
The distribution of Q8 is the same for the prosumer category.	0.933	Accept Ho
The distribution of Q9 is the same for the prosumer category.	0.497	Accept Ho
The distribution of Q10 is the same for the prosumer category.	0.947	Accept Ho
The distribution of Q11 is the same for the prosumer category.	0.656	Accept Ho
The distribution of Q12 is the same for the prosumer category.	0.865	Accept Ho
The distribution of Q13 is the same for the prosumer category.	0.563	Accept Ho
The distribution of Q14 is the same for the prosumer category.	0.384	Accept Ho
The distribution of Q15 is the same for the prosumer category.	1.000	Accept Ho
The distribution of Q16 is the same for the prosumer category.	0.201	Accept Ho
The distribution of Q17 is the same for the prosumer category.	0.645	Accept Ho
The distribution of Q18 is the same for the prosumer category.	0.890	Accept Ho
The distribution of Q19 is the same for the prosumer category.	0.418	Accept Ho
The distribution of Q20 is the same for the prosumer category.	0.973	Accept Ho
The distribution of Q21 is the same for the prosumer category.	0.986	Accept Ho

α—statistical significance level; Qs—questions from Table 2. Source: own research.

Based on the obtained results (Figure 2), we observe that the prosumers have the following positive attitudes: They purchased lights bulbs that were more expensive but saved energy (Q16); they wait until they have a full load before doing their laundry (Q6); they turn off the light when they leave a room (Q3); they only open the refrigerator when necessary and never leave it open for any reason (Q18); and they only run the dishwasher when it is full (Q21). Among the Qs, question 6 (Q6) did not receive confirmation of the Ho hypothesis according to the Mann–Whitney U test (Table 4).

The direct study used the Mann–Whitney U test, also called the Wilcoxon rank-sum test, to assess the significance of the differences in the behaviors of the prosumers (PV and HP users) due to the abnormal distribution of the data. The test consisted of ranking all the observations from both groups, combining the ranks, and calculating the sum of the ranks for each group. The U test statistic was then computed based on the difference between these two rank sums, with the null hypothesis being no difference and the alternate hypothesis being a difference. To determine whether to reject the null hypothesis, the p-value obtained from the test was compared with the significance level (usually 0.05). The test results obtained are summarized in Table 4, and it was found that there was a statistically significant difference between the two groups only for variables Q1 and Q7. The Mann–Whitney U test is commonly used in a variety of fields, including biology, psychology, and the social sciences, to compare groups that cannot be assumed to have normal distributions.

The decision to become a prosumer (installing photovoltaic panels or a heat pump) is taken by people with a high level of environmental awareness. Becoming a prosumer may encourage people to give up their previous environmental behaviors. Electricity prosumers, aware of the fact that they generate electricity themselves, may stop paying attention to the need to consciously reduce electricity consumption in everyday household operations. In the surveyed group of Polish households, more than half of the electricity prosumers

changed their electricity consumption behavior and used electrical appliances when the panels produced electricity. The installation of photovoltaic panels did not change the electricity consumption behavior of 43.9% of the surveyed households in S1_PV, and it changed the electricity consumption behavior of 56.1% of them (Table 5).

Table 5. Impacts of owning installations on changes in prosumers' energy behaviors.

Respondents/Prosumers in Our Research	%
Electricity prosumers (Segment 1: S1 _PV)	
S1_1_PV: prosumers trying to use electrical appliances only when the PV panels produce electricity	56.1
S1__2_PV: prosumers using electrical appliances regardless of whether the PV panels generate electricity	43.9
Prosumers of thermal energy (Segment 2: S2_HP)	
S2_1_HP: prosumers heating their premises without paying attention to heating costs	33.1
S2_2_HP: prosumers with efficient space heating	66.9

Source: own research.

In the group of heat prosumers, the majority (two-thirds of the respondents), despite having a heat pump and access to their own heat, still declared engaging in pro-environmental behaviors, i.e., heating the premises used sparingly (Table 4). However, one in three heat prosumers in S2_HP no longer pays attention to heating costs (Table 5). The final results of our research are presented in Figure 3.

Finally, the results of this study on the frequency of electricity reduction and thermal energy-saving actions are presented in Figures 4 and 5. For this purpose, the most characteristic behaviors related to reducing electricity consumption for saving electricity and thermal energy were selected, but they varied between PV and HP prosumers.

HP prosumers were found to be the most frequent initiators of actions that result in reduced electricity consumption. These include behaviors such as not leaving electrical appliances on standby, unplugging mobile device chargers, switching off lights in unused rooms, not using clothes dryers, and owning energy-efficient home appliances. In all cases, the dominant behaviors of HP users have higher frequencies (Figure 4).

In contrast, PV panel owners save thermal energy with greater attentiveness (Figure 5).

This includes behaviors such as not opening windows in the winter season for a longer period of time, turning off the heating when away from the dwelling for more than 4 h, and not heating the dwelling too much. In all cases, the dominant behaviors of FV users have higher frequencies.

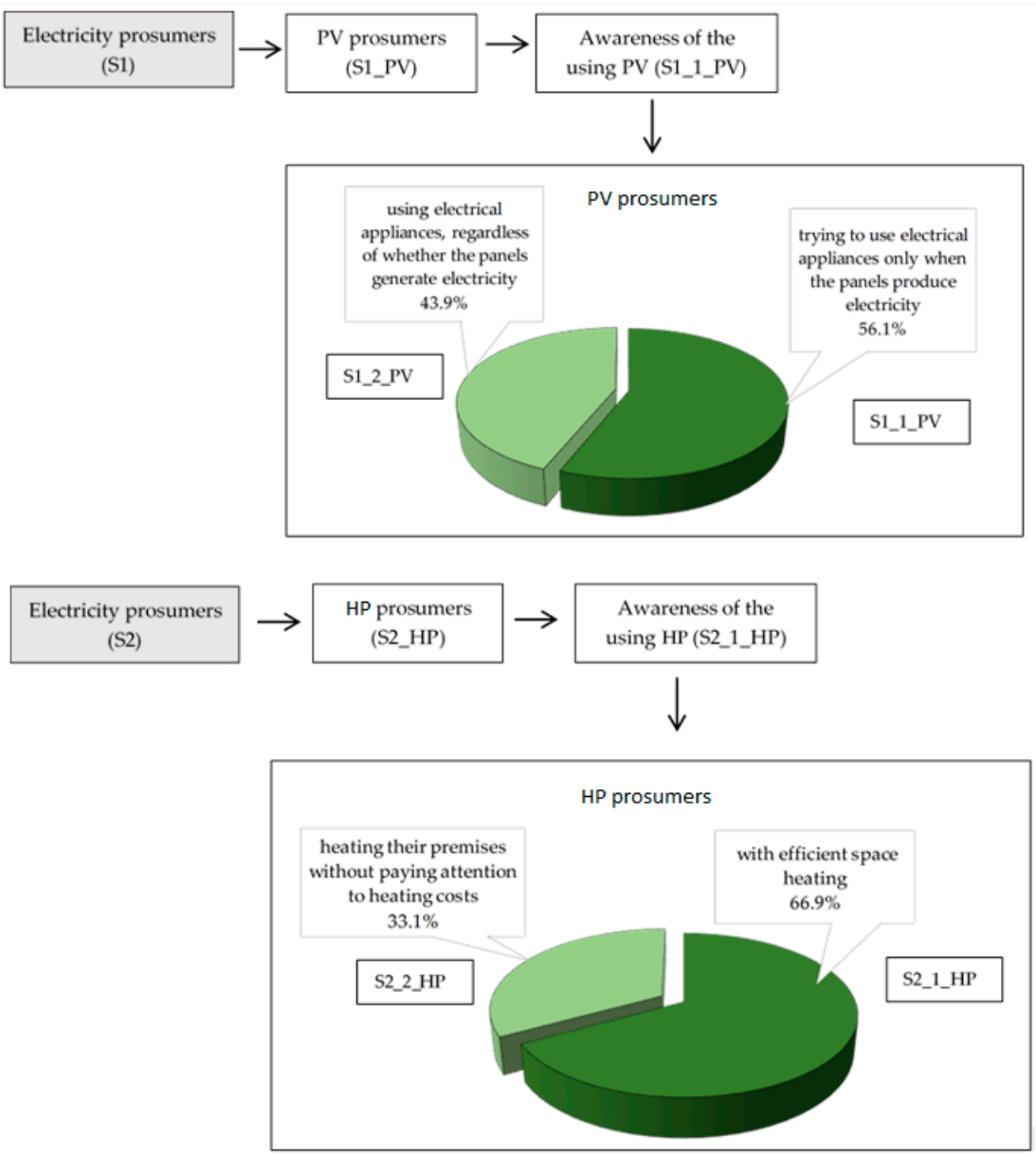

Figure 3. Behaviors of PV and HP prosumers: distribution of responses from Table 4. Source: own research.

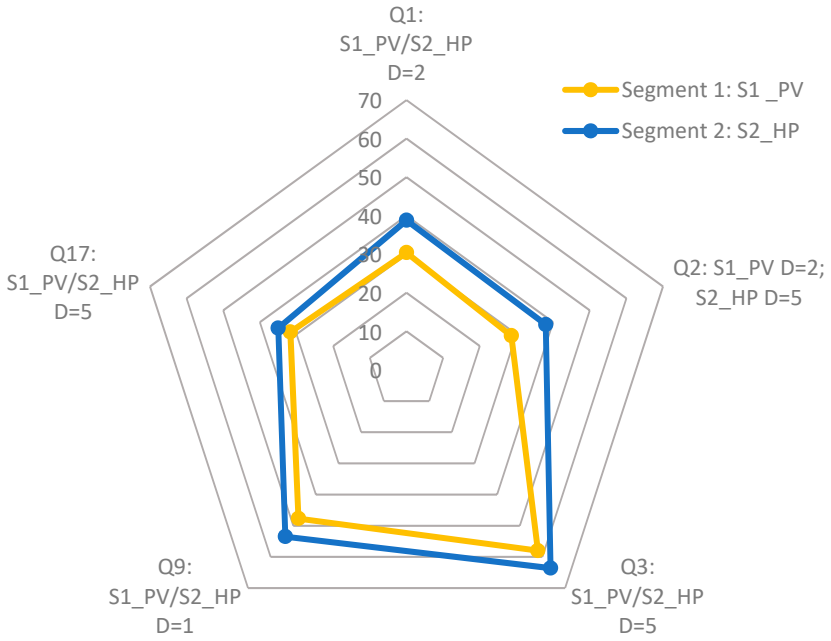

Figure 4. Prosumer behaviors related to the reduction in electricity consumption. Source: own research.

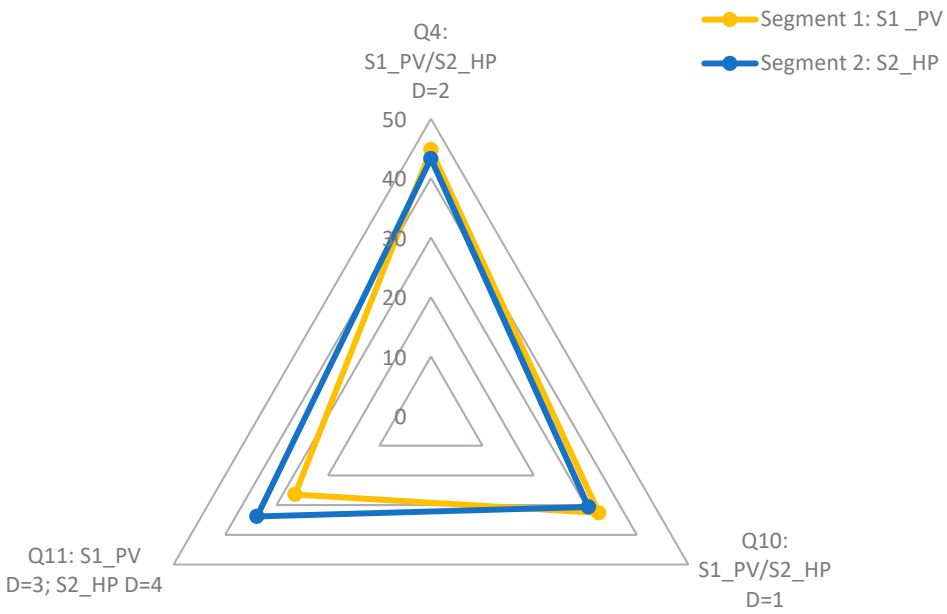

Figure 5. Prosumer behaviors related to saving thermal energy. Source: own research.

5. Discussion

In recent years, there has been a growing trend towards energy efficiency and sustainability, with individuals and households taking an active role in reducing their energy consumption and environmental impact [64,66,67]. One key aspect of this trend is the emergence of 'prosumers'—consumers who are also producers of energy through renewable sources such as solar panels. In this essay, we examined the behaviors of prosumers in regard to energy consumption in households [86,88,89].

Prosumers are individuals who not only consume energy but also produce it themselves. This is typically achieved through the installation of solar panels or other renewable energy sources on their properties [91,92]. By generating their own energy, prosumers can reduce their dependence on traditional energy sources and potentially even sell excess energy back to the grid [93,94].

One of the key motivations for prosumers is environmental sustainability. By producing their own renewable energy, prosumers can reduce their carbon footprints and help mitigate the effects of climate change. Additionally, prosumers may also be motivated by economic considerations, as generating their own energy can lead to significant cost savings in their energy bills [95,96].

On the basis of the research presented in this paper, it can be observed that prosumers are a group that is very advanced in its ecological behaviors. Most of them perform many ecological behaviors in their houses.

The majority of the analyzed prosumers do not keep electrical appliances on standby and have a tendency to remove chargers for electronic devices, turn off the lights when leaving a room, open windows only for a short period of time in winter, prefer a shower rather than taking a bath, wait until a full load to do laundry, wash dirty clothes without prewashing, use a clothes dryer turn down the heat in winter when they leaving their apartments for more than 4 h, prefer to boil as much water in the kettle as they will use at 1 time, use lids when cooking, look at the energy efficiency of household appliances when buying them, purchase light bulbs for saving energy, open the refrigerator only when necessary, regularly defrost the fridge, run the dishwasher only when it is full, etc.

These behaviors can lead to reducing energy waste and saving money on electricity bills. When a charger is plugged in, even if it is not connected to a device, it still draws power from the outlet, known as vampire power or standby power. This can add up over time and contribute to energy waste and higher electricity bills. Moreover, this behavior can lead to the extension of the lifespans of their devices [115]. Leaving a device plugged in to charge for an extended period of time can cause the battery to degrade faster, reducing the overall lifespan of the device. By removing the charger once devices are fully charged, prosumers can help prolong the life of their mobile devices [136].

Prosumers are aware that opening windows in the winter can cause a significant amount of heat loss, especially if they are left open for an extended period of time. This can cause energy waste and result in higher heating bills [137]. To minimize heat loss, prosumers should only open windows for short periods of time and make sure to close them once the desired ventilation has been achieved. It can be observed that prosumers are mindful of the amount of time that windows are open in the winter to avoid heat loss, promote energy efficiency, and maintain good indoor air quality [138].

The analyzed prosumers prefer taking showers rather than baths because of reasons including water conservation, energy efficiency, and improved personal hygiene [139]. Prosumers in Poland are aware that showers can also be more energy-efficient than baths. Heating water for a bath requires a significant amount of energy, whereas heating water for a shower uses less energy because less water is being heated. By choosing to take showers instead of baths, prosumers can reduce their energy consumption and save money on their utility bills [140].

In the analyzed data, it can be observed that the same tendency to decrease energy usage can be observed in the case of heat usage in Polish prosumers' houses. By turning down the heat when leaving for more than four hours, prosumers can conserve energy and reduce their carbon footprints. Reducing the heat when not at home can also result in cost savings on utility bills [141–146]. The less heat is used, the less energy is consumed, and the less money is spent on heating a home. By conserving energy and reducing their carbon footprints, prosumers can make a positive impact on the environment. Every little bit helps, and turning down the heat when leaving the home is a simple way to contribute to a healthier planet [147,148].

Polish prosumers also look at the energy efficiency of household appliances when buying them. Energy-efficient appliances are designed to use less energy, resulting in lower utility bills over time. While the upfront cost of an energy-efficient appliance may be higher, the long-term savings can be significant and can make up for the higher initial cost [149]. By choosing energy-efficient appliances, prosumers can reduce their carbon footprints and contribute to a healthier planet. Energy-efficient appliances often come with

features that make them more convenient to use [150–153]. For example, some refrigerators have temperature-controlled drawers, while some washing machines have larger capacity drums. These features can make it easier and more convenient to use household appliances.

Furthermore, prosumers in Poland are aware that washing machines use a significant amount of energy, especially when heating water or running through multiple cycles. By waiting until they have a full load of laundry, prosumers can minimize the number of loads they need to run and ultimately reduce their energy consumption [154–156]. Washing clothes also requires a significant amount of water, and by waiting until they have a full load, prosumers can reduce their water consumption. This is especially important in areas that are experiencing water scarcity or where water is expensive [157–159].

By reducing energy waste in their houses, prosumers can contribute to a more sustainable society. It can be observed that prosumers tend to behave in a pro-environmental way not only in their houses, whereby their behaviors can lead to many personal savings. Moreover, it can be seen that they tend to behave in an ecological way outside the house.

For example, in hotels, most of them do not change towels on a daily basis. They know that each time a towel is washed, a significant amount of water is used. By reusing towels during their hotel stays, prosumers can reduce the amount of water used for laundry and promote water conservation. Washing and drying towels requires a considerable amount of energy, and by reducing the number of times towels are washed, prosumers can help to reduce their carbon footprints and conserve energy [115].

It is also worth noting that the prosumers surveyed who have heat pumps installed, in most cases, heat their rooms economically. It can also be seen that the installation of photovoltaic panels did not contribute to their excessive use of electricity. It appears that becoming a prosumer in terms of energy and heat generation not only has a direct positive effect on the climate but also increases the environmental awareness of prosumers who, despite having access to cheaper energy and heat, try to save it.

When we try to compare the results of this research with those of other international studies, a similarity between behaviors can be observed. Generally, prosumers tend to behave in a more ecological way in many aspects of their everyday lives. For example, Stikvoort et al. [160] in their research found that solar prosumers in Sweden tend to behave in a pro-environment way, but the paper is not precise about the particular behaviors of the analyzed population. Some Polish studies have observed the tendency to increase the environmentally friendly attitudes of customers. For example, Graczyk et al. [161] found that at present, households in Poland tend to be more ecological compared with previous years. The paper points out that this is very important because Poland is in a period of transformation in their energy system like many other European Union countries. On the basis of the research presented in this paper, this transformation could be carried out faster if the opportunity of being a prosumer were to be promoted among people.

Another interesting paper about Polish consumer behavior was published by Kieżel et al. [162]. The paper also points out the tendency of Polish consumers to be more ecological at present, but it analyzed not only prosumers but consumers in general and all their pro-ecological behaviors. However, in the section of the research about the conservation of energy, they also observed some similar consumer behaviors, such as saving energy by turning off the lights in empty. Many of these prosumer behaviors are in accordance with those presented in this paper, one example being in Italy, which was identified by Mengolini [163]. Some similar environmentally friendly behaviors were also observed by Nordlung et al. [164], but the authors also investigated all consumer behaviors and not only those of prosumers.

It is interesting to compare the results presented in this publication with those of Braito's research on the example of Styria [165]. In his research, the author did not observe a tendency of prosumers to behave in a pro-environmental manner in aspects other than those directly related to the installation of appropriate equipment for the production of clean energy. He points out that for prosumers to behave in a more environmentally friendly manner, an appropriate incentive system is necessary. In the case of the research

presented in this publication, however, the tendency of the Polish prosumers surveyed to behave in a more pro-environmental manner was evident.

The environmental attitudes of prosumers will change with the development of smart technology that frees them to control their levels of energy and heat conservation. In the recently promoted concept of Industry 5.0, the focus is on people and sustainability [166–168]. Human beings are not just workers in the workplace but are also consumers and prosumers. Society 5.0 will be increasingly dependent on (and influenced by) smart technology, which will be increasingly environmentally responsible [169–171]. In the near future, we may study not the attitudes of prosumers, but the parameters of smart technologies and their usability in specific households.

6. Conclusions

It can be concluded that a very interesting finding of this research is that being a prosumer means having a general tendency to engage in ecological behaviors, not only in situations where it is economically beneficial but also on a daily basis throughout the whole life of the person. This finding is new and has not been observed in previous studies.

On this basis, it can be very beneficial for the whole society to promote prosumers using solar energy systems and heat pumps. If there are more prosumers, the level of ecological awareness and responsibility for the natural environment will be higher. An increase in the use of pro-ecological energy will lead to a higher amount of people behaving in a pro-ecological way in their lives. This will lead to a decrease in energy usage, not only in private houses but also in hotels and business entities. Because of this, the promotion of pro-ecological behaviors and increasing the number of prosumers producing clean energy and heat should be a priority at the local government level.

The present study contributes to the expansion of our understanding of the energy behaviors exhibited by prosumer households in Poland. However, as this research was limited in scope to this specific demographic, a promising avenue for future inquiry may entail a comparative analysis of the energy consumption patterns of prosumer households in different European nations. By broadening the scope of the investigation, a more comprehensive understanding of the factors that shape the energy behaviors of prosumer households can be attained, enabling more effective policy making and implementation.

The described results can be used to promote the use of solar energy systems and heat pumps among prosumers, which can have a positive impact on society as a whole. By increasing the number of prosumers, the level of ecological awareness and responsibility for the natural environment can be increased. This can lead to a higher number of people adopting pro-ecological behaviors in their daily lives, which can result in decreased energy usage, not only in private houses but also in hotels and business entities.

Based on these findings, it is recommended that local governments prioritize the promotion of pro-ecological behaviors and increasing the number of prosumers producing clean energy and heat. By doing so, they can help to reduce the carbon footprint of their region and contribute to the global effort to combat climate change. In addition, promoting prosumers can also lead to the creation of green jobs, which can boost the local economy and provide a sustainable source of income for residents.

Overall, the results highlight the potential benefits of promoting prosumers and pro-ecological behaviors. By encouraging the adoption of renewable energy systems and energy-efficient technologies, local governments can help to create a more sustainable and resilient society while also improving quality of life for their residents.

Future research can focus on the economic implications of prosumer behaviors. This includes the potential impact on energy prices, the effects on the traditional energy industry, and the economic benefits and challenges of prosumer-based systems. Additionally, research can explore the role of government policies and incentives in promoting prosumer behaviors and their economic implications.

Future research can also investigate the social and cultural factors that influence prosumer behavior. These include factors such as personal values, social norms, and

community participation in prosumer-based systems. Understanding these factors can help to develop effective strategies to promote prosumer behavior and increase community participation in renewable energy systems.

Another interesting field is the exploration of the environmental impacts of prosumer behaviors. This includes assessing the carbon footprints of prosumer-based systems, the potential benefits for reducing greenhouse gas emissions, and the potential for prosumers to contribute to biodiversity and habitat conservation through their use of sustainable energy systems.

Author Contributions: The main activities of the team of authors are described as follows: Conceptualization, M.J., B.G., R.W. (Radosław Wolniak) and R.W. (Robert Wolny); methodology, M.J. and R.W. (Robert Wolny); software, B.G., M.J, R.W. (Radosław Wolniak) and R.W. (Robert Wolny); validation, M.J. and R.W. (Robert Wolny); formal analysis, M.J. and R.W. (Robert Wolny); investigation, R.W. (Robert Wolny), M.J. and B.G.; resources, M.J., R.W. (Radosław Wolniak), B.G., R.W. (Robert Wolny) and W.W.G.; data curation, M.J. and R.W. (Robert Wolny); writing—original draft preparation, B.G., M.J., R.W. (Radosław Wolniak) and R.W. (Robert Wolny) writing—review and editing, B.G., R.W. (Radosław Wolniak), R.W. (Robert Wolny) and M.J.; visualization, B.G., M.J., R.W. (Radosław Wolniak) and R.W. (Robert Wolny); supervision, B.G., M.J.; R.W. (Radosław Wolniak) and R.W. (Robert Wolny), W.W.G.; funding acquisition, R.W. (Radosław Wolniak) and R.W. (Robert Wolny) All authors have read and agreed to the published version of the manuscript.

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