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Purchase intentions for renewable energy in Polish households: an extended technology acceptance model approach

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Introduction: Despite the presence of renewable energy appliances in the market for an extended period, they continue to be perceived as a relatively new technology. This perception may influence consumer adoption and the broader acceptance of renewable energy solutions.

Methods: In this study, the technology acceptance model (TAM) was applied to investigate individuals' intention to use green energy sources. The TAM helps understand how users perceive and support new technologies. The survey was carried out in June 2024 on a sample of 580 Polish consumers using a self-administered questionnaire, employing a random selection method.

Results: The results of structural equation modeling show a positive impact of Perceived Ease of Use and Perceived Usefulness, influenced by social factors, on Purchase Intention of green energy technology. Among these two variables, Perceived Usefulness influenced by social factors (PUS) had the more substantial effect.

Discussion: One key insight for producers, sellers of renewable energy systems, and policymakers is that potential users are primarily motivated by the Perceived Ease of Use of these systems.

KEYWORDS

renewable energy, green energy, purchase intention, Poland, technology acceptance model, photovoltaics, heat pumps

1 Introduction

Along with the growing environmental concerns raised by scientists, an increasing number of consumers around the world are recognizing that certain forms of human activity negatively impact the planet—manifesting in phenomena such as global warming, ozone layer depletion, species extinction, and hazardous pollution, including smog (Costanza et al., 2014). Anthropogenic carbon emissions have been identified as the primary cause of global warming (Yao et al., 2023; Yoro and Daramola, 2020), with the rise in global temperatures being approximately proportional to cumulative CO_2 emissions (Matthews et al., 2009; Cox et al., 2024). Public awareness of the dangers associated with excessive consumerism, particularly the use of fossil fuels, has led a significant portion of society to adopt more sustainable behaviors, at least in areas related to purchasing decisions. There is little room for doubt that a transition to renewable energy is necessary (Pauliuk, 2024), not only in large-scale power generation but also within individual households.

Poland is traditionally dependent on fossil fuels, especially coal, which is used in most of the country's energy supply systems. The energy transformation in Poland started rather late compared to many Western countries, mainly due to the political and economic reasons arising from the history and long communist reign with all its policies. As a result, in 2024 more than 62% of energy produced came from coal (Fraunhofer Institute for Solar Energy Systems ISE, 2024), and the local power plants emit approximately 60–70 million tons of carbon dioxide per year (exactly 64.14 million tons in 2022) (European Environment Agency, 2024). The country undertakes various initiatives, including widely available financial incentives for individuals to switch from coal to more sustainable technologies; however, a certain number of Polish people are still not willing to invest in renewable energy technologies, for multiple reasons, economic as well as social and practical.

The main aim of this study was to examine the Purchase Intentions of renewable energy among Polish individuals as well as to investigate the factors influencing those intentions. To fulfil this objective, the technology acceptance model (TAM) has been used as a basis for the research tool design. To provide a more comprehensive outlook on the studied matter, the classic TAM has been supplemented with additional factors widely used in the literature, namely, Environmental Concern (EC) and Perceived Cost (PC). The following specific objectives were also formulated:

O1: Assessment of the impact of Perceived Ease of Use (PEU) on the intention to purchase renewable energy technologies.
O2: Evaluation of the role of Perceived Usefulness (PU) in shaping Purchase Intention (PI) for renewable energy solutions.
O3: Assessment of the effects of social (PUS) and economic (PUE) dimensions of Perceived Usefulness on Purchase Intention.
O4: Examination of the influence of Perceived Cost (PC) on the likelihood of adopting green energy technologies.
O5: Investigation of the relationship between Environmental Concern (EC) and consumers' intention to purchase renewable energy solutions.

Green energy is a topic widely studied by researchers all around the world, for example, Asia (Irfan et al., 2019; Ali et al., 2020; Tanveer et al., 2021), North America (Arroyo and Carrete, 2019; Moghadam et al., 2022), and Australia (Das et al., 2021). Nevertheless, certain aspects still need to be investigated, especially in a more local context of Europe. This study presents evidence from a developed Central European country. It is not limited to a specific green energy technology but treats the concept of renewable energy sources as a whole. Our aim was to show the intentions of Polish consumers regarding green energy in general, not only as a specific appliance that might not be suitable for their situation (which does not necessarily mean they are not interested in renewable sources at all). Until now, studies from Poland concentrated mostly on photovoltaics and other solar technologies, for example, Grębosz-Krawczyk et al. (2021a), Zdonek et al. (2023), or Klepacka et al. (2018), with only a few papers, such as those of Talarek et al. (2023), Talarek et al. (2022), and Khalid et al. (2021), discussing renewable energy sources as a unified concept.

We have also not restricted the study to the classic TAM when defining the potential factors influencing Purchase Intention—we have added other factors that have been shown to be significant in other studies. Moreover, in case of TAM application, researchers sometimes use one of its basic elements, Perceived Usefulness (PU), divided into more precise factors, for example, economic or social PU—such division could be found in works of Ali et al. (2020), Yilmaz et al. (2024) or Zdonek et al. (2023); however, most studies use only general PU to investigate the decision-making of green energy consumers.

The significance of this work is underscored by the fact that, despite the growing popularity of green energy in Poland, the country still has a long way to go to reach a satisfying level of decarbonization. Therefore, understanding what is important for potential green energy installation users can serve as a guideline regarding what can be done by policymakers and industry to streamline and accelerate the process of energy transformation in the area of individual systems for electricity and heat generation.

The article includes both literature and empirical studies. Section 2 is dedicated to presenting the theoretical framework for the research and includes a brief overview of the Polish renewable energy sectors and a detailed review of each of the PI antecedents taken into consideration, based on TAM. Section 3 describes the material and methods: it shows the sample, data collection methods, and the measures used in the research process. Section 4 presents the results of the study, including hypothesis testing, while Section 5 is dedicated to a discussion of the results.

2 Theoretical framework

2.1 Contextual characteristics of the renewable energy sector in Poland

The threat of climate change and the depletion of non-renewable resources, particularly fossil fuels, has become a driving force for communities worldwide to seek solutions to this pressing challenge. The European Union has not remained passive in this regard. In 2014, the European Commission introduced *A Policy Framework for Climate and Energy in the Period from 2020 to 2030* (European Commission, 2014a), which outlined key guidelines for the future development of energy policy. According to this document, the primary objectives for EU member states include ensuring the security of energy supply, enhancing competitiveness, and guaranteeing a high level of sustainability in the energy sector, all with the overarching aim of establishing a low-emission economy. Among the specific targets set for the EU, the framework includes a 40% reduction in greenhouse gas emissions by the year 2030 (European Parliament, 2009). Subsequently, the EU released the European Green Deal, a strategic roadmap for future economic development, reaffirming Europe's ambition to become the first climate-neutral continent (European Commission, 2014b).

The European Energy Policy 2030 described in the document has served as a foundation for formulating the Polish Energy Policy 2050 (PEP 2050) (Wierzbowski et al., 2017), and more recently, Poland's Energy Policy until 2040 (Ministerstwo Klimatu i Środowiska, 2021). As Poland is traditionally dependent on coal, the main concept of PEP 2050 is the decarbonization of the country's energy supply, leading to a reduction in fossil-fuel-related emissions. The specific aims include increasing the energy efficiency (including reduction of grid losses), continuation of improving the renewable energy source development (along with energy storage technologies), and further deregulation of energy sector to enable effective resell of electricity to the public grid by the prosumers owning micro-installations and construction of a nuclear power plant of minimum 6000 MW (Wojtaszek et al., 2024; Paska et al., 2020). Moreover, the factor that may, despite its negative character, contribute to increasing the speed of the abovementioned changes is the global energy crisis related to the pandemic, which has intensified since the Russian invasion of Ukraine in 2022. The rising prices of fuels proved that green energy might be the long-term solution for whole societies (Gajdzik et al., 2024a).

The transition away from coal as a main energy source necessitates a swift shift in the Polish energy sector. As of 2024, coal's contribution to the country's electricity generation has decreased to approximately 62.4%, while the proportion of renewable energy has increased to approximately 30.5% (Fraunhofer Institute for Solar Energy Systems ISE, 2024). The most popular sources of green energy in Poland are the photovoltaic (PV) installations, both in the form of major industrial plants as well as individual household systems. In 2024, the installed power of photovoltaics in public power plants exceeded the record level of 18 GW, achieving a value of 18,826 MW in July (Agencja Rynku Energii, 2024a). At the same time, the installed power of prosumer micro-installations reached over 11,000 MW (with the number of individual prosumers nearing 1.44 million). It is also worth mentioning that Polish communities started engaging in energy cooperatives, local initiatives based on joint investments of communities in renewable energy sources (Gajdzik et al., 2024b); however, this form is still relatively new and in a development stage in the country.

Wind turbines are another green technology that plays a role in Polish electricity production. Onshore wind power plants provided 14.4% on average of public net electricity generation in 2024 (with 16% in July) (European Network of Transmission System Operators for Electricity, 2024), and their installed power equals almost 9500 MW (Zdonek et al., 2023). Currently, there are no offshore plants; however, there are projects underway on the Baltic Sea, assuming the creation of wind turbine farms of 8.4 GW total capacity in the first stages (Palmowski and Kwiatkowska, 2023). The challenge in the development of wind technology in Poland is connected to the natural conditions, which vary substantially across the country's regions. According to average wind speeds, the best regions for wind turbine placement are Pomerania and Central Poland, with the rest of the country presenting mediocre possibilities in this aspect (Malska and Mazur, 2017). Due to the climate issues and lack of state support, prosumer wind installations are extremely rare in Poland. While the installation of small turbines for strictly private use has been largely deregulated for years, connecting to the grid posed a significant difficulty for individuals. In July 2024, there were only 66 prosumer wind installations of 0.41 MW installed power (Agencja Rynku Energii, 2024b). Currently, the Polish government has begun to encourage individuals to apply wind turbines in their household systems, launching the "My Wind Power Plant" state subsidy program (Augustowski and Kułyk, 2024).

Even though the idea of green energy is, in the minds of many, equivalent to the photovoltaic technology, the generation of electricity is not the only area that must be taken into consideration. Another unit that can be more frequently observed in both private households and public buildings is the heat pump, which is the main factor in decarbonizing the heat supply of buildings (Lämmle et al., 2023). Heat pumps operate by a simple mechanism of extracting heat from the environment (e.g., air or ground) and delivering it to a target space (e.g., central heating system in houses) (Jelić et al., 2023). At the same time, it cannot be forgotten that the pumps need electricity to operate, especially in unfavorable atmospheric conditions. Even though all of them are based on the same idea of heat exchange, there are multiple variants of heat pumps depending on the heat source, heat transfer material, and the heat receiver, such as simple air-air pumps, often used air-water pumps, or more advanced and more costly ground-coupled brine-water pumps. Obviously, those variants differ in terms of efficiency and reductions of CO_2 emissions. The best results are obtained by combining the pump with photovoltaic panels. For example, a system containing an air-source heat pump and PV can decrease the emissions by 52%, while applying PV in combination with a geothermal ground pump equipped with a 110-m borehole heat exchanger can lower emissions by 63% (Chhugani et al., 2023).

Currently, in Poland, the heat pump market has experienced a temporary fluctuation and a decline in sales, which can be attributed to the broader crisis in the construction sector. According to the Polish Organization for Heat Pump Technology Development (PORT PC), a leading Polish organization dedicated to research and the promotion of heat pump technology, 2023 marked the first year since the organization's founding in 2012 that a decline in heat pump sales was recorded–a drop of nearly 39% compared to 2022 (Polska Organizacja Rozwoju Technologii Pomp Ciepła PORT PC, 2024). Interestingly, the only category of heat pumps that did not experience a decline in sales was ground-coupled heat pumps, which saw a 12% increase compared to 2022, despite typically being the most expensive option and requiring the most complex installation procedures. Accessing the ground as a heat source involves either the shallow excavation of a large surface area or the drilling of deep boreholes, making the process more resource-intensive than other heat pump systems.

A crucial aspect of Polish decarbonization and the switch to green energy is the implementation of national financial incentives for those willing to install a renewable energy system in their households. Currently, among the most popular are the My Electricity program, thermal modernization tax relief, and the Clean Air Priority Program. The My Electricity program was launched in 2019 and aimed at increasing the number of prosumer PV micro-installations in the country by more than 200,000 (Olczak et al., 2021). It was based on providing partial reimbursement of costs incurred in the investment in the installation. Thermal modernization tax relief was implemented into the fiscal system in 2019 and allowed the PIT payers to deduct the costs of modernization investment (including installation of green energy and heating systems) from their incomes (Bednarz and Babiarz, 2023; Łożykowski et al., 2023). The Clean Air Priority Program (CAPP), launched in 2018, is also aimed at individual households and offers non-refundable grants to be spent on partial repayment of a bank loan taken in order to purchase and install a photovoltaic micro-installation (Mazurek-Czarnecka et al., 2022; Matczak et al., 2023). Such incentives effectively encourage many household owners to use renewable energy resources. In addition, scientists point out that prosumers show a general tendency to act in an eco-friendly way also in other consumption situations (Gajdzik et al., 2023).

2.2 Factors influencing the Purchase Intention of renewable energy sources by individuals

Although appliances that utilize renewable energy sources have been available in the Polish market for a considerable period, they continue to be regarded as a relatively novel technology. Due to their high initial price, equipment such as photovoltaic panels or heat pumps has become available to the wider public only quite recently. Multiple models could be applied to investigate the level of adoption of new technology among the consumer group, leading to the identification of the Purchase Intention. Some of the most widely used, already well-established notions in this context are the Theory of Planned Behavior (TPB) (Hill et al., 1977) and the Theory of Reasoned Action (TRA) (Ajzen, 1991; Ajzen and Madden, 1986). Drawing from those two theories, Davis (1989) proposed a new concept—the technology acceptance model (TAM)—mostly employed to explain the general determinants influencing technology adoption (Musa et al., 2024; Marangunić and Granić, 2015). TAM offers the researchers insights into how the society views and embraces new technologies, studying their intentions based on its two major antecedents: Perceived Usefulness (PU), associated with benefits for the users, and Perceived Ease of Use (PEU), referring to seeing the technology or device as simple and convenient (Elangovan et al., 2024).

Since its formulation, TAM has been applied in multiple study areas related to new technologies, including, for example, Internet used for diverse purposes (Shih, 2004; Liaw and Huang, 2003; Castaneda et al., 2007), mobile technologies (Ngubelanga and Duffett, 2021; Lu et al., 2005; An et al., 2023), tourism (Morosan, 2012; Go et al., 2020), e-learning (Zhang et al., 2008; Cheung and Vogel, 2013), electric mobility (Handarujati, 2024; Zdonek and Melnarowicz, 2023), or robots used for diverse purposes (Parvez et al., 2022; Hogan et al., 2020; Chatzopoulos et al., 2022). The technology acceptance model has also been successfully used in multiple studies regarding various aspects of renewable energy sources or other clean technologies. TAM and its elements have been a basis for research tools in investigations related to photovoltaic panels (Zdonek et al., 2023; Khalid et al., 2021; Bouaguel and Alsulimani, 2022; Alam et al., 2021), solar panels used for water heating systems (Elmustapha et al., 2018; Liu et al., 2022), heat pumps (Yilmaz et al., 2024; Bai et al., 2022), and renewable energy in general (Gârdan et al., 2023; Piselli et al., 2021; Fatoki, 2022).

Despite its widespread use, TAM is not the only model that can be used to examine consumers' intentions related to renewable energy sources. Other concepts include Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) (Apfel and Herbes, 2021; Aggarwal et al., 2019), social cognitive theory (SCT) (Li and Dai, 2024; Bandura, 2001), or diffusion of innovation (DOI) theory (Franceschinis et al., 2017; Rogers, 2003). DOI introduces five significant innovation features: compatibility, complexity, trialability, observability, and relative advantage, which are believed to be among the best predictors of innovation adoption. There is a theoretical discussion whether relative advantage can be identified with Perceived Usefulness, as both variables concentrate, directly or indirectly, on the superiority of one technology over others. However, relative advantage can be defined as the degree to which the innovation is perceived to be better than current solutions (Franceschinis et al., 2017; Bjørnstad, 2012); therefore, it is strongly connected with comparison to other technologies, while Perceived Usefulness concentrates on the benefits for the user. It could be concluded that these factors might be similar at first, but are not equal to each other, with PU showing a strong direct positive effect on the acceptance of new technologies (Venkatesh et al., 2003).

TAM can be adjusted to a given context as it may be extended in various directions by adding new constructs suitable for the topic (King and He, 2006). Already-used models can be merged to create a tool fitted specifically for the study theme. For example, studies mix TAM with DOI (Tran and Cheng, 2017). Researchers applying TAM often add other factors to PU and PEU, such as PC (also called Perceived Reasonable Cost) (Ali and Naushad, 2023; Alam and Rashid, 2012), social norms or social influence (Grębosz-Krawczyk et al., 2021b; Lee, 2010), financial incentives, frequently used in case of green technologies (Chel and Kaushik, 2018; Yang and Park, 2020), and Environmental Concern (Malik et al., 2020; Gadenne et al., 2011). As some scientists believe basic TAM to be too parsimonious (Bagozzi, 2007; Schierz et al., 2010), the authors decided to use TAM as a foundation and supplement the original factors with the Perceived Cost (PC) and Environmental Concern (EC).

The TAM was selected as the analytical framework due to its proven effectiveness in explaining user acceptance of technological innovations across various contexts, including energy-related behaviors. Compared to more complex models such as the Unified Theory of Acceptance and Use of Technology (UTAUT), TAM offers a more parsimonious structure while maintaining strong explanatory power. Its core constructs—Perceived Ease of Use and Perceived Usefulness—are well established in the literature and have demonstrated reliability in predicting behavioral intentions. Additionally, TAM is highly adaptable, allowing for the incorporation of context-specific variables, which in this study include EC and PC. This flexibility makes TAM particularly suitable for investigating consumer attitudes toward renewable energy technologies in the Polish context.

In the proposed model, the dependent variable is the Purchase Intention (PI) of green energy technology among Polish consumers. The PI can be defined as the likelihood that a consumer actually intends to purchase a specific product (Younus et al., 2015) or the preference of the respondent to buy the product or service in question (Peña-García et al., 2020). The research also includes four control variables in the form of basic demographic factors describing the respondents: gender, age, education, and place of residence.

The following subsections present the independent variables that are potential antecedents of green energy Purchase Intentions.

2.2.1 Perceived Ease of Use

This subsection discusses Perceived Ease of Use (PEU) in the context of renewable energy technologies. PEU was originally defined by the creator of TAM as the degree to which a potential user believes that using the new technology would be effortless (Davis, 1989) or the "extent to which novelty in technology is considered to be easy to understand and use" (Ali et al., 2020). Other authors also include the impression of how much effort is needed to learn to operate a new technology product (Amin et al., 2014; Rouibah et al., 2011). Therefore, PEU is "inversely associated with the amount of resources (time and energy) required to learn the instructions for a new technology" (Venkatesh and Davis, 2000). Considering the technology as user-friendly increases the willingness to acquire and to keep using it in the future (Tsai et al., 2022) as well as to repurchase certain products (Wen et al., 2011; Saoula et al., 2023).

In the case of green energies, two groups of factors are included in the PEU concept: the ease of ongoing maintenance and the ease of initial learning to operate the appliance. Usually, the potential users omit the effort to install the renewable energy system at home, as installation is done by professionals in most cases (Zdonek et al., 2022). The more challenging element of switching to photovoltaics or heat pumps is learning how to use them: how to get the right settings, how to regulate the system according to external circumstances, or how to react to potential unexpected incidents. Although the requirements for everyday users are scarce, the uncertainty over the ability to learn the principles might be a factor discouraging the switch to green energy (Hua and Wang, 2019; Toft et al., 2014). On the other hand, the ease of use of renewable energy sources might be considered an advantage of the green technologies for those switching from the oldest and least technologically advanced units, such as various types of pellet fuel or coal-fired boilers, to a heat pump (Yan et al., 2020). Green technologies need practically no action on an everyday basis, while traditional boilers demand frequent refilling of the fuel, which might become a considerable obstacle as it requires quite strenuous physical effort. In the light of current research, the PEU has a generally favorable impact on the consumers' PIs (Matczak et al., 2023; Bouaguel and Alsulimani, 2022; Zdonek et al., 2022; Hua and Wang, 2019), even despite the natural apprehension a part of society might feel toward learning to use new appliances.

On the basis of previous studies, the following research hypothesis was formulated:

Hypothesis 1: Perceived Ease of Use (PEU) has a positive impact on Purchase Intention (PI) of green energy technology.

2.2.2 Social and economic Perceived Usefulness

This subsection discusses Perceived Usefulness (PU) in the context of renewable energy technologies. The first factor believed to influence the PI of renewable energy appliances is the Perceived Usefulness. Originally, Davies (1989) defined it as "the degree to which a person believes that using a particular system would enhance his or her job performance," and currently, PU relates to the extent to which an individual believes that implementing new technology would enhance the ability to carry out a specific task, simplify a job to be done, or improve the efficiency of certain processes (Wang et al., 2017; Chen and Aklikokou, 2019). In other words, PU might be treated as the degree to which the consumers notice the potential benefits of choosing a specific product over other options, in this case, the advantages renewable energy sources have over classical technologies, for example, in the context of cutting electricity or gas bills and the reduced contribution to the global warming and other environmental dangers (Gârdan et al., 2023). Researchers also point out to the relationship between PU and PEU—a high level of Perceived Ease of Use positively contributes to seeing the product as generally useful (Hua and Wang, 2019).

It should be emphasized that technology, particularly innovative solutions, is typically implemented to improve the efficiency and performance of systems and tasks. Individuals are likely to accept and incorporate technology into their daily lives only when they are convinced that it will support them in achieving their goals. Accordingly, the concept of PU in the context of new technologies represents a key determinant of individuals' attitudes and behaviors toward innovation (Khalid et al., 2021).

Perceived Usefulness is by many considered a concept of one dimension; however, some authors suggest a need to look at the utility of new technologies from different angles (Hamari et al., 2016; Martens et al., 2017). Such an approach of including more precise variables in the TAM may help gain higher explanatory power within a context specific for the main issue investigated (Gbongli et al., 2019; Chang et al., 2017). Therefore, PU can be also applied as a second-order variable and divided into three separate aspects (Ali et al., 2020; Garay et al., 2019): PU influenced by social factors (e.g., the use of new technology is contributing to the wellbeing of the society), economic PU (e.g., the technology serves the purpose of reducing the costs), and environmental PU (e.g., the application of new technology is reducing the consumption of natural resources).

In this study, the authors use two dimensions of Perceived Usefulness: social and economic, as the ecological issues are considered within the separate variable of Environmental Concern (EC). Social PU is connected with the overall impact that the decision to switch to renewable energy might have on society or at least on the people in proximity. In case of the issue of this work, a decision to install green energy systems at home might be considered a move contributing to the society's wellbeing by, for example, reducing emissions, saving available fossil fuels for those who need them more, or minimizing the impact on environment in order to preserve it for the future generations (Garay et al., 2019).

Economic PU concerns potential financial gains or losses that might be incurred due to the choice of new technology (Kotilainen and Saari, 2018). It might also be sometimes identified with the concept of perceived financial benefit or economic feasibility (Rahmani et al., 2023); however, the feasibility contains both profits and costs as elements of the investment decision. In this paper, the impact of costs is covered by a separate variable, Perceived Reasonable Cost, while economic PU is strictly related to gains. Considering the topic of renewable energy, two factors might be crucial: the savings related to lower energy bills and potential earnings from selling the excess energy back to the grid (Zhang et al., 2020). Multiple researchers have proven that perceived economic gains are a high-priority element in assessing the PIs for green energy products (Li and Dai, 2024; Rahmani et al., 2023; Hasheem et al., 2022).

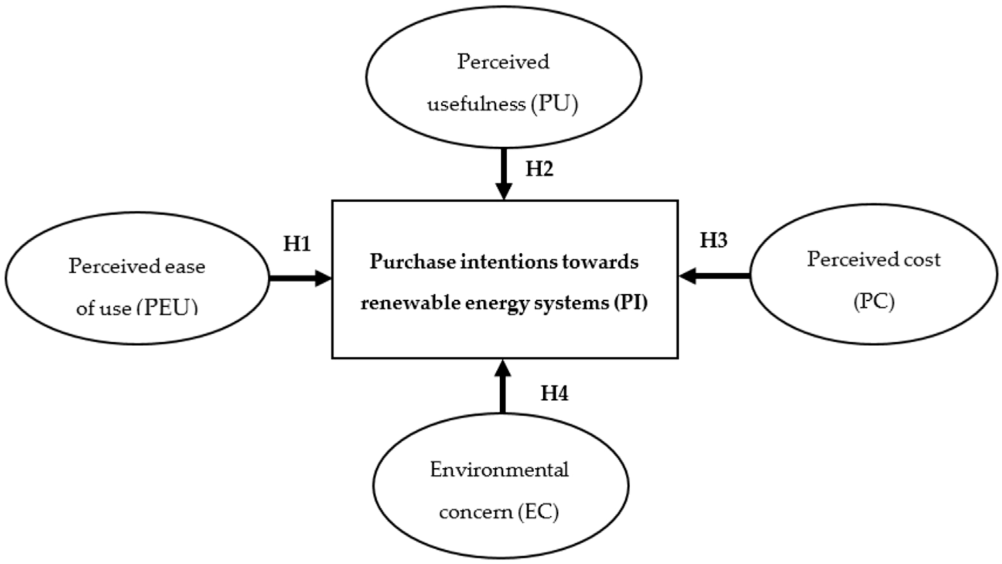

FIGURE 1
Conceptual model.

Relying on preceding studies, the following hypotheses are presented.

Hypothesis 2: Perceived Usefulness (PU) has a positive impact on Purchase Intention (PI) of green energy technology.

Hypothesis 2A: Perceived Usefulness Influenced by Social Factors (PUS) has a positive impact on Purchase Intention (PI) of green energy technology.

Hypothesis 2B: Economic Perceived Usefulness (PUE) has a positive impact on Purchase Intention (PI) of green energy technology.

2.2.3 Perceived Cost

This subsection discusses Perceived Cost in the context of renewable energy technologies. The variable that often strongly influences the intention to purchase new technology is Perceived (reasonable) Cost. Appliances utilizing renewable energy, such as PV panels or heat pumps, require an upfront investment, usually larger than standard-powered home systems, and take time to break even (Niekurzak, 2021). Therefore, the consumer must be assured about the reasonableness of such expense (Zainab et al., 2017). This reasonableness is strongly linked to the evaluation of technology's usefulness—consumers would decide to invest in innovative technology and believe the cost to be reasonable because they expect this technology to be useful (Kim and Cho, 2019).

In the context of renewable energy, a key factor considered by individuals evaluating the advantages and disadvantages of adopting new household systems is the availability of financial incentives, often provided by national or local governments. In many countries, investments in green energy technologies are supported through government subsidies or tax credits, which have been shown to have a positive impact on PIs (Zhang et al., 2011; Lekavičius et al., 2020; Nicolini and Tavoni, 2017). In Poland, various monetary and legal incentives have been introduced to encourage the transition from coal-based systems to more sustainable energy sources. Among the most prominent programs are (Mazurek-Czarnecka et al., 2022):

- the My Electricity Program, which provides partial reimbursement for investments in photovoltaic (PV) systems;
- the Thermal Modernization Tax Relief, which covers expenses related to the installation of heat pumps or solar collectors; and
- the Clean Air Priority Program (CAPP), which offers non-refundable grants to support the repayment of loans used for the purchase and installation of PV systems.

On the basis of previous studies, the following research hypothesis was formulated.

Hypothesis 3: Perceived (reasonable) Cost (PC) has a positive impact on Purchase Intention (PI) of green energy technology.

2.2.4 Environmental Concern

Another variable that might be applied in research regarding the PI of new technologies connected with ecology and saving natural resources in the Environmental Concern (EC). The concept is related to the awareness of environmental risks and an attitude involving worry about potential environmental harm, together with a commitment to protect nature. In general, EC depicts one's overall attitude toward preserving the environment (Wei et al., 2018; De Canio et al., 2021) and presents the extent to which people are aware of environmental issues and are willing to address problems of ecology with their own behaviors (Alibeli and Johnson, 2009). In current studies, EC has gained significant attention as it is strongly associated with predicting eco-friendly behaviors of the individuals (De Canio et al., 2021; Ahmed et al., 2020). Moreover, some researchers suggest that the importance of EC has grown as a result of COVID-related lockdowns and restrictions, as in

TABLE 1 Characteristics of respondents.

Demographic features	N	%
Gender		
Female	304	52.4
Male	276	47.6
Age		
18–24	33	5.7
25–34	115	19.8
35–44	136	23.4
45–54	92	15.9
55–64	102	17.6
65 and over	102	17.6
Education		
Primary	31	5.3
Secondary	342	59.0
Higher	207	35.7
Place of living		
Countryside	12	2.1
City with a population of fewer than 50,000 inhabitants	13	2.2
City with a population from 50,000 to 150,000 inhabitants	111	19.1
City with a population from 150,000 to 500,000 inhabitants	244	42.1
City with a population of more than 500,000 inhabitants	200	34.5

such circumstances, consumers have once again acknowledged the critical role of nature in one's life, thus awakening a will to protect it (Cachero-Martínez, 2020).

Switching to renewable energy sources is known to be a part of a pro-ecological lifestyle as it contributes to reducing the harmful emissions (being a cause of the greenhouse effect), conserving Earth's natural resources, and preventing air pollution (Kowalska-Pyzalska, 2018). Therefore, it is often chosen by people representing a high level of Environmental Concern. It has been suggested by multiple studies that EC directly influences environmentally friendly PIs (Hoang and Tung, 2024; Ogiemwonyi et al., 2023; Suhartanto et al., 2023; Newton et al., 2015), obviously including the market of renewable energy technologies (Elangovan et al., 2024; Bouaguel and Alsulimani, 2022; Gârdan et al., 2023).

Relying on preceding studies, the following hypothesis is presented:

Hypothesis 4: Environmental Concern (EC) has a positive impact on the Purchase Intention (PI) of green energy technology.

Taking all the individual factors influencing the consumers' PIs regarding renewable energy systems for individual households, a conceptual model was built. It is presented in Figure 1.

3 Materials and methods

3.1 Sample and data collection

The survey was carried out on a sample of Polish consumers using a self-administered questionnaire, employing a random selection method (Groves et al., 2011). The survey utilized a database provided by a data collection and market research company, which maintains online panels of 3,000,000 consumers across 19 European countries. The survey was conducted in June 2024, a period marked by intensified public discussions in Poland about the national energy transition, EU environmental policies, and high energy prices. These factors may have influenced consumer perceptions of renewable energy technologies, particularly regarding their usefulness and economic feasibility.

In the initial step, we randomly selected 20 potential respondents to conduct a pretest. These respondents evaluated the survey's content and relevance, offering feedback that led to minor adjustments for improved readability and clarity. After the trial stage, the final questionnaire was developed. In the second step, a sample of 1,000 consumers was drawn from a database of over 40,000 individuals aged 18 and older. The data collection process yielded a final sample size of 580 consumers, resulting in a response rate of 58%, which is acceptable for this type of survey (Baruch, 1999). The initial sample consisted of 1,000 consumers selected from a database as a representative sample. We received 580 complete responses. While the final sample is not fully representative of the entire Polish population, it is relatively large compared to similar studies conducted in this field, particularly considering the context of a country with 37.7 million inhabitants. This sample size ensures a solid foundation for meaningful analysis and identifying relevant trends. Although certain limitations related to demographic representativeness remain, the diversity and scale of the responses strengthen the robustness and validity of our findings. The sample allows for the exploration of key behaviors and attitudes related to renewable energy, which are likely to reflect patterns present in specific subgroups of the population. To reduce biases, respondents were randomly approached at various times and on different days (Sakshaug et al., 2010). The main characteristics of the respondents are detailed in Table 1.

Most were women aged 35 to 44 with secondary education, and participants were primarily city dwellers from urban areas with populations exceeding 500,000 residents.

3.2 Measures

The questionnaire comprised 24 questions of three different types. First, respondents were asked about their behavior regarding green energy sources. They could select from three possible answers: (1) "Yes, I use them," (2) "Yes, I plan to use them within the next 4 years," or (3) "No." We explained what green energy sources are before asking the question.

TABLE 2 Items investigated in the study.

Construct	Item	Statement
Environmental Concern	EC1	Using green energy technology, I help reduce environment pollution.
	EC2	I am willing to commit myself to environmental protection.
	EC3	I am convinced that my moral obligation to help the environment is important.
Perceived Cost	PC1	Green energy technology is reasonably priced.
	PC2	Green energy technology offers value for money.
	PC3	The incentive programs provided by the government to promote green energy technology are attractive for me.
Perceived Ease of Use	PEU1	I find green energy technology easy to use.
	PEU2	The ongoing maintenance of green energy technology is easy.
	PEU3	Learning how to use green energy technology is easy for me.
	PEU4	Green energy technology doesn't require a lot of knowledge.
Purchase Intention	PI	
Perceive Usefulness	PU1	Introducing green energy technology in my house allows me to contribute something to society.
	PU2	Introducing green energy technology in my house allows me to help those who need fossil fuels more than I do.
	PU3	Introducing green energy technology in my house allows me to do something for others.
	PU4	Introducing green energy technology in my house allows me to save money.
	PU5	Introducing green energy technology in my house allows me to reduce costs.

Subsequently, we developed a set of five items to measure Perceived Ease of Use of green energy sources and six items to assess Perceived Usefulness, divided into two dimensions: three items addressing economic usefulness and three items reflecting socially influenced usefulness. Additionally, three items were constructed to evaluate Perceived (Reasonable) Cost, and three items were dedicated to measuring Environmental Concern among consumers. A five-point Likert scale was employed, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). This scale was chosen due to its suitability for simplifying survey responses while minimizing systematic measurement error (Lee and Turban, 2001). The initial pool of measurement items was generated through an extensive literature review on pro-environmental consumer attitudes and behaviors. These items were subsequently adapted and refined to align with the context and specificity of the green energy market. In constructing the questionnaire, we considered insights from numerous studies examining green consumer behavior. Ultimately, measurement items from Garay et al. (2019), Grębosz-Krawczyk et al. (2021a), Hamari et al. (2016), Malik et al. (2020), Parasuraman (2000), Paul et al. (2016), and Wang et al. (2017) were selected and, where necessary, modified to suit the research objectives. The final set of items is presented in Table 2.

Finally, demographic information about respondents, including gender, age, education level, and place of living, was gathered using a multiple-choice response scale.

4 Results

4.1 Measures, scale validation, and reliability analysis

To evaluate the validity of our measurements, we performed a confirmatory factor analysis (CFA) using maximum likelihood estimation. This analysis was conducted to determine if the observed measures align with our conceptualization of the construct and to assess how well the data fit a proposed measurement model (Kline, 2015; Nguyen et al., 2020; Podsakoff et al., 2003). Convergent validity of the scale was confirmed by calculating the standardized loadings. The results of this convergent validity, as indicated by the factor loadings, are detailed in Table 3.

Conducting CFA, one item was dropped because of the undesirable values of standardized loadings associated with it (i.e., the values were lower than 0.5) (Kline, 2015; Nguyen et al., 2020; Podsakoff et al., 2003). As a result, we were unable to establish the convergent validity of Environmental Concern.

We also assessed the scale's convergent validity using average variance extracted (AVE). AVE exceeded 0.5 for all variables except Environmental Concern (EC), which had an AVE of 0.197, indicating that this variable should be excluded. Reliability was evaluated by calculating both standardized and unstandardized

TABLE 3 Factor loadings.

Item	EC	PC	PEU	PI	PUE	PUS
EC1	0.434					
EC2	0.430					
EC3	0.468					
PC1		0.786				
PC2		0.719				
PC3		0.752				
PEU1			0.977			
PEU2			0.986			
PEU3			0.749			
PEU4			0.758			
PI				1.000		
PU1					0.983	
PU2					0.899	
PU3					0.996	
PU4						0.708
PU5						0.653

Cronbach's α, as well as composite reliability (CR). The results demonstrate good reliability, with both Cronbach's α and CR exceeding the 0.7 threshold for all variables except EC. Additionally, in the case of PUS, Cronbach's α and CR are smaller than 0.7, and AVE is smaller than 0.5. However, according to Hair et al. (2009), Cronbach's α and CR can be higher than 0.6, and AVE can be higher than 0.4 in the case of new constructs. Table 4 provides details on convergent validity based on AVE, as well as reliability as measured by Cronbach's α and CR.

In the case of PC, PEU, PI, PUE, and PUS, all statistics are at an acceptable level. Thus, good internal consistency among the items was confirmed.

The Fornell–Larcker criterion suggests that the root square of each construct's AVE should be higher than the correlation with any other construct (Fornell and Larcker, 1981), as presented in Table 5.

4.2 The structural equation model and hypothesis testing

We used structural equation modeling (SEM) with maximum likelihood (ML) estimation, utilizing the covariance matrix as input to evaluate our conceptual model and hypotheses. The ML estimation method, which is widely recommended for theory testing and development (Gerbing and Anderson, 1988), was employed to uncover causal relationships between variables. The model demonstrated a good fit, as indicated by standardized residuals below 0.05. Model fit statistics further support this: $\chi^2/df = 4.121$, RMSEA = 0.078, GFI = 0.911, CFI = 0.941, and TLI = 0.917 (Thakkar, 2020). Hypotheses were evaluated based on standardized beta (β) values, t-values, and significance levels. Detailed results from the SEM are presented in Table 6 and depicted in Figure 2.

Only two of the four hypotheses proposed were supported by the data. Hypothesis H1, considering a positive impact of Perceived Ease of Use on Purchase Intention of green energy technology, was confirmed. Similarly, hypothesis H2A, which suggested a positive impact of Perceived Usefulness influenced by Social Factors on Purchase Intention of green energy technology, was also supported. Among these two variables, Perceived Usefulness Influenced by Social Factors (PUS) had a more substantial effect.

However, hypotheses H2B and H3 were not supported. The impact of economic Perceived Usefulness and Perceived Reasonable Cost was found to be statistically insignificant ($p > 0.05$). Moreover, their impact was negative. Additionally, we could not test hypothesis H4 due to the inability to construct the latent variable for Environmental Concern required for this hypothesis.

When considering the control variables—respondents' gender, education level, and place of residence—additional relationships were observed. In case of women, we statistically more often observe the impact of PU influenced by social factors on PI of green energy technology ($\beta = 0.314$; $t = 2.780$; $p < 0.05$). In the case of men, we observe a statistically significant impact of PEU on PI of green energy technology ($\beta = 0.112$; $t = 2.185$; $p < 0.05$). In the case of people with secondary education, we statistically more often observe the impact of PUS on PI of green energy technology ($\beta = 0.271$; $t = 2.865$; $p < 0.05$). However, in the case of people with primary education, we observe a statistically significant impact of economic PUE on PI of green energy technology ($\beta = 0.870$; $t = 5.211$; $p < 0.05$). Age and place of residence do not have a statistically significant impact on the PI of green energy technology.

5 Discussion

The research described above enabled us to indicate certain antecedents of Purchase Intentions (PI) regarding household renewable energy systems among Polish consumers. The study shows that Perceived Ease of Use (PEU) and Perceived Usefulness Influenced by Social Factors (PUS) both have a positive impact on the PI, with PUS presenting the more substantial effect.

In case of positive impact of PEU, those results are consistent with findings of Khalid et al. (2021) or Zdonek et al. (2022) regarding Poland, and those of Nguyen, Mai and Hoang (2023), Bouaguel and Alsulimani (2022), Gârdan et al. (2023), Ali et al. (2020), Hua and Wang (2019), Ashinze et al. (2021), Bandara and Amarasena (2020), or Li and Dai (2024) from other countries. All these studies have shown that PEU indeed has a beneficial contribution to adopting green energy sources such as photovoltaic panels or heat pumps, which agrees with our recent findings. However, some researchers have proven a contradictory thesis showing the lack of statistically significant impact of PEU, for example, Masukujjaman et al. (2021).

When it comes to the impact of PU influenced by social factors, not many studies divide PU into more detailed constructs; therefore,

TABLE 4 Convergent validity and reliability of variables.

Item	Cronbach's α	Composite reliability (CR)	Average variance extracted (AVE)
EC	0.423	0.422	0.197
PC	0.793	0.796	0.567
PEU	0.938	0.928	0.766
PI	1.000	1.000	1.000
PUE	0.942	0.941	0.923
PUS	0.632	0.632	0.464

TABLE 5 The Fornell–Larcker criterion.

Item	PC	PEU	PI	PUE	PUS
PC	0.753				
PEU	0.156**	0.875			
PI	−0.074	0.081	1.000		
PUE	0.730**	0.068	−0.044	0.961	
PUS	−0.145*	−0.080	0.174**	0.034	0.697

Note: the diagonal values (in bold) present the square roots of AVE.
*Correlation is significant at the level of 0.05 (2-tailed).
**Correlation is significant at the level of 0.01 (2-tailed).

findings regarding social PU (PUS) are quite rare. Ali et al. (2020) have found that PUS indeed has a positive impact on green energy adoption (in the form of PV), and Yilmaz et al. (2024) have shown that perceived benefits for society have favorably influenced the acceptance of heat pumps.

The results do not support the existence of a positive impact of PUE on consumers' PIs. It has been found to be negative and, what is more, statistically insignificant. Similarly, as in the case of PUS, not many researchers have used this exact factor in their works regarding green energy. Ali et al. (2020), Ropuszyńska-Surma and Węglarz (2018), and Zdonek et al. (2023) show the positive impact of PUE, which is not consistent with our findings at all. The negative (though insignificant) coefficient for PUE may indicate that economically-oriented respondents are less motivated to adopt such technologies unless clear and immediate cost savings are evident.

Our results may also be compared with those regarding PU as a singular factor; however, it would be problematic, as our findings confirm the impact of PUS and do not corroborate the impact of economic PU. Therefore, it might be acknowledged that PU should be studied as a multidimensional construct, while the finance-related factors might be a deterrent for technology adoption. At the same time, the aspects connected to environmental or social benefits might act as a strong incentive towards the same technology. Similarly, some dimensions of PU might turn out to be significant, while others might not be of particular interest to the same group. Investigating only PU without differentiating its separate aspects might overly simplify the findings.

Our study has not proven the impact of Perceived Cost (PC) on the PIs regarding green energies, as its influence turned out to be statistically insignificant. Such results contradict the works of Ashinze et al. (2021), Bandara and Amarasena (2020), or Jabeen et al. (2021). Our findings are also in strong opposition to the study outcomes of Hobman and Frederiks (2014), who have shown that cost is one of the most important factors in acceptance of green technologies (with high cost being a major deterrent from adopting these systems in the household). However, there are also papers presenting a similar stance, where the impact of cost turned out to be insignificant—such conclusions have been reached by, for example, Ali and Naushad (2023). The lack of significance for PC may reflect a persistent perception among Polish consumers that renewable energy technologies remain financially inaccessible, especially when compared to conventional energy sources. It might indicate the need to educate people about the economic benefits of green energy, even though these might not be instantaneous.

We have not managed to construct the latent variable for Environmental Concern (EC) required for the hypothesis test; therefore, our work cannot confirm or oppose the findings of other scientists. In general, most of the researchers corroborate the fact that EC positively impacts the PIs for renewable energy technologies, see, for example, Wall et al. (2021), Hartmann and Apaolaza-Ibanez (2012), Dienes (2015), or Khalid et al. (2021). Nevertheless, some papers oppose this thesis. Asif et al. (2023) found EC to be statistically insignificant for the PIs of consumers. No conclusion can be drawn from our study in that aspect.

As far as control variables in the form of demographic characteristics are concerned, our study has not confirmed the impact of age and place of residence on the PIs for green energy systems. These findings conflict with the works of Kowalska-Pyzalska (2018) and Zorić and Hrovatin (2012), which show that age is negatively correlated with the adoption of green energy (the older the consumer, the less willing they are to switch to renewable energy resources). The results we obtained are also not consistent with the findings of Zdonek et al. (2023) and Graczyk (2016), who indicated that people living in rural areas are more inclined towards installing a prosumer installation.

The demographic findings revealed certain discrepancies compared to general population trends, particularly in terms of age

TABLE 6 Results of structural equation modeling.

Relations between items	β	SE	t-values	p-values	Path coefficients (standardized)
PC -> PI	−0.054	0.062	0.879	0.380	−0.051
PEU -> PI	**0.081**	**0.035**	**2.328**	0.020	0.097
PUE -> PI	−0.023	0.047	0.501	0.617	−0.026
PUS -> PI	**0.230**	**0.079**	**2.927**	0.004	0.186

Values in bold indicate statistically significant path coefficients at $p < 0.05$.

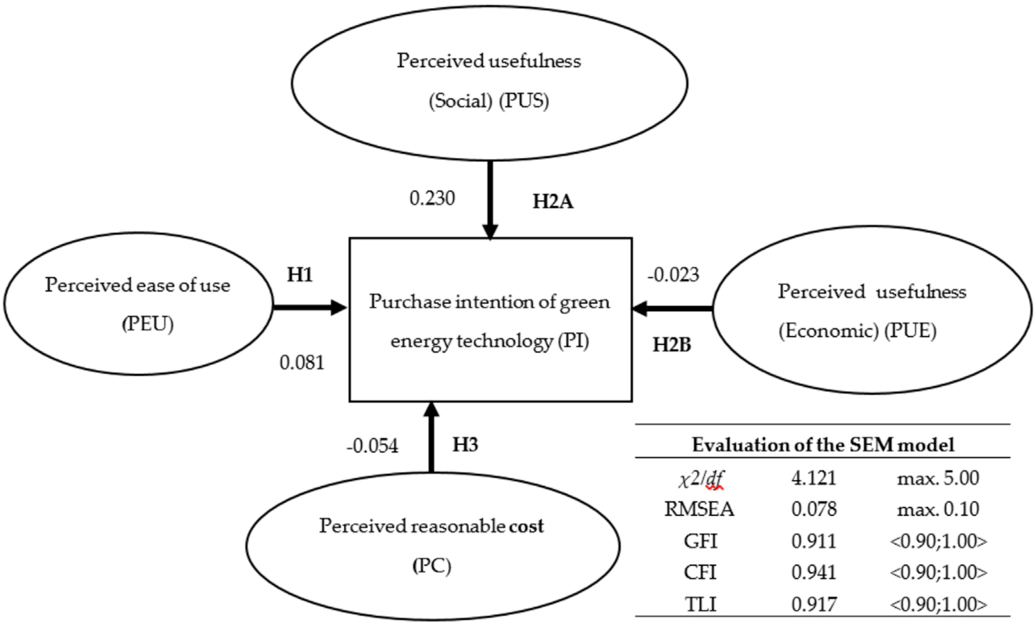

FIGURE 2
SEM model.

and education. While previous studies often suggest that younger individuals are more inclined to adopt sustainable innovations, our results indicate mixed patterns. One possible explanation lies in the role of socioeconomic status, digital literacy, and value orientation, which may mediate the relationship between age and openness to renewable energy (Diamantopoulos et al., 2003; Gifford and Nilsson, 2014). Similarly, education level does not always translate directly into pro-environmental action as consumer behavior may be influenced more by perceived personal relevance or social norms than by general knowledge (Grankvist et al., 2004). These observations underscore the importance of considering not only demographic variables in isolation but also the broader sociocultural and psychological context in which energy-related decisions are made.

6 Conclusion

It is evident that green energy has been a subject of extensive global research; however, certain aspects—particularly those within local or regional contexts—still warrant further investigation. This study contributes to the literature by providing evidence from a developed Central European country and adopts a comprehensive approach by examining renewable energy sources as a whole, rather than focusing on a specific technology. The findings of this research confirm a positive influence of both Perceived Ease of Use and Perceived Usefulness, driven by social factors, on consumers' PI regarding green energy technologies.

These results offer valuable insights for manufacturers, retailers of renewable energy systems, and policymakers. Notably, the data indicate that potential users of renewable energy systems are significantly influenced by their perceptions of ease of use. As such, communication strategies should emphasize the simplicity and convenience of the daily operation of these systems. Manufacturers would benefit from designing devices that are intuitive and user-friendly, particularly in terms of installation, programming, control, and troubleshooting. Additionally, retailers should ensure that clear and accessible user manuals and instructional materials are provided, demonstrating that the technology is approachable, even for individuals with limited technical expertise.

The impact of Perceived Usefulness influenced by social factors, in turn, could be a guideline for the government as well as organizations connected with ecology to communicate the advantages for the whole society that arise from choosing green energy for an individual household. It can be done by means of social campaigns promoting the switch to renewable sources as a contribution to societal wellbeing and individual investments in a better future.

Our present study has certain limitations; therefore, it leaves space for further discussion and consideration in subsequent research endeavors. First, despite the research sample being relatively large (580 respondents), it was not representative. Therefore, it would be interesting to repeat the study on a larger sample, representative of the Polish society. As the study is cross-sectional, it captures consumer attitudes and intentions at a single point in time. These perceptions may evolve in response to external factors, such as changes in environmental policies, market dynamics, or broader economic conditions. Moreover, our research concerned green energy as a general concept that included electricity and heat generation from solar, thermal, and wind technologies. It might be beneficial for further studies to ask the same questions separately for each of the green technologies. Therefore, it might be determined whether the investigated factors play the same role in shaping the PIs in regard to all types of systems or whether they differ along with the technology. In addition, other research items might be used in the case of the Environmental Concern variable to obtain a reliable result. This variable did not meet the threshold for convergent validity, indicating that the set of items used may not adequately reflect a coherent, unidimensional construct. As a result, the EC variable was excluded from the final structural model. This outcome suggests the need for further refinement of the EC measurement approach in future research. It may be beneficial to explore Environmental Concern through its potential sub-dimensions—such as cognitive, emotional, and behavioral aspects—to achieve better internal consistency and conceptual clarity. Future studies may also consider employing well-validated measurement scales, such as the New Ecological Paradigm (NEP) scale, to strengthen construct validity and ensure more reliable assessment of environmental attitudes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

DS: conceptualization, data curation, methodology, visualization, writing – original draft, and writing – review and editing. MG: conceptualization, formal analysis, investigation, methodology, validation, and writing – original draft.

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