INTERNATIONAL REVIEW OF BUSINESS AND SOCIAL SCIENCE E-ISSN: 2226-4124

VOL 6 ISSUE 1 2026

EXPLORING PUBLIC PERCEPTION AND ATTITUDE TOWARDS HOUSEHOLD SOLAR ENERGY SYSTEMS

Arbaz Khan Khattak

Department of Environmental Sciences, Abdul Wali Khan University, Mardan

khanarbazkhan679@gmail.com

Maryam Saad

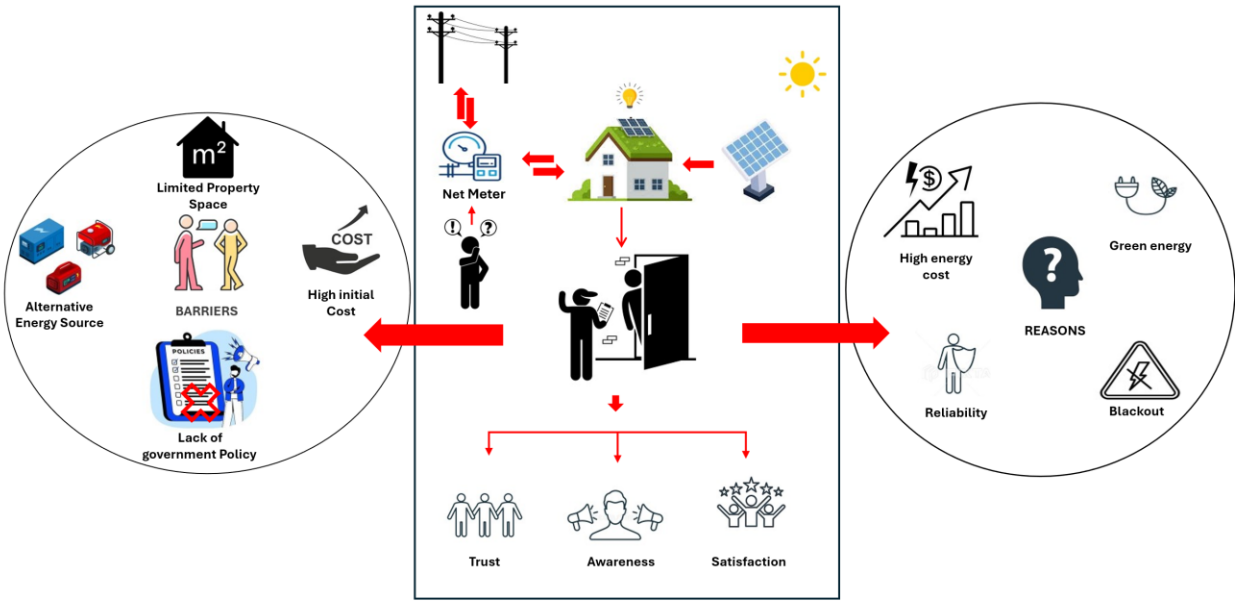
Department of Environmental Sciences, Abdul Wali Khan University, Mardan

maryamsaad@awkum.edu.pk

Muhammad Hussam Ul Haq

Department of Environmental Sciences, Abdul Wali Khan University, Mardan

hussamk418@gmail.com



Graphical abstract: *Overview of public perception and acceptance of household solar photovoltaic systems in Pakistan, highlighting factors influencing adoption and willingness to pay.*

INTERNATIONAL REVIEW OF BUSINESS AND SOCIAL SCIENCE

E-ISSN: 2226-4124

Abstract: *Transitioning to renewable energy sources, such as solar power, is critical for reducing climate change and attaining long-term development goals. The adoption of household solar photovoltaic systems (HSPVS) has enormous potential for reducing carbon emissions and enabling citizens to participate actively in the renewable energy revolution. Hence, public perception is crucial in influencing popular acceptance and implementation of such systems. This study adopts a survey approach with a sample size n= 400 using Yamane's method ±5% margin of error. The study found a high preference for solar energy as a sustainable, environmentally acceptable solution for slowing climate change. Most respondents were enthusiastic about community solar projects, and around 54% of the participants showed interest in leasing solar energy systems (SES). Almost 60% of respondents are unaware of net metering, which suggests a lack of knowledge of policies. To improve public awareness and support sustainable growth in SES, social media and effective incentives are required, as approximately 60% of respondents get information about solar energy from social media sources. The findings showed that the majority perceive solar energy as a sustainable and clean energy source with no adverse environmental impacts. Despite long-term benefits, high initial expenditure is a major barrier. The findings of this thorough analysis can help policymakers, researchers, and industry stakeholders develop strategies and interventions to enhance public perception and facilitate the acceptance of SES.*

Keywords: *Renewable energy, public attitude, Level of Awareness, Willingness to pay, Net Metering.*

1. INTRODUCTION

Pakistan is a developing country, grappling with a severe energy crisis. The nation has struggled for many years to fulfil the energy needs of its expanding population. Power cuts are a major issue, ranging from 8 -10 h in metropolitan regions to 18-22 h in rural ones (Mirjat et al., 2018). A sizeable amount of the country's energy production comes from fossil fuels like coal, oil, and gas (Pakistan Economic Survey, 2022). To meet energy demands, reliance on fossil fuels has exacerbated climate change and global warming, resulting in an increasing need for renewable and environmentally sustainable alternatives such as biomass, hydropower, wind, and solar energy (Sayed et al., 2023). Among RE sources, biomass energy is increasingly considered less feasible due to its association with deforestation and limited efficiency compared to other renewables (Searchinger et al., 2008). While hydropower dams lead to significant ecosystem disruption, which has resulted in substantial losses of aquatic and terrestrial biodiversity (Bohada-Murillo et al., 2021). Solar energy has attracted attention as the most widespread, never-ending, and greenest of all RE options (Barone et al., 2019; Mishra & Tiwari, 2020; Sathe & Dhoble, 2017). Sun emits energy in the form of solar radiation of around 6.4*107 W/m^2 from the fusion of hydrogen atom (Global Climate and Energy Project, 2006). The amount of solar energy that strikes Earth's continents is over 200

million times more than the entire yearly commercial energy usage (Alrikabi, 2014). Due to its geographical location, Pakistan is one of the richest countries with an average solar irradiation of 5.5 kWh/m^2 and a total solar power potential of 1.6 TW (Shakeel et al., 2016). Solar energy is used in at least four distinct ways, ranging from heating water to creating electricity. Photovoltaic technologies are at the top of the list of solar power applications (Tyagi et al., 2013). PV technology experienced a 22% increase in 2021, surpassing wind as the second-largest absolute generation increase. Its cost-effective nature encourages investment in RE (IEA, 2022). By 2050, solar PV technology may provide around 6,000 TWh, or 16% of the world's energy demands, as per the IEA (Ahmar et al., 2022).

In the worldwide shift to sustainable energy, installing solar energy systems has become a key strategy. The success of these technologies, however, is greatly impacted by public acceptability and perception and is not only reliant on technical or financial considerations (Wüstenhagen et al., 2007). Public opinion is crucial to the adoption of solar technology. A worldwide meta-analysis revealed that attitudes, behavioral control, and social norms act as mediators to promote HSPV adoption, which is strongly influenced by perceived environmental and individual advantages (Schulte et al., 2022). According to Alrashoud and Tokimatsu (2019), four major factors, including awareness, cost effectiveness, trust, and literacy, influence public opinion. Encouraging policies on net metering and developed solar marketplaces are highly correlated with favorable public opinion in the United States (Kim, 2021). These results demonstrate that attitudes and awareness are important factors in determining public acceptability of SPVS.

To conserve natural resources and lower greenhouse gas emissions, public acceptance and desire to engage are just as crucial as technological advancements. For renewable energy options to be successfully adopted, the public's approval and willingness to pay are essential. On the other hand, the knowledge gap exists in the social aspects of SPV (Sommerfeld et al., 2017). Ud Din et al. (2023) found that subjective norms have a negative correlation with awareness and a positive correlation with moral duty. However, there is no indirect correlation between the factors of moral duty and awareness and readiness to pay based on subjective standards. Alsabbagh (2019) acknowledged that purchasing and installing SPVS presented several difficulties, such as capital costs, information gaps, and maintenance needs. Research conducted by Naqvi (2020) in South Punjab, Pakistan found that showed that the overwhelming majority of households supported SPVS; however, many users were unaware of the system's components, NM, and billing system. According to Sommerfeld et al. (2017), there are clear gaps in homeowners' incentives to use SPV on their rooftops and related technologies. Kumar et al. (2023) reported that attitudes, subjective norms, and perceived behavioral control are key determinants of villagers' desire to use HSPV systems.

The adoption of HPVS has been increasing in recent years, but there still exists a significant gap between the potential for widespread use of solar energy and the actual adoption of SES. Despite the many benefits of SES, including cost savings and reduced carbon emissions, many households have not yet installed them. One possible factor contributing to this lack of adoption is public perception and attitude toward HPVS. The success and acceptance of environmental policies and technology are greatly influenced by public perception. It shows how people perceive, comprehend, and respond to environmental concerns, including the use of renewable energy (Devine-Wright, 2007). Public perception is also considered a key factor affecting the adoption of SPV technology (Alrashoud & Tokimatsu, 2019). Thus, assessment of public opinion is essential for making successful outreach plans, enhancing the policy outcomes, and guaranteeing the societal acceptance of modern technology. This study aims to determine the knowledge, attitudes of the public regarding HSES in Pakistan. Secondly, to assess the willingness to pay for households to adopt SES and to identify the potential barriers to the adoption of HSES.

Problem Statement

The adoption of HSES has been increasing in recent years, but there is still a significant gap between the potential for widespread use of SE and the actual adoption of SES. Despite the many benefits of SES, many households have not yet installed them. One possible factor contributing to this lack of adoption is public perception and attitude towards HSES. It is important to understand public view of SES and how it impacts adoption rates. By identifying the factors that influence people's decision making, policymakers and businesses can develop strategies to encourage wider adoption of RE installation.

Research Objectives

1. To determine the knowledge and attitudes of the public regarding HSES
2. To identify the barriers to adoption of HSES
3. To assess willingness of households to adopt HSES

2. MATERIALS AND METHODS

Study Area

The study was carried out in the District Nowshera, Khyber Pakhtunkhwa, Pakistan, with a total area of around 1,748 square kilometers (Farnaz et al., 2025). Nowshera district is located between latitudes 30.42 and 34.09N and longitudes 71.41 and 72.15E as given in Figure 1. It is divided into three tehsils (sub-districts), including Nowshera, Jehangira, and Pabbi and 47 Union Councils (clusters) (Zulfiqar et al., 2019). As per the 2023 census, the total population of the district is 1,740,705, with the population of Tehsil Nowshera, Pabbi and Jehangira of 796,226, 509,495 and 434,984, respectively. The average family has a population of 6.7 and a 91% electricity supply (PWD-KP, 2023).

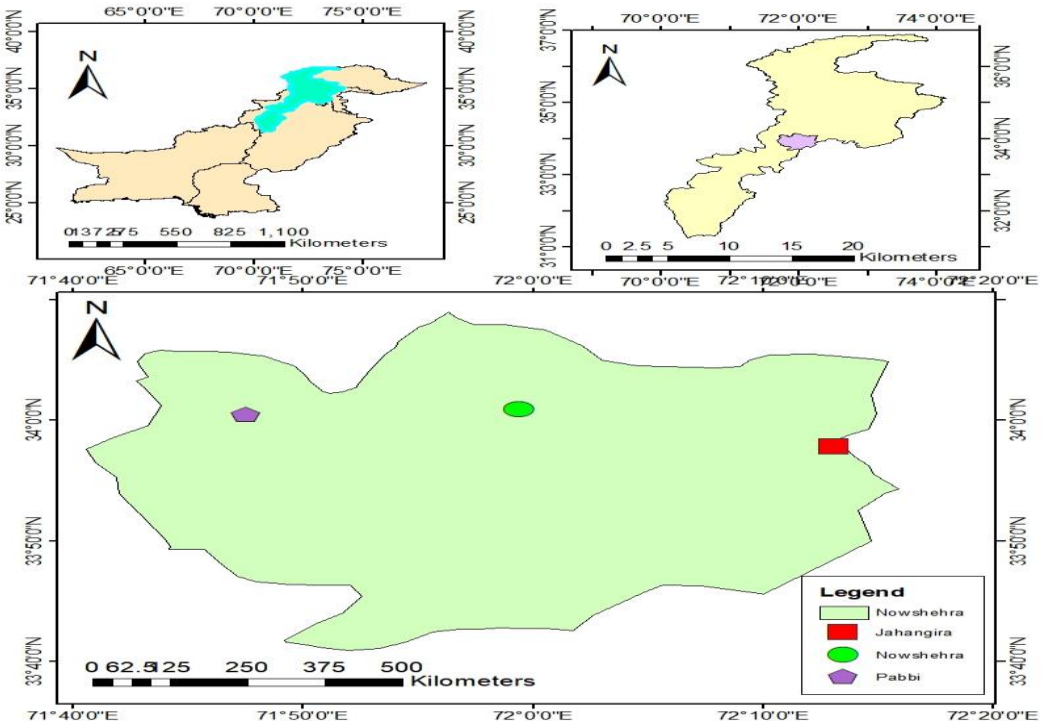


Figure 1 Map of the study area

Sample Size

Primary data was gathered from the respondents using the survey method. This study employs Yamane's (1967) formula to determine the sample size. Similar studies also used this method to calculate sample size (Afroz et al., 2019; Andrade-Arias et al., 2025; Talpur et al., 2017). A sample size of 400 was calculated with ±5% margin of error (*e*) and confidence level of 95% using the following equation:

$$n = \frac{N}{1+N.e^2} \quad eq\ (1)$$

$$n = \frac{1740705}{1+1740705(0.05)^2}$$

$$n = 399.91 \approx 400$$

Whereas *n* = sample size, *N* = total population (1,740,705), *e* = margin of error (0.05 or ±5%). The distribution of the whole sample size (n = 400) across the Nowshera district's three tehsils was determined by applying a proportionate allocation method based on each tehsil's population. Jan et al. (2020) have also used a similar approach in a study on "Social acceptability of SPS in Pakistan". This approach improves the representativeness and dependability of the findings by ensuring that each tehsil is represented in accordance with its proportion in the total population.

$$ni = \left(\frac{Ni}{N}\right) \times n \qquad eq\ (2)$$

As a result, 183 respondents were chosen from Tehsil Nowshera, 117 from Tehsil Pabbi, and 100 from Tehsil Jehangira as indicated in Table 1.

Table 1 Sample size distribution across the research area

Sub-district	Sample Size (n)
Nowshera	183
Pabbi	117
Jehangira	100
Total	400

Sampling Instrument

Various households in the research area filled out the survey questionnaire. The questionnaire consists of 31 closed-ended questions, divided into sections, including sociodemographic, awareness level, attitude and willingness to pay for SES. The survey respondents were interviewed from February to May 2024. The questionnaire was also translated into Urdu, and the age limit for the survey was 18 years and above.

3. RESULTS AND DISCUSSION

The survey findings indicated that 61.75% respondents were male, while 38.25% female, as presented in Table 2. Most participants (33.75%) were aged 21-30, followed by 31-40 and above 50 years, with 24% and 18.25% sequentially. The remaining 16% and 8% aged 41-50 and less than 21 years, respectively. Around 52.25% had a monthly income of 26-100k PK. Around 35.25% with less than 25k PKR. Nearly 30% claimed higher secondary education as the maximum qualification. Over 73% own a home or live in a joint family, and the remaining individuals rent a home.

Table 2 Represents sociodemographic information of the survey participants

Features	Range	Frequency	Percentage (%)
Gender	Male	247	61.75%
	Female	153	38.25%
Age	< 21 years	32	08%
	21-30 years	135	33.75%
	31-40 years	96	24%

	41-50 years	64	16%
	> 50 years	73	18.25%
Education	No schooling	56	14%
	Primary school	76	19%
	Secondary school	112	28%
	Higher Secondary	120	30%
	Bachelor's or higher	36	09%
Occupation	Own business	107	26.75%
	Public sector	60	15%
	Private sector	84	21%
	Student	49	12.25%
	Unemployed	24	06%
	other	76	19%
Monthly income (PKR)	< 25000	141	35.25%
	25 to 50'000	113	28.25%
	> 50'000 to 100'000	96	24%
	> 100'000	50	12.50%
Housing Type	Own house/joint family	292	73%
	Rented House	108	27%

Using a 5-point Likert scale, the respondents were asked to rate the following statements from strongly agree to strongly disagree. Respondents were asked the statement "Solar energy is a good source of RE", the majority 73% agreed with a mean score of 3.90, as shown in Figure 2.1. Approximately 6% remained neutral, a small proportion of 21% "strongly disagree" or "somewhat disagree". Survey respondents were prompted to answer the question, "Solar energy is a clean source of energy". On average, respondents rated this statement 3.90. A positive inclination towards solar energy as a clean energy source was observed. Most respondents (76%) agreed with the notion, 18% disagreed, while 6% remained neutral. Respondents provided their opinion on the statement "SPVS do not have negative Environmental impacts". Most participants rated the statement positively, with an average score of 4. A large proportion (75%) agreed with the notion. In terms of climate change, the survey included the statement, "SPVS can contribute to mitigate climate change" which received a mean score of 3.52 on a 5-point Likert scale. A

high percentage (64%) of respondents agreed that the use of SPVS instead of fossil fuels can contribute to mitigating climate change. Approximately 86% strongly agreed that solar energy is a viable option for Pakistan, with an average Likert score of 4.24. On the other hand, 88% of the participants agreed that SPVS are a beneficial and suitable option for rural communities.

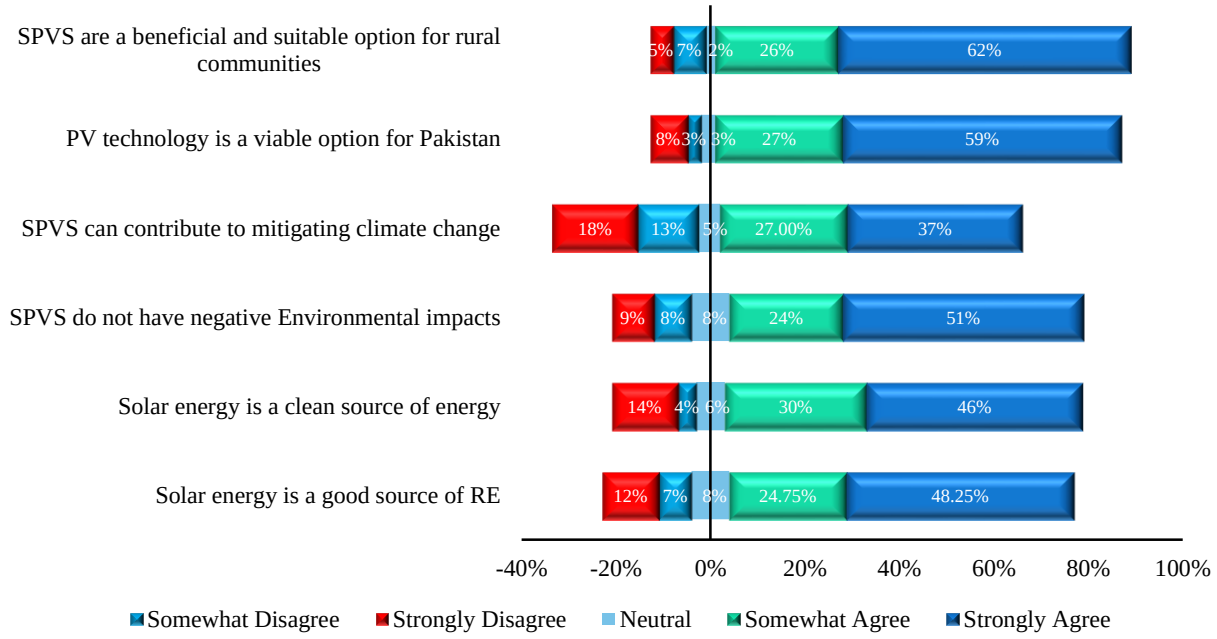


Figure 2.1 Represents the Likert scale responses regarding awareness level

A considerable majority (76%) view installing an SPVS as a favorable option. Results revealed that 84% do not have SPVS installed in their homes. Half of the participants (50%) were unfamiliar with government incentives for SPVS. Only 28% affirmed their familiarity with such incentives, and the remaining were uncertain. A majority of 88% of respondents strongly support government incentives to promote the use of SES.

Lack of awareness in exploring solar energy was observed as most of the individuals, 60%, rarely seek information about SPVS. According to 60% of respondents, social media is the major source of information, followed by television (24%), feedback from others (9%), radio (2%), and others (5%) as presented in Figure 2.2. NEPRA announced a net metering (NM) policy in 2015, with access to record the inflow and outflow of power, and users will be billed for their net power. Both residential and business customers have been motivated to build their own SPS to alleviate the nation's energy difficulties (Irfan et al., 2019). With a capacity of 1950 MW, the number of NM users achieved around 100,000 by May 2024 (Khan et al., 2024). These findings align with our results, indicating a lack of awareness of NM policy, as 70% of respondents were unaware of NM, as illustrated in Figure 2.3. Only 22% of respondents reported being aware of

the NM policy, while the remaining 8% were not sure, as shown in Figure 1.3. Results highlight the need for increased public awareness about NM.

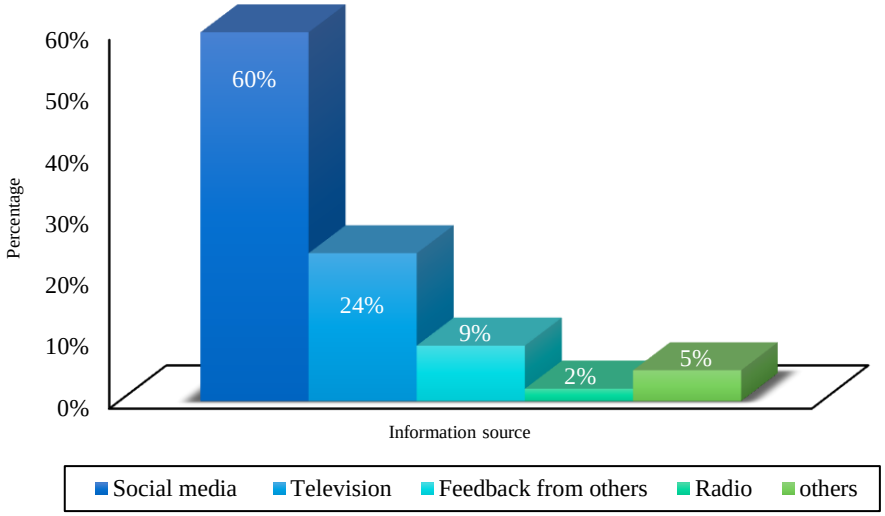


Figure 2.2: Represents the means of information regarding SES

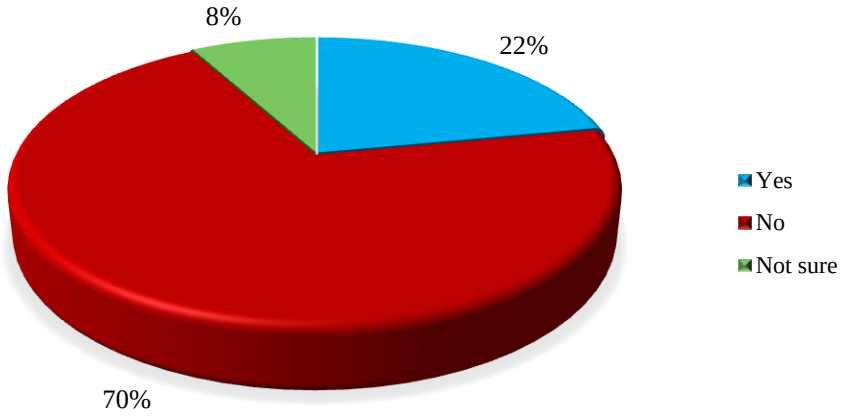


Figure 2.3: Represents the public's knowledge of net metering/green metering.

This study's goal was to determine the perceived barriers to HSPV adoption by the general population. Various obstacles to using solar energy are identified. Over 66% of participants reported that the high initial cost of SPV installation is considered a major barrier to adopting PV technology, as illustrated in Figure 2.4. Other barriers include the availability of alternative power generation sources, with 15%. The remaining include a lack of government interest, limited space availability, and low public awareness, as shown in Figure 2. The findings reveal

the willingness of respondents to invest in SES, with varying budget preferences. Approximately 39.75% expressed a willingness to pay up to 100k PKR, and 34% indicated a budget range of 100-200k PKR as indicated in Figure 2.5. A smaller proportion, 12.25% and 14% stated to invest between 200-300k PKR, and more than 300k respectively. Regarding the SPV prices, 36% of participants believe in a decrease in future SPV prices. An equal proportion of 36% anticipates a cost increase, while 28% remain unsure about the future trajectory of SPV prices.

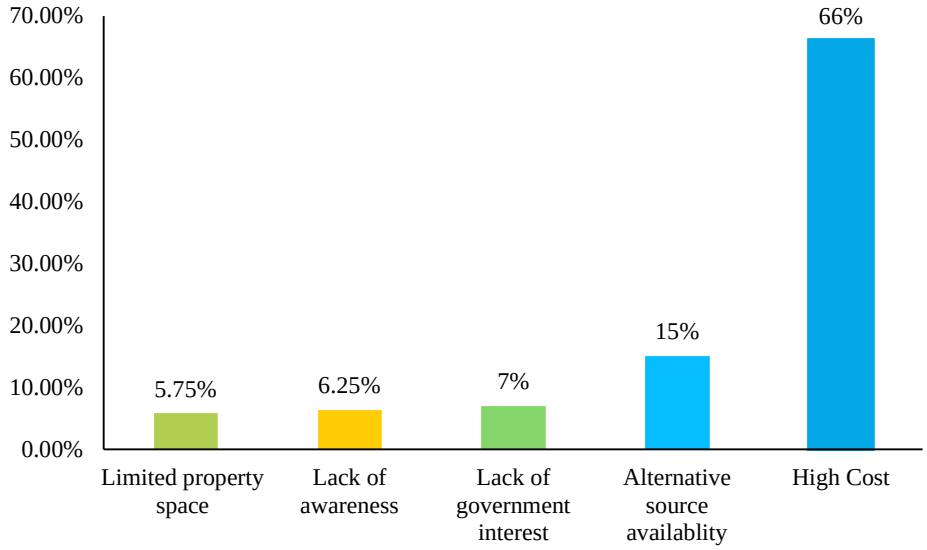


Figure 2.4: Represents the barriers in installation of SPVS.

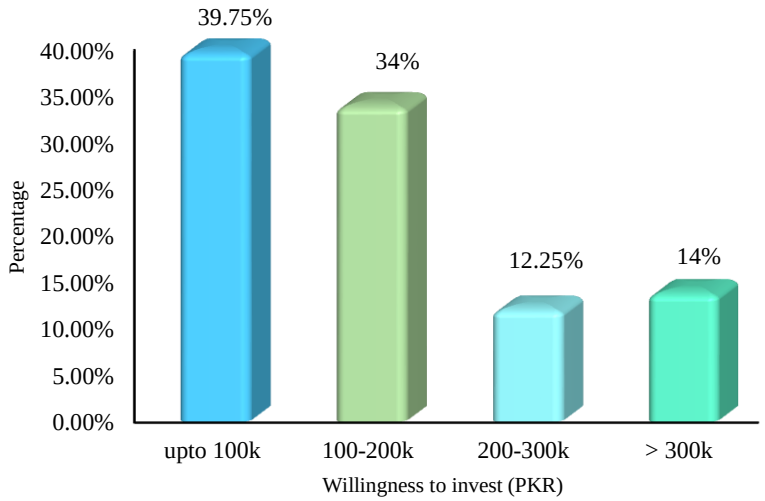


Figure 2.5: Public Willingness to Invest in HSPVS

Regarding the anticipated lifetime of a solar panel system, more than half (52%) expect their SPVS to last for 10 years. Approximately 31% of participants anticipate a lifespan of 5 years. Remaining consider 10-20 years as their projected lifespan. Purchasing SPVS may be financed in a variety of ways. Many respondents, 55%, prefer upfront payment, 38.25% express a preference for instalment, and 6.75% suggest alternative loan options. Participants were also questioned about their willingness to lease HSPVS, to which 54% of participants expressed a positive inclination, 38% declined the option, and 8% of respondents remained uncertain. Electricity outage is the main reason cited by 40% of participants for installing SPS, followed by "hedge against high energy prices," with 34.25% and “Energy independence” (13%), as shown in Figure 2.6. Additional factors include "clean" and “reliable” power sources, considered by 7% and 5.75% respectively.

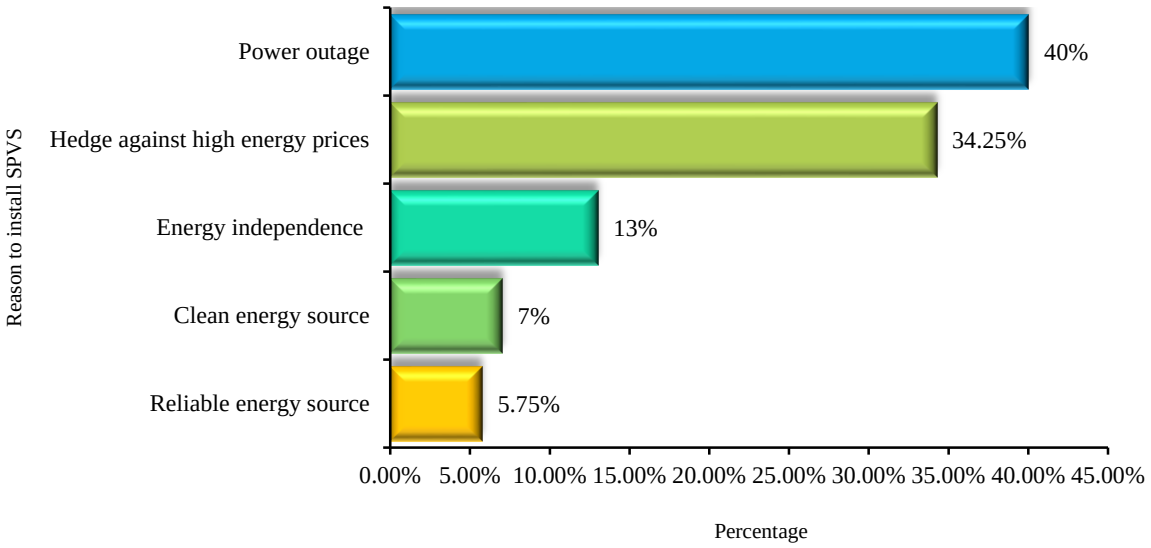


Figure 2.6: Represents the reason for the adoption of SPV

Participants were asked to rate the statements on 5 5-point Likert scale ranging from “very likely” to “very unlikely”. Around 76% of the respondents were likely to install SPVS with a mean score of 3.93, as given in Figure 2.7. Around 21% were unlikely to install, and others remained neutral. More than 78% "strongly agree" to embrace the usage of SPV. A total of 59% of respondents expressed a likelihood (very likely or likely) to install SPVS in their homes within the next 5 years, with a mean score of 3.51. Most respondents (60%) had positive opinions; however, about 14% remained neutral, and 27% indicated unlikeliness (unlikely or very unlikely). In response to the statement, “Would you accept solar power at cost parity with fossil fuels?”, with a mean score of 3.52, 65% expressed a likelihood. About 8% remained neutral; conversely, 27% were unlikely to utilize solar energy under equal cost conditions. Participants were questioned, “How likely are you to learn more about SES and its potential

benefits for your community?" which received a mean score of 4.02. Respondents predominantly (76%) were very likely to learn more about SES and its potential benefits for their community. Only 14% responded negatively, and 10% of the participants remained neutral. When prompted "How likely are you to participate in a community solar project?", the perceived mean Likert score of 3.98. Most respondents, accounting for 71%, declared a willingness to participate. On the other hand, 14% were unlikely, and 15% of the respondents remained neutral.

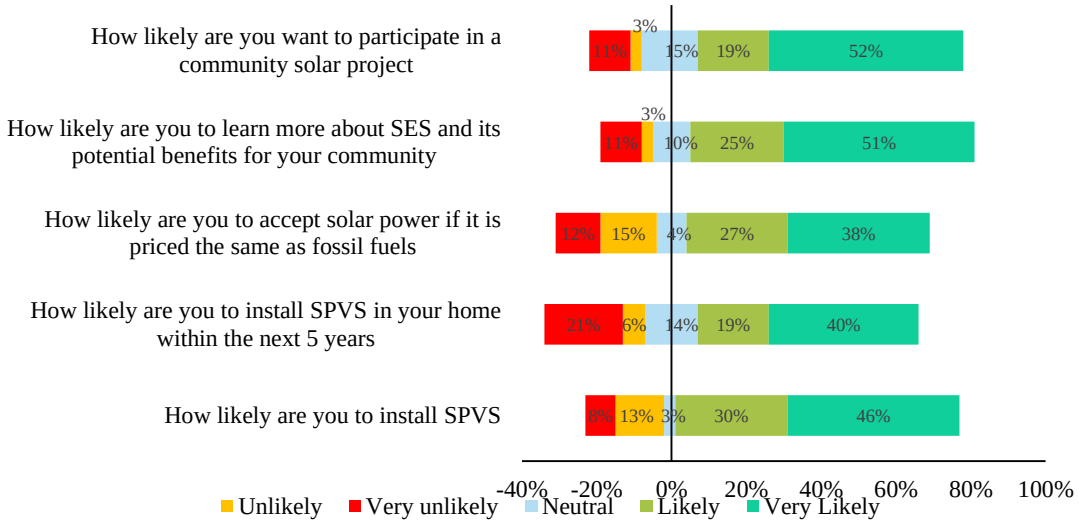


Figure 2.7: Shows respondents' opinion regarding acceptance of SPV technology

The satisfaction levels related to SPVS revealed diverse opinions. A significant proportion of 72% were very satisfied or somewhat satisfied with the statement "Are you satisfied with the performance of your SPVS". Approximately 7% remained neutral, while 21% expressed a degree of strong or somewhat dissatisfaction with their SPVS. Nearly 78% of the respondents recommended SPVS installation to others. Only a small fraction, 14%, expressed disagreement, and the remaining 8% of participants were uncertain about the possible advantages of adopting SPVS.

DISCUSSION

The findings indicate an overall positive perception of HSPVS among respondents, particularly regarding SE as a clean energy source. These results are consistent with those of Baharoon et al. (2016) and Andrade-Arias et al. (2024) and who also reported that most individuals agree that solar power produces clean energy, with 60% and 72% respectively. In terms of climate change impacts, the use of SPVS instead of fossil fuels was positively perceived by respondents. This shows similar results to those found by Baharoon et al. (2016) stated that over 70% of respondents said that using solar energy to generate power helps to slow down climate change. Environmental concerns and awareness of climate change may have contributed to favorable

attitudes toward renewable energy solutions. Consistent with our findings, Andrade-Arias et al. (2024) reported that most of the individuals consider installing SPS as a viable option. Compared to Alrashoud and Tokimatsu (2019) who found that 97% of participants accepted installing HSPVS, our study showed a significantly lower rate but still reflects a relatively high level of acceptance among the respondents.

In contrast to earlier studies, the present findings indicate lower confidence in SPV installation. Jan et al. (2020) reported that 46% of the homes in the study region had SPVS. This divergence from previous research may be attributed to regional socio-economic differences. Comparable results were reported by Solangi et al. (2013), according to the findings, 88% of participants favored government subsidies on solar appliances. The majority of the public seeks information from social media. Tham et al. (2025) also reported that the internet is the primary information source (63.48%) on SPS and solar energy. One of the main obstacles to the growth of net-metering in Pakistan is a lack of knowledge among the public Qamar et al. (2016). These findings, aligning with the study results, indicate a lack of awareness of NM policy. Despite recognizing the long-term economic benefits of solar energy, many respondents were hesitant due to high initial investment requirements. The findings of this study are consistent with those of Zhou et al. (2017) and Alsabbagh (2019), who also reported high prices as the main hurdle. According to Jordan and Kurtz (2013), a panel would still generate around 87% of its initial capacity after 25 years, with an average yearly degradation rate of about 0.5%. The findings of this study are consistent with those of Jan et al. (2020), who also reported the unavailability of electricity as the main factor in the acceptance of SPS. The findings are also in agreement with those reported by Ashour et al. (2021) more than 78% "strongly agree" to embrace the usage of SPV. This study yields similar results to those found by Codemo et al. (2023) regarding the installation of SPV; most respondents (60%) expressed positive opinions. Our findings indicate a greater level of acceptance of SPV than that reported by Zhou et al. (2017) (31%). A high degree of consumer satisfaction was observed with SPVS, similar to a study conducted by Naqvi (2020), which reported that 60% of consumers were satisfied with HSPVS. The positive attitude observed in this study reflects trends documented in previous renewable energy perception research.

CONCLUSION:

A questionnaire survey was carried out in the research area to gauge public perceptions about solar energy and their attitudes towards it. A clear and widespread preference was expressed by most participants, indicating a strong desire to invest in SPVS at some point in the future. The sum-up displays a range of preferences for budget allocations. Most participants view solar energy as a sustainable, eco-friendly technology that can slow down climate change, and most people are willing to install SPVS. Most respondents (71%), when asked about their interest in a community solar project, stated their enthusiasm and willingness to take part. Among the

participants, more than half expected that their solar panel system would operate properly for ten years. Additionally, they expressed a high interest in leasing SES. Most participants rely on SPVS to avoid unexpected power cuts, while the second main cause is rising energy costs. Most people are unaware of the government's initiatives on NM. The respondents to the survey expressed great satisfaction with their use of SPVS installations. The main obstacle is the initial expense of installation; hence awareness and education are required. Social media is crucial for raising awareness of solar energy systems. Effective incentives that can meet the country's energy demands and promote sustainable development are required to raise public awareness of SES.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

FUNDING

There is no funding source for this research or publication.

REFERENCES

Afroz, R., Morshed, M., Duasa, J., Khalid, H., & Muhibbullah. (2019). *Willingness to pay of the households for solar energy: A case study in Kuala Lumpur, Malaysia* International Conference on Economic, Entrepreneurship and Management, Langkawi, Malaysia.

Ahmar, M., Ali, F., Jiang, Y., Wang, Y., & Iqbal, K. (2022). Determinants of adoption and the type of solar PV technology adopted in rural Pakistan. *Frontiers in Environmental Science*, *10*, 895622.

Alrashoud, K., & Tokimatsu, K. (2019). Factors influencing social perception of residential solar photovoltaic systems in Saudi Arabia. *Sustainability*, *11*(19), 5259.

Alrikabi, N. (2014). Renewable energy types. *Journal of Clean Energy Technologies*, *2*(1), 61-64.

Alsabbagh, M. (2019). Public perception toward residential solar panels in Bahrain. *Energy Reports*, *5*, 253-261.

Andrade-Arias, A. S., Kabir, G., Elizondo-Noriega, A., & Mirmohammadsadeghi, M. (2024). Public Acceptability of Solar Energy Implementation in Mexico. *Engineering Proceedings*, *76*(1), 7.

Andrade-Arias, A. S., Kabir, G., Mirmohammadsadeghi, M., Gunasekaran, A., & Elizondo-Noriega, A. (2025). Exploring public perspectives on solar energy adoption in Mexico. *Renewable and sustainable energy reviews*, *212*, 115410.

Ashour, A. M., Mohamad, T. I., Azeem, S. M., Thomas, S. P., Aina, Y. A., Sopian, K., & Ibrahim, A. (2021). Deployment of rooftop solar photovoltaic electrification for residential buildings in an industrial city: a study on public perception and acceptance. *Int. J. Renew. Energy Res*, *11*(2), 945-951.

Baharoon, D. A., Rahman, H. A., & Fadhl, S. O. (2016). Publics′ knowledge, attitudes and behavioral toward the use of solar energy in Yemen power sector. *Renewable and sustainable energy reviews*, *60*, 498-515.

Barone, G., Buonomano, A., Forzano, C., Palombo, A., & Panagopoulos, O. (2019). Photovoltaic thermal collectors: Experimental analysis and simulation model of an innovative low-cost water-based prototype. *Energy*, *179*, 502-516.

Bohada-Murillo, M., Castano-Villa, G. J., & Fonturbel, F. E. (2021). Effects of dams on vertebrate diversity: a global analysis. *Diversity*, *13*(11), 528.

Codemo, A., Barbini, A., Mantouza, A., Bitziadis, A., & Albatici, R. (2023). Integration of public perception in the assessment of licensed solar farms: a case study in Greece. *Sustainability*, *15*(13), 9899.

Devine-Wright, P. (2007). Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. In *Beyond NIMBYism: A Multidisciplinary Investigation of Public Engagement with Renewable Energy Technologies* (pp. 15).

Farnaz, Nuthammachot, N., Shabbir, R., & Iqbal, B. (2025). Pixel and region-oriented classification of Sentinel-2 imagery to assess LULC dynamics and their climate impact in Nowshera, Pakistan. *Open Geosciences*, *17*(1), 20220745.

Global Climate and Energy Project, G. (2006). *An Assessment of Solar Energy Conversion Technologies and Research Opportunities*. S. University.

IEA, I. E. A. (2022). *Electricity Market Report, January 2022*. O. Publishing. https://doi.org/10.1787/71a62db8-en

Irfan, M., Zhao, Z.-Y., Ahmad, M., & Mukeshimana, M. C. (2019). Solar energy development in Pakistan: Barriers and policy recommendations. *Sustainability*, *11*(4), 1206.

Jan, I., Ullah, W., & Ashfaq, M. (2020). Social acceptability of solar photovoltaic system in Pakistan: Key determinants and policy implications. *Journal of Cleaner Production*, *274*, 123140.

Jordan, D. C., & Kurtz, S. R. (2013). Photovoltaic degradation rates—an analytical review. *Progress in Photovoltaics: Research and Applications*, *21*(1), 12–29.

Khan, N. S., Kazmi, S. A. A., Anwar, M., Mughal, S. U. R., Ullah, K., Rathi, M. K., & Salal, A. (2024). Enhancing renewable energy integration in developing countries: a policy-oriented analysis of net metering in Pakistan amid economic challenges. *Sustainability*, *16*(14), 6034.

Kim, M. J. (2021). Air pollution, health, and avoidance behavior: evidence from South Korea. *Environmental and Resource Economics*, *79*(1), 63-91.

Kumar, P., Kumar, P., & Aggarwal, V. (2023). A behavioral study on villagers' adoption intention and carbon neutrality toward rooftop solar photovoltaic systems in India. *International Journal of Energy Sector Management*.

Mirjat, N. H., Uqaili, M. A., Harijan, K., Walasai, G. D., Mondal, M. A. H., & Sahin, H. (2018). Long-term electricity demand forecast and supply side scenarios for Pakistan (2015–2050): A LEAP model application for policy analysis. *Energy*, *165*, 512-526.

Mishra, P. K., & Tiwari, P. (2020). Solar photovoltaic technology—A review. *Advanced Science, Engineering and Medicine*, *12*(1), 5-10.

Naqvi, S. B. (2020). Solar energy in South Punjab/Pakistan: domestic users' perceptions. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *67*(1), 171-182.

Pakistan Economic Survey. (2022). https://www.finance.gov.pk/survey_2022.html

PWD-KP. (2023). *Population Welfare Department Khyber Pakhtunkhwa-Demography*. Retrieved 9 September from https://pwdkp.gov.pk/page/demography

Qamar, H., Qamar, H., & Khan, M. U. (2016). Solar irradiance & on grid solar power systems with net metering in Pakistan. *Advances in Science, Technology and Engineering Systems Journal*, *1*(2), 1-5.

Sathe, T. M., & Dhoble, A. (2017). A review on recent advancements in photovoltaic thermal techniques. *Renewable and sustainable energy reviews*, *76*, 645-672.

Sayed, E. T., Olabi, A. G., Alami, A. H., Radwan, A., Mdallal, A., Rezk, A., & Abdelkareem, M. A. (2023). Renewable energy and energy storage systems. *Energies*, *16*(3), 1415.

Schulte, E., Scheller, F., Sloot, D., & Bruckner, T. (2022). A meta-analysis of residential PV adoption: the important role of perceived benefits, intentions and antecedents in solar energy acceptance. *Energy Research & Social Science*, *84*, 102339.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., & Yu, T.-H. (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science*, *319*(5867), 1238-1240.

Shakeel, S. R., Takala, J., & Shakeel, W. (2016). Renewable energy sources in power generation in Pakistan. *Renewable and sustainable energy reviews*, *64*, 421-434.

Solangi, K., Badarudin, A., Kazi, S., Lwin, T., & Aman, M. (2013). Public acceptance of solar energy: The case of Peninsular Malaysia. IEEE 2013 Tencon-Spring,

Sommerfeld, J., Buys, L., & Vine, D. (2017). Residential consumers' experiences in the adoption and use of solar PV. *Energy policy*, *105*, 10-16.

Talpur, M. A. H., Chandio, I. A., Baig, F., Shaikh, F. A., & Napiah, M. (2017). Energy crisis and household's perception about solar energy acceptance: District Hyderabad, Pakistan. *Sindh University Research Journal – SURJ (Science Series)*, *49*(3), 601–604.

Tham, P. N., Thuy, T. D., Nam, P. K., & Papyrakis, E. (2025). Policy uncertainty, public perception, and the preferences for rooftop solar power systems: A choice experiment study in Vietnam. *Renewable and sustainable energy reviews*, *208*, 115067.

Tyagi, V. V., Rahim, N. A., & Rahim, N. (2013). Progress in solar PV technology: Research and achievement. *Renewable and sustainable energy reviews*, *20*, 443-461.

Ud Din, S., Wimalasiri, R., Ehsan, M., Liang, X., Ning, F., Guo, D., Manzoor, Z., Abu-Alam, T., & Abioui, M. (2023). Assessing public perception and willingness to pay for renewable energy in Pakistan through the theory of planned behavior. *Frontiers in Energy Research*, *11*, 1088297.

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy policy*, *35*(5), 2683–2691.

Zhou, D., Shah, T., Jebran, K., Ali, S., & Ali, A. (2017). Acceptance and willingness to pay for solar home system: Survey evidence from northern area of Pakistan. *Energy Reports*, *3*, 54-60.

Zulfiqar, M., Mian, I. A., Khan, N., Hanan, N. G. D. F., Qazi, M. A., Fahad, S., Afsar, N., Jehan, S., & Naushad, M. (2019). *District Nowshera–Pakistan*.