Journal of Infrastructure, Policy and Development 2024, 8(16), 10227.
https://doi.org/10.24294/jipd10227

Article

Exploring consumer motivations and barriers in solar energy investments in North Transdanubia

Szilvia Módosné Szalai[1], Szonja Jenei[1], Elena Moreno-García[2], Vasantha Patibandla Lakshmi[3], Erika Tóthné Juhász[4], Csaba Bálint Illés[5,*]

[1] Széchenyi István University, Kautz Gyula Faculty of Business and Economics, 9026 Győr, Hungary
[2] Universidad Cristóbal Colón, Financial Literacy Research Center, 91930 Veracruz, Mexico
[3] Department of International Business, ITM Skills University, ITM Group of Institutions, 410210 Navi Mumbai, India
[4] Wol Solar, 9024 Győr, Hungary
[5] Doctoral School of Management and Business Administration, John von Neumann University, 6000 Kecskemét/Budapest, Hungary
*** Corresponding author:** Csaba Bálint Illés, illes.b.csaba@nje.hu

CITATION

Szalai SM, Jenei S, Moreno-García E, et al. (2024). Exploring consumer motivations and barriers in solar energy investments in North Transdanubia. Journal of Infrastructure, Policy and Development. 8(16): 10227. https://doi.org/10.24294/jipd10227

ARTICLE INFO

Received: 11 November 2024
Accepted: 8 December 2024
Available online: 19 December 2024

Abstract: The global significance of the energy crisis and the need for a sustainable European electricity system have intensified interest in renewable energy sources. This study aims to explore the attitudes toward solar energy systems among the population of the North Transdanubian region, which is crucial for companies in the region specializing in solar system installation. The research sheds light on trends in energy prices, potential strategies for addressing the energy crisis, and the regulatory environment for solar systems in Hungary and Austria, focusing on the Burgenland region. The study is divided into two main sections: secondary and primary research. The secondary research presents various applications of renewable energy sources, especially solar energy, and examines energy pricing trends in the two countries, with particular emphasis on the payback period and the impact of changes in energy prices. The primary research is also divided into two parts: the first examines the satisfaction of customers who already use solar systems, and the second focuses on the attitudes of potential customers toward solar investments. The findings provide a comprehensive view of both current users' and prospective investors' perspectives on solar energy systems. The practical significance of this research lies in identifying development opportunities for companies, advancing energy efficiency goals, and supporting sustainability efforts.

Keywords: sustainability; solar energy; payback; customer satisfaction; potential buyers

1. Introduction

Renewable energies are energy sources continuously replenished by natural resources, including sunlight, wind, rain, waves, tides, and geothermal heat. These energy sources regenerate within a short period. The concept of renewable energy also encompasses technologies that convert these natural resources into energy sources, such as wind, wave, tidal, and hydropower (including micro-hydro and river hydro), solar energy (including photovoltaic energy), biomass and biofuel technologies (including biogas), and waste recycling (Lund, 2010). Solar energy is the fundamental basis of all renewable energy sources except geothermal energy (**Figure 1**). The energy from sunlight that reaches Earth provides the foundation for various energy generation processes. For example, wind is generated as a result of pressure differences created by solar radiation and is harnessed in wind turbines. Through evaporation, solar energy also ensures the renewal of the ocean's water supply, while precipitation falling in mountainous regions represents energy that can be converted into kinetic or electrical energy in hydropower plants (Juhász et al., 2009). Solar energy utilization can be classified into two main approaches: active and passive use. In active utilization, solar radiation is converted into heat or electricity with the help of devices such as solar panels or collectors. Within active utilization, photothermal systems directly convert solar radiation into thermal energy (Cheng et al., 2022), while photovoltaic systems generate electricity directly, which can be stored or used immediately. In contrast, passive utilization does not require technical equipment; instead, buildings are optimized for solar energy usage through proper orientation, insulation, and design (Semberry and Tóth, 2004). Energy efficiency and sustainable practices play an important role in the adoption of renewable energy sources. Mousazadeh et al. (2023) highlight that sustainable tourism can support these efforts.

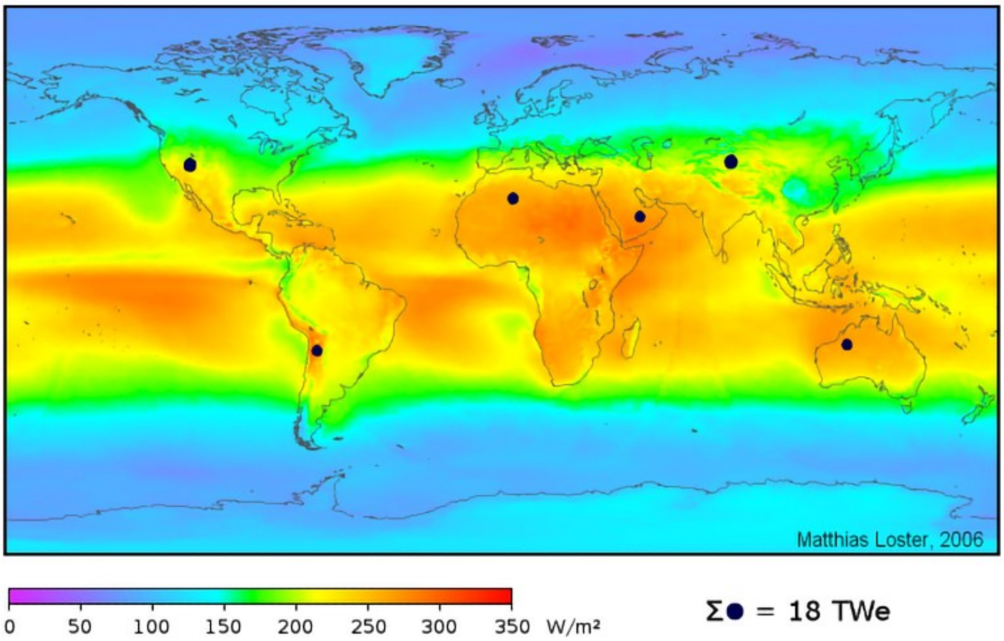

Figure 1. Global solar radiation and energy production potential.
Source: e-genius, 2023: PV System Design and Sizing.

Different countries experience varying levels of solar radiation (**Figure 2**). Hungary's annual global radiation ranges from 1100 to 1250 kWh/m^2, based on the number of sunshine hours. In Austria, this value varies by region, from around 1100 kWh/m^2 (near Vienna) to 1400 kWh/m^2 (in the southern Alpine regions) (e-genius, 2023; Wagner Solar, 2017). Across the EU, solar energy distribution also varies, with certain areas receiving 10%–30% more energy per square meter than others (Solar Panel Advice, 2023). Active utilization of solar energy particularly emphasizes photothermal and photovoltaic methods (Li et al., 2022). In the photothermal process, solar energy is directly converted into heat through a fluid or air-circulating device known as a solar collector. In liquid-based systems, the stored energy can be held in an insulated tank (Semberry and Tóth, 2004). Photovoltaic systems, on the other hand, convert solar radiation directly into electricity using solar panels. These systems can power appliances directly or store the generated energy, ensuring a power supply during nighttime or cloudy periods (Fülöp, 2023). Passive solar energy utilization aims to improve buildings' energy efficiency by capturing, storing, and using solar radiation within the indoor environment. In well-designed buildings, heat energy generated by solar radiation flows in and contributes to the building's thermal balance. Key considerations for passive solar energy utilization include building orientation, insulation quality, the choice of wall materials and mass, and the application of solar air systems (Semberry and Tóth, 2004).

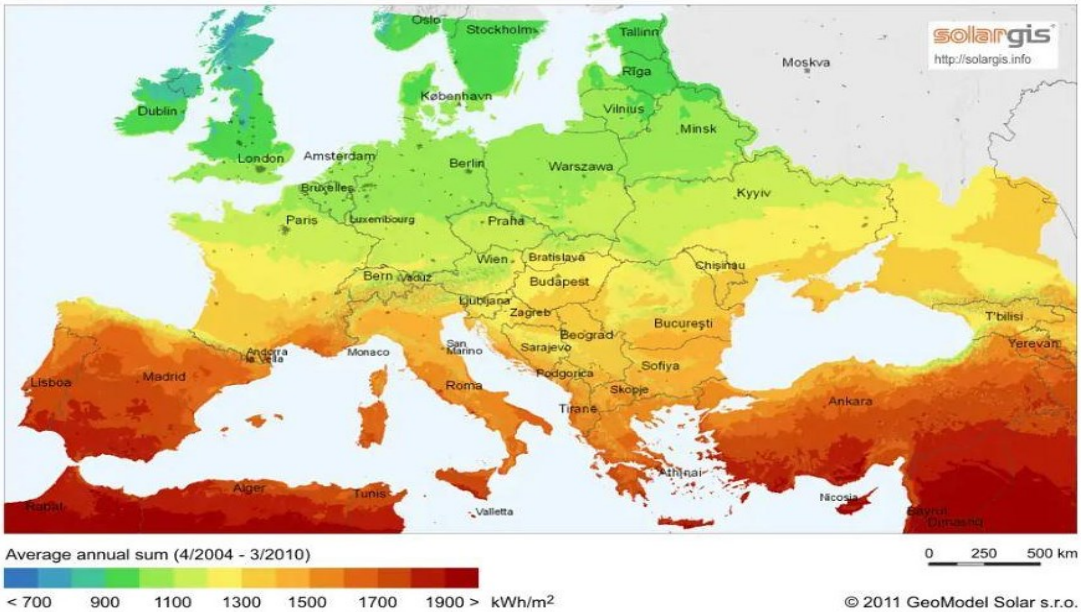

Figure 2. Solar radiation data within the European Union.

Source: Solar Panel Advice, 2018: Why is Hungary an Optimal Location for Solar Energy Utilization?

2. Literature review

Renewable energies include sources that are replenished by natural resources, such as sunlight, wind, water, and geothermal heat, making their use sustainable (Lund, 2010). In Hungary, residential energy prices have significantly increased in recent years: according to the Central Statistical Office, household energy costs rose by 43.1% in 2023 compared to the previous year (KSH, 2023). Currently, E.ON's electricity rates range between 35.293 and 70.104 HUF/kWh. As a result of government intervention, regulated energy prices in Hungary were reduced by a quarter between 2013–2014, and in 2022, a restrictive system was introduced that provides a subsidized rate for consumption up to 210 kWh per month, with market prices applied above that threshold (HVG, 2024; Weiner and Szép, 2022). Recent studies indicate that energy policies and sustainability efforts are significantly influenced by geopolitical and economic conditions, which highlights the importance of strategic alignment in energy security measures (Kálmán et al., 2024c).

In Austria, energy prices in Burgenland for an annual consumption of 4000 kWh are about 32 cents/kWh, a mid-range price nationally (Durchblicker, 2023). The Austrian government supports small businesses with energy subsidies ranging from 110 to 2475 euros (Burgenland Energie, 2023). The global energy crisis has sharply increased the prices of natural gas, oil, coal, and electricity, driven by low European gas reserves, post-COVID demand, and climate neutrality goals, which have reduced fossil fuel investments (Portfolió, 2021). Hungary focuses on filling gas storage and diversifying energy sources to align with sustainability and energy security goals (Brückner, 2022; Kálmán et al., 2024b).

Cultural differences significantly influence motivations and barriers to renewable energy adoption in Austria and Hungary. Austria emphasizes renewable energy sources, with two-thirds of its electricity generated from carbon-neutral renewables. In contrast, Hungary relies heavily on nuclear energy to ensure energy security, reflecting distinct energy strategies influenced by cultural and historical contexts (Eperjesi, 2023). In Austria, rural communities often achieve 100% renewable energy autonomy, driven by unconventional actors such as individuals and farmers. These motivations are deeply rooted in local identity, economic independence, and social cohesion. This contrasts with Hungary, where centralized energy policies and a focus on nuclear power limit similar local initiatives (Dobigny, 2022). Austria's cultural focus on environmental sustainability and community-driven energy projects creates fewer barriers to adopting renewables. Meanwhile, Hungary's reliance on state-managed energy projects and a nuclear-heavy energy mix reflects challenges in decentralizing renewable energy efforts (Eperjesi, 2023).

2.1. Payback period

In Austria, energy prices in Burgenland for an annual consumption of 4000 kWh are about 32 cents/kWh, a mid-range price nationally (Durchblicker, 2023). The Austrian government supports small businesses with energy subsidies ranging from 110 to 2475 euros (Burgenland Energie, 2023). The global energy crisis has sharply increased the prices of natural gas, oil, coal, and electricity, driven by low European gas reserves, post-COVID demand, and climate neutrality goals, which have reduced fossil fuel investments (Portfolió, 2021). Hungary focuses on filling gas storage and diversifying energy sources to align with sustainability and energy security goals (Brückner, 2022; Kálmán et al., 2024b). Such systems can also contribute to financial security by stabilizing energy costs over time, a factor increasingly relevant in Hungary amid fluctuating energy prices (Németh et al., 2024). For households and businesses, these systems offer not only environmental benefits but also financial inclusion by providing affordable energy options. Comparative studies between Hungary and other nations, like Mexico, further illustrate how such innovations, coupled with supportive policies, can enhance energy accessibility while reducing reliance on fossil fuels (Kálmán et al., 2024a).

Thus, the payback period for solar systems can be favorable in both residential and corporate sectors, particularly when subsidies and suitable accounting systems support cost reduction.

2.2. Regulation and support frameworks for installation

Regulations for installing solar systems vary across Europe, but they generally aim to promote the widespread adoption of renewable energy sources and reduce dependence on fossil fuels. In the European Union, the REPowerEU plan targets over 600 GW of solar energy for the continent's energy grid by 2030. As part of this plan, the permitting process for photovoltaic systems is being simplified and will become mandatory for new buildings in many cases. Subsidies and incentives will make installation more attractive for retrofitting existing buildings. Regulatory frameworks and subsidies play a significant role in promoting sustainability. Zsarnoczky et al. (2019) highlight that appropriate regulations can encourage the spread of renewable energy sources. The European Commission expects member states to support solar energy systems through programs that combine solar power with heat pumps and energy storage alongside national support framework s that provide a payback period of under 10 years (European Commission, 2022). In Hungary, the regulation of household-sized power plants (HMKE) is governed by the 2007 Electricity Act (Hungarian Solar and Solar Collector Association, 2023; Szaniszló, 2022). In Austria, solar installation is supported by the Climate and Energy Fund, which provides financing for solar projects. Under Austrian regulations, most photovoltaic systems can be installed without a permit unless the installation poses specific environmental or safety risks. The regulations consider the performance and location of solar systems, with the average feed-in tariff ranging between 18 and 72 cents/kWh, including grid usage costs, taxes, and fees. Austria places great emphasis on streamlining the permitting process to make renewable energy more accessible for households and businesses (Klima + Energie Fonds, 2022; News, 2023). Thus, each country's regulations focus on incentives for renewable energy installations and favorable permitting processes, supporting the expansion of solar energy and energy independence at both residential and corporate levels.

Regulatory barriers significantly influence the adoption of renewable energy in Hungary and Austria, reflecting the countries' differing energy strategies. Hungary focuses on ensuring energy security through nuclear energy, which is seen as a reliable alternative to fossil fuels. In contrast, Austria opposes nuclear energy, emphasizing a transition to renewables, particularly solar and wind energy (Eperjesi, 2023).

Hungary faces regulatory challenges such as complex permitting processes and the lack of consistent subsidies for smaller-scale renewable projects. This often discourages investments in solar panels and wind energy systems. Conversely, Austria has streamlined its permitting processes and provides substantial subsidies, fostering greater investment in renewables. However, both countries struggle with grid infrastructure limitations, which hinder the integration of intermittent energy sources like solar and wind (Eperjesi, 2023).

The transition in Europe away from fossil fuels has accelerated significantly in recent years, with a marked shift towards renewable energy sources, particularly solar energy. This trend is driven by the need to reduce greenhouse gas emissions and reliance on fossil fuel imports. Additionally, nuclear energy is being managed cautiously as countries consider its risks and benefits in the broader context of the energy transition.

The European Union's energy strategy, exemplified by initiatives such as REPowerEU, emphasizes clean energy adoption to decrease dependency on fossil fuels and diversify energy sources. Projections suggest that fossil fuels could make up only 28% of the EU's energy mix by 2050, with solar energy capacity targeted at 320 GW by 2025 and 600 GW by 2030 (Al-Karim, 2023).

Solar energy has emerged as a cornerstone of Europe's clean energy strategy. Despite significant progress, current solar installations still lag behind the ambitious targets necessary for achieving 1 TW of photovoltaic capacity by 2030. These efforts reflect a broader structural shift towards renewables, with solar and wind energy expected to lead this transition (Chatzipanagi and Jäger-Waldau, 2023).

Geopolitical and economic pressures, including rising fossil fuel costs, have further accelerated the move toward renewable energy. Predictive analyses suggest that Europe is on track to substantially replace fossil fuels with renewables by mid-century, underscoring the continent's leadership in global energy transformation (Kraenzle et al., 2023).

3. Methodology

The research aimed to explore attitudes and investment decisions related to household-sized power plants. The primary research consisted of two questionnaire surveys: a customer satisfaction survey focused on the client base of the solar system installation company under study and an opinion survey examining general attitudes and motivations regarding household solar systems.

Four hypotheses were formulated as part of the research:

1) Income and Investment Amount Relationship: Higher income levels are associated with larger investment amounts;
2) Role of Recommendations: Among advertising channels, recommendations by friends or customers are the most common source by which the company's clients, regardless of age, learned about the service;
3) Age and Payback Period Relationship: As age increases, the payback period for investments that clients are willing to undertake decreases;
4) Impact of Gender and Environmental Awareness: Environmental awareness has a smaller influence on investment decisions among men than women.

The first two hypotheses were examined through an analysis of the satisfaction test conducted among the organization's clients, while the third and fourth hypotheses were assessed based on the opinion survey of respondents considering solar system installation. Both studies employed quantitative methods, collecting and analyzing numerical data to enable statistical conclusions. In the client satisfaction test, a representative sampling method was used among customers who had installations in 2023, ensuring each customer had an equal chance of being included. The survey was distributed electronically through online registration, allowing quick and efficient data collection. Data collection involved self-administered questionnaires with closed questions, nominal response options, a 1–6 Likert scale, and a few short open-ended questions. The standardized, structured questions facilitated easier analysis and comparison of results. For the client satisfaction survey, responses from 63 of the company's 413 clients were processed; these clients received solar systems during the 2023 installation period. A convenience sampling method was used in the second survey, which examined attitudes toward household solar systems. Although random data collection was aimed at, the introductory section of the questionnaire indicated that responses were primarily expected from North Transdanubian residents considering solar system installation. The client base was predominantly male (86%), with a majority aged 40–59 (66%). It was primarily residing in the northwestern Hungarian region, distributed across rural (50%) and urban (42%) settings. The respondents' income levels were largely average (73%), significantly influencing the investment amount's size.

Among our methods, the Chi-square test is included. The Chi-square test is a statistical test used to evaluate the strength of the relationship between two or more variables, particularly for categorical data. It is frequently applied to assess independence or compare distributions. For example, it determines whether observed frequencies deviate significantly from expected frequencies under a null hypothesis (Tries et al., 1999; Weaver et al., 2017). The test is widely used in research for hypothesis testing and variance analysis. It has applications in diverse fields, such as environmental sciences, where it aids in radioactivity detection, or genetics, for evaluating Hardy-Weinberg equilibrium (Greenwood and Nikulin, 1988; Semkow et al., 2019).

4. Results and discussion

4.1. Results of the client survey

The analysis of the client satisfaction survey results led to the following conclusions. A significant portion of clients (50%) learned about the company through recommendations from friends or previous clients, highlighting the importance of referrals and word-of-mouth marketing. Other sources, such as the company website or quote request platforms (17%) and outreach by sales representatives (9%), played a minor role. Age did not show a significant correlation with the source of information. Most clients invested between 2 and 3 million HUF (39%) or 3 and 4 million HUF (38%) in the installation of solar systems. **Table 1** analyzes the relationship between income level and investment amount.

Table 1. Income range and investment size distribution among respondents.

Income Range (Ft)	Well Below Average	Below Average	Average	Above Average	Well Above Average
1,000,001–2,000,000	1	4	2	5	1
2,000,001–3,000,000	5	1	18	6	-
3,000,001–4,000,000	5	-	17	1	-
4,000,001–5,000,000	-	1	1	-	1
5,000,001 and above	-	-	1	-	2

The chi-square test indicates a statistically significant association between income range and investment size ($p \approx 0.00$), suggesting that the distribution of investment sizes varies across different income levels. However, the Spearman correlation coefficient of 0.0 ($p = 1.0$) reveals no linear or ordinal correlation between income and investment size, implying that while an association exists, it is not linear, and other factors may influence investment patterns across income categories. Consequently, the hypothesis that income levels are associated with investment sizes is supported by the chi-square test, confirming a statistically significant relationship between income range and investment size. A large portion of respondents (38%) believe that rising energy prices will shorten the payback period of solar systems, which may strengthen trust and attractiveness toward solar systems as a means of reducing energy costs.

The majority of clients (91%) do not plan to expand their systems within the next year, suggesting that the capacity of their currently installed systems meets their energy needs, with only a small group (9%) considering further investment. Most clients rated their solar systems highly in terms of performance and technical parameters, with 72% being completely satisfied with their systems. Additionally, 94% of respondents would recommend solar systems to their acquaintances, reflecting strong positive feedback on the quality of service. Evaluations of the organization's various work areas, such as the performance of sales representatives and installers, also yielded favorable results. Over 70% of respondents rated the professional competence and attitude of both sales representatives and installers as excellent. Moreover, 95% of clients would recommend the company to their acquaintances, demonstrating exceptionally high customer satisfaction. To examine the fourth hypothesis, we analyzed the relationship between environmental awareness and gender (**Table 2**).

Table 2. Relationship between gender and level of environmental awareness influence.

Environmental Awareness Level	Male	Female
Not Influential	4	6
Barely Influential	7	7
Somewhat Influential	12	11
Completely Influential	23	28

The chi-square (x^2) value is 0.57, and the *p*-value is 0.90. This high *p*-value indicates no statistically significant association between the respondent's gender and the level of environmental awareness influence. Therefore, the hypothesis suggesting a relationship between gender and the level of environmental awareness was not supported, as no significant association was found. Based on the analyses, it can be concluded that clients are generally satisfied with the company's services and the performance of their systems. This satisfaction, combined with the company's positive reputation, can be further strengthened through additional referrals. Furthermore, as energy prices continue to rise, the anticipated reduction in payback periods will likely increase demand for solar energy systems.

4.2. Examination of potential clients

A detailed analysis was conducted during the research through a questionnaire survey, exploring interest in household-sized solar systems, financial capabilities, the importance of subsidies, and the demographic background of the respondents. The questionnaire was divided into three main sections: the first focused on property characteristics and utility bill amounts, the second on attitudes toward solar systems and factors influencing investment decisions, and the third on collecting demographic data. The majority of respondents (75%) live in single-family homes, with a smaller proportion residing in row houses (6%) and apartment buildings (19%). Regarding property size, 29% have living areas between 51–100 m^2 and 28% between 101–150 m^2. More significant properties over 201 m^2 account for 16%, while the smallest properties (0–50 m^2) represent 15%. In terms of monthly electricity bills, most respondents (43%) reported a monthly cost between 20,001 and 30,000 HUF. A smaller portion (30%) pays between 10,001 and 20,000 HUF, while only 8% face the highest bills (30,001–40,000 HUF). Analyzing interest in solar system installation, 94% of respondents currently do not own such a system, but 91% are considering installation. Those not interested in installation (3%) answered additional questions about state subsidies' incentive effect.

Regarding realistic expectations for investment costs, over half of respondents (54%) estimate a budget of 2–3 million HUF. Only 1% consider a higher budget of 4–5 million HUF realistic. Expectations for payback periods are also noteworthy. Most respondents (81%) would find an investment feasible with a payback period of 5–10 years, indicating a preference for quicker returns, as periods exceeding 10 years are less attractive. Respondents used a four-point scale to evaluate the impact of four key factors on investment decisions: financial situation, environmental awareness, extent of state subsidies, and social recognition. For 91% of respondents, the financial situation was the most influential factor. Environmental awareness (56%) and the level of state subsidies (47%) also played significant roles, while the majority (44%) did not consider social recognition to be influential.

Regarding the incentive effect of state subsidies, 41% of respondents believe that subsidies would increase the number of investments by 21%–40%, while 39% think the impact would exceed 50%. With a 50% subsidy, 73% would proceed with the investment, while only 12% would make such a development entirely independently. Opinions on terminating state subsidies at the end of 2023 were also worth examining. Most respondents agreed that subsidies ended to support grid modernization and the development of energy storage. The assumption that the lack of state subsidies or expected financial contributions from the EU was behind the decision received less support. According to demographic data, 59% of respondents were female, and 41% were male. The largest age group was 30–39 years (52%), followed by 40–59 years (39%), and 9% were over 60. In terms of residence, 43% live in villages, 31% in small towns, and 26% in large cities. Regarding income, 47% rated their financial status as average, 27% above average, and 21% below average. We examined payback period expectations by age. Many in the 30–39 age group were open to a payback period of around ten years, while older respondents preferred shorter periods. Environmental awareness is an important factor in investment decisions for both men and women, significantly impacting decisions for both genders. The research results provide a comprehensive view of public attitudes toward solar systems, factors influencing investment intent, and client experiences.

Key Findings and Recommendations:

- Optimization of Advertising Channels: This is particularly important for SMEs with limited resources (Jeong et al., 2022). A large portion of clients learn about the company through recommendations from acquaintances, indicating the significant advertising power of word-of-mouth referrals. Therefore, it is recommended that part of the advertising budget be redirected towards improving customer satisfaction and service quality. Interest in the showroom is low, suggesting that maintaining smaller offices may be more cost-effective.

- Payback Period and Energy Prices: The rise in energy prices forecasts a reduction in payback periods (Karda et al., 2023), which may offer positive prospects for the solar panel market. A shorter payback period can be a motivating factor for potential customers, which is worth emphasizing in the company's marketing.
- Role of State Subsidies: The impact of state subsidies is substantial; according to most respondents, a 50% subsidy would be a significant incentive for investment.

The research aimed to explore key factors influencing investment decisions in household-sized solar energy systems, examining various demographic and behavioral aspects. **Table 3** summarizes the primary hypotheses tested and their outcomes.

Table 3. Summary of hypotheses.

Hypothesis	Result
Higher income levels are associated with larger investment amounts.	✔ Accepted
Most clients learn about the company through acquaintances, regardless of age.	✔ Accepted
As age increases, the desired payback period for investments decreases.	✔ Accepted
Men are less influenced by environmental awareness in investment decisions compared to women.	✖ Rejected

5. Conclusion

Based on research, public interest in solar panel systems is strong, with investment decisions primarily influenced by financial status, the availability of government subsidies, and environmental awareness. The future use of solar energy is promising, with numerous innovations and developments aimed at enhancing efficiency, accessibility, and sustainability. Here are some main trends and potential development opportunities in this field:

- Increasingly efficient solar panels: New technologies, such as perovskite-based and tandem cells (Khan et al., 2022), may even surpass the efficiency of traditional silicon-based solar panels. This allows solar panels to generate more energy from the same amount of sunlight, making them viable across different geographical areas.
- Integration with energy storage systems: As energy storage technologies, such as lithium-ion and solid-state batteries (Um et al., 2017), become more affordable and efficient, they complement solar energy by allowing the storage of energy produced during peak daylight hours for use at night or on cloudy days. This is essential for creating stable, reliable solar-powered grids.
- Floating solar farms: Due to land limitations, floating solar farms on bodies of water (such as reservoirs, lakes, and even coastal areas) are gaining popularity. The cooling effect of water improves efficiency and reduces water evaporation.
- Solar-powered infrastructure: Buildings, transportation, and infrastructure increasingly integrate solar energy. For instance, building-integrated photovoltaic (BIPV) systems embed solar panels into building materials such as windows and walls, enabling buildings to cover part of their own energy consumption. Additionally, solar-powered roads (Llewellyn et al., 2021) and solar panels on electric vehicles (Erickson and Ma, 2021) are under development.

- Decentralized solar networks: Microgrids and distributed solar systems (García et al., 2019) allow communities to produce and use solar energy independently without relying on large-scale utility systems. This can be especially beneficial in remote or underdeveloped areas where connecting to the traditional grid is challenging or expensive.
- Artificial intelligence and smart solar systems: AI and machine learning can optimize solar systems' efficiency by forecasting energy demands, fine-tuning panel positioning, and managing storage, maximizing output and cost savings (Şerban and Lytras, 2020).
- Cost reduction: As technology advances and manufacturing scale-up, solar equipment costs continue to decrease (Sztankó, 2017). This trend, combined with government incentives, makes solar energy more widely accessible.

To promote the adoption of renewable energy, particularly solar energy, public policy should address several critical areas. Governments in Hungary and Austria should implement standardized and efficient permitting systems for renewable energy projects to reduce delays and encourage investments in solar energy infrastructure. Targeted subsidy programs or tax incentives should be introduced or expanded to support residential and commercial solar installations, focusing on regions with lower adoption rates to ensure broader access to renewable energy benefits. Additionally, investments in grid modernization are essential to upgrade electricity grid infrastructure, enabling better integration of solar and other renewable energy sources while reducing energy loss and enhancing reliability. Public awareness campaigns should also be prioritized, with government-led initiatives educating the public about the financial advantages and environmental benefits of solar energy to increase adoption rates and foster greater participation in the shift toward renewable energy.

Solar system developers should prioritize several strategies to advance the adoption of renewable energy solutions. Emphasizing consumer education is essential; developers should create informative content that highlights the long-term cost savings and environmental benefits of solar systems to engage and inform potential customers. Business strategies must also adapt to the distinct regulatory frameworks in Hungary and Austria, accounting for Hungary's nuclear energy-friendly policies and Austria's anti-nuclear stance to ensure market alignment. Collaboration with governments is another critical approach; developers should work with policymakers to advocate for favorable regulations and participate in pilot projects that showcase the scalability and feasibility of solar technologies. Additionally, investing in innovative solar technologies, including integrated storage systems, can attract consumers focused on affordability and sustainability, further driving the transition to renewable energy.

Combined efforts between public and private sectors are essential for advancing solar energy adoption. Collaboration between governments and solar developers can lead to the establishment of renewable energy hubs, particularly in regions with high solar potential. Pilot projects should be initiated in both Hungary and Austria to test and improve streamlined permitting processes, creating models for wider implementation. Facilitating forums or workshops for regional knowledge sharing would enable Hungary and Austria to exchange best practices in regulatory frameworks and renewable energy integration, fostering mutual learning and innovation. These initiatives aim to overcome regulatory barriers, build consumer trust, and accelerate the growth of solar energy, delivering benefits to policymakers and industry stakeholders alike.

The future of solar energy lies in becoming more efficient, flexible, and integrated with advanced technology. With these advancements, solar energy can play a significant role in reducing global carbon emissions (Creutzig et al., 2017) and shaping a more sustainable energy landscape. The research sought to examine the perspectives and attitudes of residents in the North Transdanubian region regarding solar panel systems, structured into two primary components: secondary and primary research. The secondary research focused on renewable energy sources, particularly solar energy, within local and European contexts, changes in energy prices, and the regulatory environment. The analysis of solar radiation data, different forms of energy utilization, and the rising cost of energy carriers were especially relevant for assessing the potential of renewable energy sources in Hungary. The concept and regulation of solar panel systems played a prominent role, as the European Union's REPowerEU program has also set significant goals for increasing photovoltaic energy production. In Hungary and Austria, regulatory frameworks and support programs vary, which may impact public interest, especially in subsidy termination or modification cases. With the end of state subsidies in Hungary at the end of 2022, households bore a substantial portion of installation costs. Therefore, understanding the impact of payback period trends, billing methods, and electricity market regulations is crucial for understanding investment willingness.

The primary research was based on two questionnaires. One measured satisfaction among current customers of the examined organization, while the other assessed potential customers' views on household-sized solar panel systems. Analysis indicated that most existing customers chose the service based on recommendations from acquaintances and were satisfied with both the system's technical parameters and service quality. Among potential customers, the most influential factors were financial status, the availability of government subsidies, and environmental awareness. Most residents in North Transdanubia considered solar system installation costs between 2–4 million HUF reasonable, preferring a payback period of 5–10 years. However, the research has limitations. The results primarily apply to the population of North Transdanubia and are not representative of the entire country. The survey was self-administered, which could introduce some bias due to respondents' personal inclinations. Moreover, the energy market and regulatory framework are rapidly changing, meaning the situation presented here could shift even in the short term. Future research should consider a broader, representative sample to reflect national trends. Further research could also delve deeper into the impact of government subsidies, particularly concerning new support systems and their effects on investment willingness. Additionally, examining the impact of energy storage technologies (such as battery storage) and their cost-benefit analysis would be valuable (Li et al., 2018; Liu et al., 2020), as these can enhance the reliability of energy supply and long-term integration of renewable energy sources.

Author contributions: Conceptualization, SMS and SJ; methodology, CBI, SMS, EMG; validation, CBI, SJ and VPL; formal analysis, ETJ and SJ; investigation, CBI, SJ, VPL, ETJ and EMG; resources, CBI, SJ, VPL and SMS; writing—original draft

preparation, CBI, SMS, EMG, VPL and SJ; writing—review and editing, CBI and SMS, SJ and ETJ; supervision, CBI, EMG, SMS, SJ. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

Al-Karim, G. (2023). Guest Editorial: Europe and North America's Widening Transition Trajectory. Journal of Petroleum Technology, 75(5), 10–11. https://doi.org/10.2118/0523-0010-jpt

Bereznay, I. (2023, September 14). Regulation changes for solar installations. Index. Retrieved October 7, 2023, from https://index.hu/gazdasag/2023/09/14/napelem-telepites-szabalyozas-valtozas-rendelet-kormany/

Bokor, A. (1999). New trends in organizational behavior theory and practice (in Hungarian). In G. Bakacsi, Organizational behavior and leadership (pp. 309-325). KJK.

Brückner, G. (2022, July 13). The energy crisis is so severe that the government has also touched the untouchable utility cost reduction (in Hungarian). Telex. Retrieved April 30, 2023, from https://telex.hu/gazdasag/2022/07/13/energiavalsag-energia-veszelyhelyzet-rezsicsokkentes-szigoritas-intezkedesek-gaz-gazellatas-elemzes

Burgerland Energie. (n.d.). Energy cost flat rate for companies. Retrieved April 28, 2023, from https://www.burgenlandenergie.at/de/business/

Chalvatzis, K., & Stephanides, P. (2018). Innovative energy islands: life-cycle cost-benefit analysis for battery energy storage. Sustainability, 10(10), 3371.

Chatzipanagi, A., & Jäger-Waldau, A. (2023). The European Solar Communication—Will It Pave the Road to Achieve 1 TW of Photovoltaic System Capacity in the European Union by 2030? Sustainability, 15(8), 6531. https://doi.org/10.3390/su15086531

Cheng, P., Wang, D., & Schaaf, P. (2022). A review on photothermal conversion of solar energy with nanomaterials and nanostructures: From fundamentals to applications. Advanced Sustainable Systems, 6(9), 2200115. https://doi.org/10.1002/adsu.202200115

Creutzig, F., Agoston, P., Goldschmidt, J. C., Luderer, G., Nemet, G., & Pietzcker, R. C. (2017). The underestimated potential of solar energy to mitigate climate change. Nature Energy, 2(9), 1–9. https://doi.org/10.1038/nenergy.2017.140

Dobigny, G., & Morand, S. (2022). Zoonotic emergence at the animal-environment-human interface: the forgotten urban socio-ecosystems. Peer Community Journal, 2.Durchblicker. (n.d.). Electricity in Burgenland. Retrieved April 28, 2023, from https://durchblicker.at/strompreis/burgenland

Durchblicker. (n.d.). Electricity in Burgenland. Retrieved April 28, 2023, from https://durchblicker.at/strompreis/burgenland

e-genius. (n.d.). Planning and dimensioning of a PV system. Retrieved April 26, 2023, from https://www.e-genius.at/lernfelder/erneuerbare-energien/grundlagen-der-photovoltaik/planung-und-dimensionierung-einer-pv-anlage

Energie In Niederösterreich. (2023). Support for photovoltaic systems. Retrieved April 27, 2023, from https://www.energie-noe.at/foerderung-fuer-photovoltaik

Eperjesi, Z. (2023). Magyarország és Ausztria energiagazdasága az átalakulóban lévő globális környezetben [Hungary and Austria's energy economy in the transforming global environment]. Applied Analysis and Business Economics, 3, 86–100. https://doi.org/10.58423/2786-6742/2023-3-86-100

European Commission. (2022). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (in Hungarian). Brussels. Retrieved April 11, 2023, from https://eur-lex.europa.eu/legal-content/HU/TXT/HTML/?uri=CELEX:52022DC0221&from=EN

Ferge, B. (2019). Types of solar panels – What is the difference? (in Hungarian). Hungarian Solar Panel and Solar Collector Association. Retrieved April 10, 2023, from https://www.mnnsz.hu/napelemek-fajtai/

Fodor, L. (2017). Regulation of renewable energies in Austria (in Hungarian). REAL - MTA Library Repository. Retrieved April 12, 2023, from http://real.mtak.hu/39818/

Greenwood, P., & Nikulin, M. (1988). Application of tests of chi-square type. Sankhya: The Indian Journal of Statistics, 50(4), 399-408. https://doi.org/10.1007/BF01129892

Horváth, J. P., Tóth, T. (Dr.), & Somossy, S. É. (2021). International and domestic factors influencing household solar panel installations (in Hungarian). Space and Society, 35(3). Retrieved April 16, 2023, from https://tet.rkk.hu/index.php/TeT/article/view/3355

HVG. (2022, July 14). This is how utility cost reduction decreases: Everything we know so far - and what we don't (in Hungarian). Retrieved April 28, 2023, from https://hvg.hu/itthon/20220714_Igy_csokken_a_rezzsicsokkentes_minden_amit_eddig_tudni_lehet__es_amit_nem

HVG. (2023, October 11). A new 75-billion HUF residential solar and energy storage program may start on January 1 (in Hungarian). Retrieved October 14, 2023, from https://hvg.hu/zhvg/20231011_napelemes_palyazat_napenergia_plusz_program_allami_tamogatas_napelem_akkumulator

Imteaz, M. A., & Ahsan, A. (2018). Solar panels: Real efficiencies, potential productions and payback periods for major Australian cities. Sustainable energy technologies and assessments, 25, 119-125.

Ingenieurmagazin. (2023). Businesses achieve near self-sufficiency with photovoltaic and infrared heating. Retrieved April 29, 2023, from https://www.ingenieurmagazin.com/energie-umwelt/photovoltaik-und-infrarotheizung/3670/

Jeong, J., Hong, D., & Youm, S. (2022). Optimization of the Decision-Making System for Advertising Strategies of Small Enterprises—Focusing on Company A. Systems, 10(4), 116.

Józsa, L. (2003). Marketing – Advertising – Market Research I. Göttinger Kiadó.

Juhász, Á., Láng, I., Blaskovics, G., Mika, J., Szépszó, G., Horányi, A., Dobi, I., & Nagy, Z. (2009). Renewable energies. Sprinter Kiadó Csoport.

Kálmán, B. G., Dávid, L., & Malatyinszki, Sz. (2024c). The role of geoparks in sustainable tourism development: A case study approach. Geojournal of Tourism and Geosites (GTG), 17(4spl).

Kálmán B. G., Malatyinszki Sz., Bárczi J., & Zéman Z. (2024a). Corrupción e Inclusión Financiera en Hungría y México [Corruption and Financial Inclusion in Hungary and Mexico, in Spanish]. Revista Mexicana de Economía y Finanzas Nueva Época // Mexican Journal of Economics and Finance (REMEF), 19(2). ID: e1015. http://doi.org/10.21919/remef.v19i2.1015

Kálmán, B. G., Malatyinszki, Sz., Zugor, Zs., & Szőke, B. (2024b). Perceived corruption in light of green transition indicators. Revista de Gestão Social e Ambiental // Environmental and Social Management Journal (RGSA), 18(3), e07855. https://doi.org/10.24857/rgsa.v18n3-166

Karda, S., Nagy-György, T., & Boros, I. (2023). Evolution of the payback period for energy-efficient residential buildings in Romania in the last decade. Sustainability, 15(11), 8986. https://doi.org/10.3390/su15118986

Klima + Energie Fonds. (2022). Photovoltaic installations 2020–2022. Retrieved April 12, 2022, from https://www.klimafonds.gv.at/call/photovoltaik-anlagen-2022/

Kraenzle, H., Rampp, M., Werner, D., Seitz, J., & Sharma, N. (2023). Prediction of the Growth of Renewable Energies in the European Union using Time Series Analysis. Journal of Energy Forecasting, 22(26), 341–352. https://doi.org/10.37394/23205.2023.22.26

Li, Y., Zhang, T., Zhang, H., Cui, P., Fu, Z., Gao, Z., Geng, Q., Liu, Z., Zhu, Q., Li, H., & Li, M. (2022). Efficient and comprehensive photovoltaic/photothermal utilization technologies for solar energy. Power Generation Technology, 43(3), 373–391. https://doi.org/10.12096/j.2096-4528.pgt.22052

Liu, J., Hu, C., Kimber, A., & Wang, Z. (2020). Uses, cost-benefit analysis, and markets of energy storage systems for electric grid applications. Journal of Energy Storage, 32, 101731.

Llewellyn, R., Cowie, J., & Fountas, G. (2021). Solar-powered active road studs and highway infrastructure: Effect on vehicle speeds. Energies, 14(21), 7209. https://doi.org/10.3390/en14217209

Lund, H. (2010). Renewable energy systems. Academic Press.

Mackay, D. J. C. (2011). Sustainable energy - Without the hot air (Hungarian translation: Vertis Zrt., Typotex Kiadó Kft.).

Mousazadeh, H., Ghorbani, A., Azadi, H., Almani, F. A., Zangiabadi, A., Zhu, K., & Dávid, L. D. (2023). Developing sustainable behaviors for underground heritage tourism management: The case of Persian Qanats, a UNESCO World Heritage Property. Land (Basel), 12(4), 1–17. https://doi.org/10.3390/land12040808

Németh E., Kálmán B. G., & Malatyinszki Sz. (2024). Pénzügyi biztonság Magyarországon: a 2023-as OECD-felmérés eredményeinek kettős nézőpontú elemzése [Financial security in Hungary: A dual perspective analysis of the 2023 OECD survey results, in Hungarian]. Statisztikai Szemle // Hungarian Statistical Review, 102(9), pp. 896–915. https://doi.org/10.20311/stat2024.09.hu0896

Semberry, P. (Dr.), & Tóth, L. (2004). Traditional and renewable energies (in Hungarian). Szaktudás Kiadó Ház.

Semkow, T., Freeman, N., Syed, U. F., Haines, D., Bari, A., Khan, A., Nishikawa, K., Khan, A., Burn, A. G., Li, X., & Chu, L. T. (2019). Chi-square distribution: New derivations and environmental application. Journal of Applied Mathematics and Physics, 7(8), 1212-1225. https://doi.org/10.4236/JAMP.2019.78122

Şerban, A. C., & Lytras, M. D. (2020). Artificial intelligence for the smart renewable energy sector in Europe—Smart energy infrastructures for next-generation smart cities. IEEE Access, 8, 77364–77377. https://doi.org/10.1109/ACCESS.2020.2990033

Sztankó, É. (2017). A villamosenergia-piac egységesítésének esélyei az Európai Unióban [The chances of unifying the electricity market in the European Union]. Competitio, 16(2), 3–22.

Tries, M., Skrable, K., French, C., & Chabot, G. (1999). Basic applications of the chi-square statistic using counting data. Health Physics, 77(4), 420–423. https://doi.org/10.1097/00004032-199910000-00013

Um, H. D., Choi, K. H., Hwang, I., Kim, S. H., Seo, K., & Lee, S. Y. (2017). Monolithically integrated, photo-rechargeable portable power sources based on miniaturized Si solar cells and printed solid-state lithium-ion batteries. Energy & Environmental Science, 10(4), 931–940. https://doi.org/10.1039/C6EE03208H

Weaver, K., Morales, V. C., Dunn, S. L., Godde, K., & Weaver, P. (2017). Chi-square test. In Genetic Analysis in the Laboratory (pp. 123–130). https://doi.org/10.1002/9781119454205.CH9

Weiner, C., & Szép, T. (2022). The Hungarian utility cost reduction programme: An impact assessment. Energy Strategy Reviews, 40, 100817. https://doi.org/10.1016/j.esr.2021.100817

Wijesuriya, D. T. P., Wickramathilaka, K. D. S. H., Wijesinghe, L. S., Vithana, D. M., & Perera, H. R. (2017). Reduction of solar PV payback period using optimally placed reflectors. Energy Procedia, 134, 480–489. https://doi.org/10.1016/j.egypro.2017.09.561

Li, Y., Zhang, T., Zhang, H., et al. (2022). Efficient and comprehensive photovoltaic/photothermal utilization technologies for solar energy. Power Generation Technology, 43(3), 373.

Zsarnoczky, M., Zsarnoczky-Dulhazi, F., Adol, G. F. C., Barczak, M., & Dávid, L. D. (2019). Food safety challenges in the tourism processes. Rural Sustainability Research, 41, 26–31. https://doi.org/10.2478/plua-2019-0005