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Survey-Based Assessment of Public Awareness and Adoption Intent for Rooftop Solar Photovoltaic (PV) Systems Among Individuals in Pakistan

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ABSTRACT

The objective of the study was to explore the solar familiarity and adoption intent among individuals in Pakistan. Although Pakistan is traditionally seen as a country rich in fossil fuels, it also has strong potential for solar energy generation due to its geographic location and climate. Therefore, it is important to understand the level of awareness individuals have about solar energy and their intentions to install solar panels. In this study, a survey-based questionnaire was developed. It was distributed among different universities, shared with the public sector, and approached locally. Their responses were collected via Google Form and analyzed in Excel. The demographics of the respondents were also taken to better understand their stance and opinions on solar adoption. The findings suggest that although most people are highly familiar with solar and intend to install solar, they are unable to do so. There are several barriers, including high-cost installments, long installation procedures, a lack of financial support or subsidies, and governmental actions or policies. Overall, the study highlights a clear gap between awareness and actual adoption of solar energy in Pakistan, suggesting that stronger governmental support, policy reforms, and financial incentives are necessary to convert positive intentions into practical implementation.

INTRODUCTION

Energy security is defined not just by fuel availability, but by geopolitics, decarbonization, and system resilience. Modern energy security, encompassing availability, affordability, and environmental sustainability, is shaped by the interplay of climate-driven energy transitions, persistent supplier concentration, and concerns over equity and affordability (Ayoo, 2020; Strojny et al., 2023; Wang et al., 2024). The relevance of this topic is linked to the United Nations Sustainable Development Goals (SDGs), specifically the seventh SDG, which focuses on ensuring access to affordable, reliable, sustainable, and modern energy for all (Akpan and Olanrewaju, 2023). The Paris Agreement, signed in 2015, establishes a global framework to limit global warming to below 2°C and, if possible, to 1.5°C above pre-industrial levels.

Pakistan is also one of the countries that signed both the SDGs and the Paris agreements. Therefore, similar to other countries, Pakistan must also focus on the following two key areas to meet these agreements' targets: (i) reduction in greenhouse gas emissions, which are largely contributed by fossil fuel consumption by increasing the share of renewable energy in the energy mix, and (ii) reduction in energy consumption by increasing energy efficiency (Rafique and Rehman, 2017). To achieve these targets, shifting to solar power is essential for Pakistan, as it has abundant solar resources, making it a highly promising energy option (Bednar and Reames, 2020; Bhandari et al., 2024). In addition to meeting international climate commitments, these transition policies play a crucial role in achieving energy security, economic stability, and environmental security.

Pakistan is an ideal location for solar energy, as it receives approximately 300 sunny days annually and receives 5–7 kWh of solar radiation per square meter (Asghar et al., 2023). Harnessing solar energy can provide affordable electricity to underserved regions and support economic growth by reducing energy costs and import burdens (Irfan et al., 2019; Muhammadi et al., 2024; Hussain et al., 2023). Increasing Pakistan's reliance on solar power will significantly reduce import bills, create new job opportunities, and increase access to electricity by decreasing its dependence on fossil fuel imports, thereby enhancing energy security (Hasan et al., 2023). According to the Alternative and Renewable Energy Policy 2019, this

can help the country achieve a 30% share of renewable energy generation by 2030 (González-García et al., 2022).

There are several reasons why Pakistan cannot fully use its large solar PV potential. It is mainly due to financial, institutional, and technical obstacles rather than a lack of sunlight. High upfront system cost, limited access to credit, budget constraints, high perceived investment risk, and tariffs on PV components make systems unaffordable for most households and small firms. Weak, inconsistent policies, a lack of effective incentives or subsidies, poor implementation by agencies (AEDB, PCRET), and political instability slow deployment and deter investors (Irfan et al., 2019). Regulatory issues and policy gaps also persist, hindering the development of solar energy. Uncertainty stemming from inconsistent policies, bureaucratic bottlenecks, and a slow system, along with an undefined regulatory framework, prevents investors from developing potential renewable energy projects (Shahzad et al., 2023).

Public awareness is important as it directly influences willingness to adopt solar technologies. Studies have shown that higher awareness levels are correlated with greater interest and a willingness to install solar systems (Shahid et al., 2022). This situation creates significant obstacles, including a lack of information, misconceptions about costs, and a lack of trust in providers. These issues are repeatedly cited as key barriers that slow the development of solar energy in Pakistan (Shahid et al., 2022). Addressing these societal and informational gaps is important for accelerating solar adoption and attaining national energy goals. Therefore, it is necessary to understand how social acceptance and individual willingness shape adoption behavior across different socioeconomic and regional contexts in Pakistan.

The aim of the study is to analyze the public awareness, behaviors, perceived barriers, and adoption intentions towards solar systems in Pakistan. The study used a survey-based quantitative approach. It has been analyzed how demographic factors and understanding can impact the adoption status of solar.

MATERIALS AND METHODS

1. Research Design

A survey-based quantitative research design was made to assess public awareness, perceived barriers, and adoption intent regarding Rooftop Solar Photovoltaic (PV) systems among individuals in Pakistan. A structured questionnaire (Table 1) was designed using Google Forms. It was disseminated to collect primary data from a diverse sample of respondents. It aimed at getting the respondents' demographic characteristics, awareness of rooftop solar PV systems, attitudes toward adoption, and perceived barriers.

Table 1

Survey Questionnaire

Section	Questions	Options
General Information	What is your age group?	☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56 and above
	What is your highest level of education?	☐ Elementary ☐ Middle school ☐ High school ☐ Bachelors ☐ Masters ☐ Other (please specify)
	What sector do you currently work in?	☐ IT ☐ Retail Services ☐ Government Official ☐ Engineer/Technician ☐ Education ☐ Banking/Finance ☐ Healthcare ☐ NGO/Non-Profit ☐ Other ☐ I am not working
	How familiar are you with solar energy?	☐ Very Familiar ☐ Familiar ☐ A little familiar ☐ Not Familiar at All
Energy Consumption and Preferences	What is the source of electricity you use at home?	☐ National Grid ☐ Solar Energy ☐ Generator (Diesel/Petrol) ☐ Other (please specify)
	Do you experience frequent power outages?	☐ Yes, daily ☐ Yes, weekly ☐ Yes, monthly ☐ No
	Have you considered installing solar panels at your house?	☐ Yes, already installed ☐ Planning to switch ☐ Maybe ☐ No
	Factors encouraging solar adoption (select all that apply)	☐ Lower installation costs ☐ Government incentives ☐ Reliable energy ☐ Environmental benefits ☐ Easily accessible
Solar Energy Development and Barriers	Biggest barriers to solar energy adoption (select all that apply)	☐ High costs ☐ Lack of government support ☐ Limited awareness ☐ Grid issues ☐ Availability of cheap fossil fuels
	Can solar energy replace conventional electricity in future?	☐ Yes, in 10 years ☐ Yes, in 20-30 years ☐ No, fossil fuels will dominate ☐ Not sure
	Government policies to promote rooftop solar	☐ Tax reductions ☐ R&D funding ☐ Subsidies ☐ Awareness campaigns ☐ Simplified regulations
Environmental and Economic Impact	Can solar energy reduce carbon emissions?	☐ Yes ☐ No ☐ Not sure
Final Thoughts	How will solar energy impact the economy? (select more than one)	☐ Create new jobs ☐ Increase energy independence ☐ Minimal economic impact ☐ Not sure ☐ Environmental benefits
	Additional suggestions/comments	Open-ended

2. Sampling and Participants

Data were collected using a convenience sampling method. The questionnaire link was distributed among two groups: Students and faculty members from Quaid-e-Azam University, Islamabad. General public, including family members and neighbors.

The sample included individuals with diverse educational and professional backgrounds. It includes individuals with bachelor's degree holders in finance, engineering, Islamic studies, government employees, private sector workers, and retired individuals. A total of **82 responses** were received. ***The age range of participants was 18 to 50 years***. It represents a mix of young adults and middle-aged individuals.

3. Data Collection Procedure

The questionnaire link was shared electronically through social media platforms (Email, WhatsApp, LinkedIn) and

direct messaging applications. Participants were informed about the academic purpose of the study. They were assured that their responses would remain confidential and be used solely for research.

4. Data Analysis

The collected responses were exported from Google Forms into Microsoft Excel/Statistical software. Descriptive statistics were used to summarize demographic variables and assess trends in awareness, perceptions, and adoption intent toward rooftop solar PV systems.

RESULTS AND DISCUSSION

Results are organized into respondent characteristics, awareness levels, energy-use patterns, adoption intent, motivating factors, barriers, policy preferences, and perceived environmental and economic impacts. percentages are reported as shares of valid responses for each question ('n' showing no. of samples on each chart).

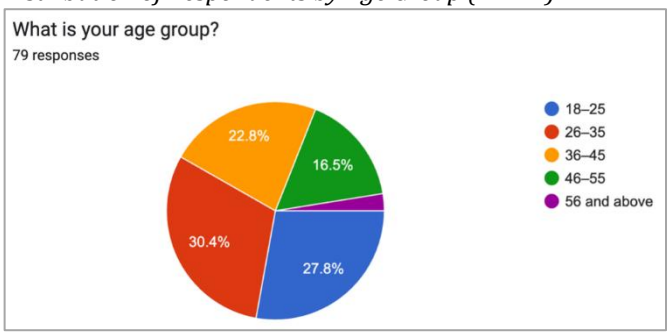
1. Respondents Profile

1.1. Age Distribution (n = 79)

The sample consists primarily of younger and mid-career adults: 18–25 years (27.8%), 26–35 years (30.4%), 36–45 years (22.8%), and 46–55 years (16.5%). Only a small proportion is above 56. Younger groups tend to be more climate-conscious and flexible but face affordability constraints, whereas mid-career adults, often homeowners, represent the segment with the highest near-term adoption potential.

Figure 1

Distribution of Respondents by Age Group (n = 79)

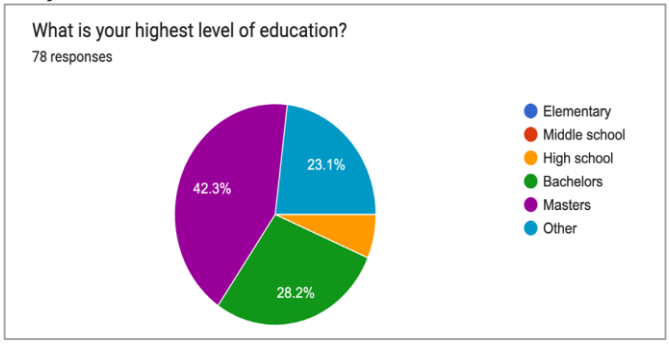


1.2. Education Level (n = 78)

The sample is highly educated. A small number report schooling below Bachelor's level. This context helps explain the high familiarity with solar and strong adoption interest reported in later sections.

Figure 2

Distribution of Respondents by Highest Level of Education (n = 78)

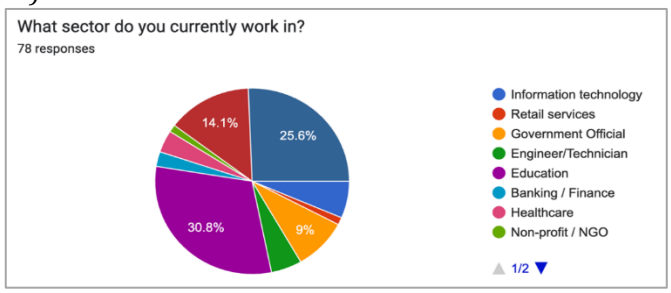


1.3. Employment Sector (n = 78)

These formal-sector professions indicate stable income streams, greater digital literacy, and typically higher capacity to evaluate long-term financial decisions such as solar investments. This sectoral composition is reflective of an early-adopter profile and suggests opportunities for workplace-based awareness programmes or group-financing schemes.

Figure 3

The Distribution of Respondents by Employment Sector (n = 78)



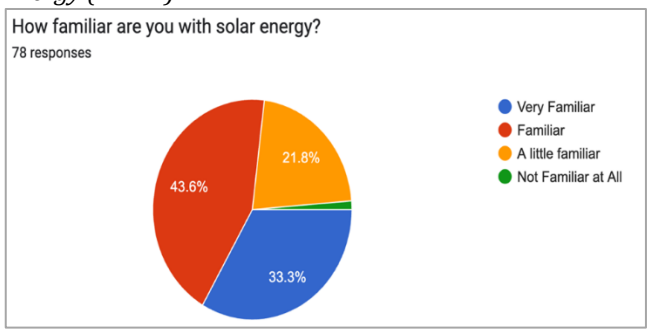
2 Awareness and Energy-Use Patterns

2.1. Respondents' Familiarity with Solar Energy

A strong majority report being familiar (43.6%) or very familiar (33.3%) with solar energy. Only 2% are not familiar at all. This high baseline awareness aligns with the sample's education level and implies that adoption barriers are less informational and more financial or procedural.

Figure 4

Level of Awareness Among Respondents Regarding Solar Energy (n = 78)

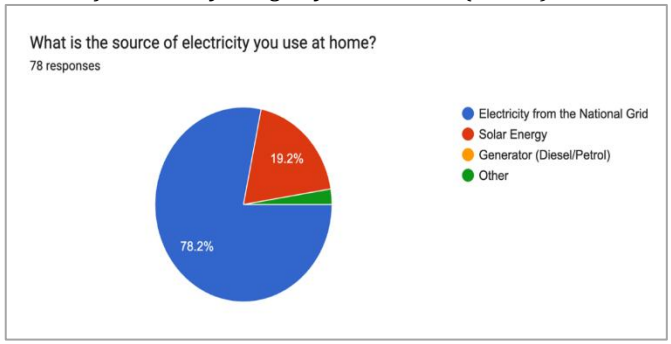


2.2. Primary Household Electricity Source (n = 78)

Most respondents rely on the national grid (78.2%). Notably, 19.2% already use solar systems at home, reflecting visible early penetration in urban, educated communities.

Figure 5

Source of Electricity Usage by Individuals (n = 78)

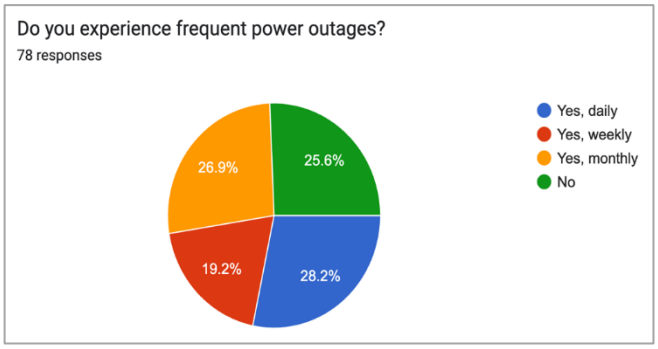


2.3. Frequency of Power Outages (n = 78)

The results underscore the need for solutions that enhance resilience and service continuity, such as right-sized rooftop solar PV systems and formal maintenance agreements (SLAs).

Figure 5

Power Outrages in Urban Cities (Karachi and Islamabad), Pakistan



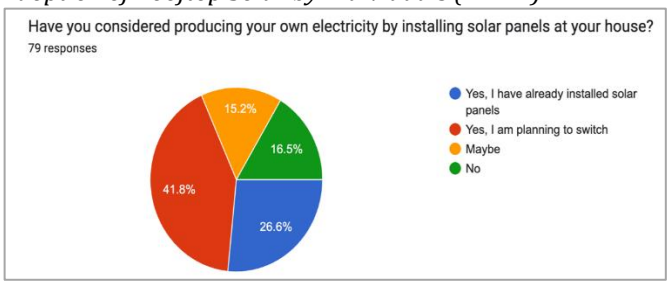
3. Adoption Intent and Behavior

3.1. Consideration or Adoption of Rooftop Solar (n = 79)

This distribution indicates a strong readiness-to-adopt trajectory, with the main constraints lying in affordability, financing convenience, and installer trust rather than lack of conviction.

Figure 6

Adoption of Rooftop Solar by Individuals (n = 79)

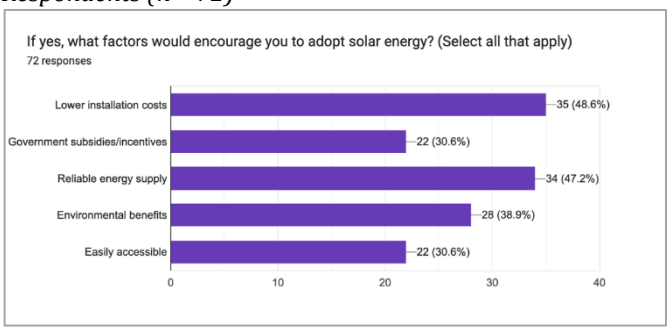


4 Motivating Factors (n = 72, multi-select)

The pattern implies households are already sold on the idea but constrained by Capital Expenditure (CAPEX) and perceived performance risk. Effective interventions therefore combine cost buy-downs (time-bound subsidies, Value Added Tax VAT/tariff relief), concessional finance (on-bill Equated Monthly Installments (EMIs), green mortgages, zero-down leases), and assurance mechanisms (production guarantees, vetted installers, service SLAs)..

Figure 7

Factors Encouraging Adoption of Solar Energy Among Respondents (n = 72)

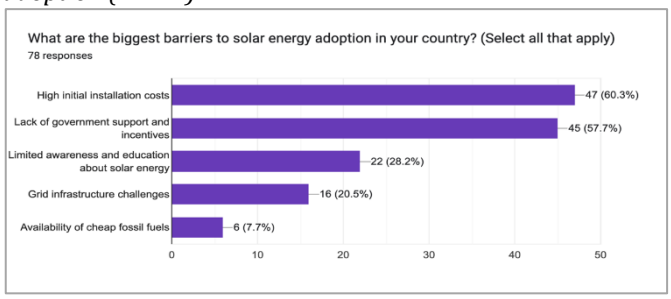


5 Barriers to Adoption (n = 78, multi-select)

The results indicate that adoption is not hindered by skepticism but by **capital intensity** and **policy uncertainty** particularly around subsidies, net-metering terms, and system approvals.

Figure 8

Survey responses on the biggest barriers to solar energy adoption (n = 78)

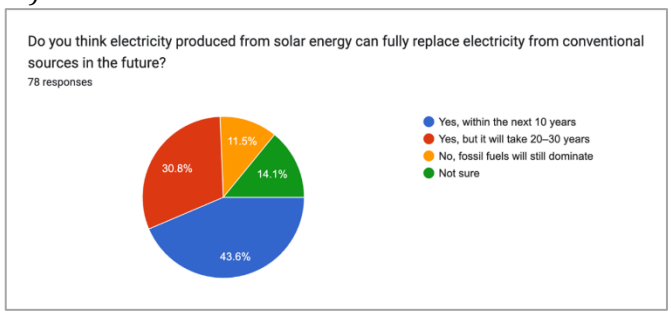


6. Expectations for Solar Transition (n = 78)

This suggests confidence in solar as a long-term solution, provided grid modernization and policy stability are achieved.

Figure 9

Timeline for Solar to Replace Conventional Electricity (n = 78)

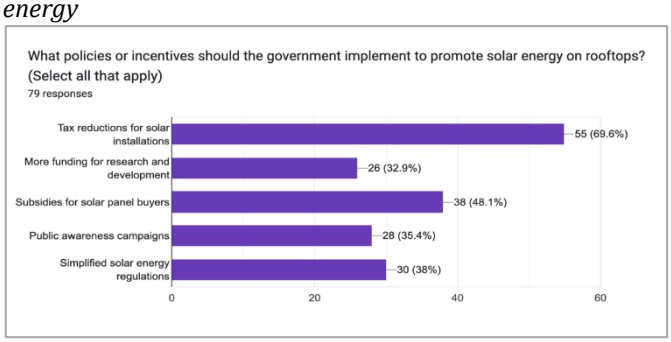


7. Policy Preferences (n = 79, multi-select)

These preferences imply that respondents believe the technology is mature but that the adoption process remains financially and administratively cumbersome. The policy appetite is overwhelmingly for household-facing fiscal relief and administrative simplicity rather than upstream technology bets.

Figure 10

A bar chart showing that tax reductions are the most preferred government policy to promote rooftop solar energy

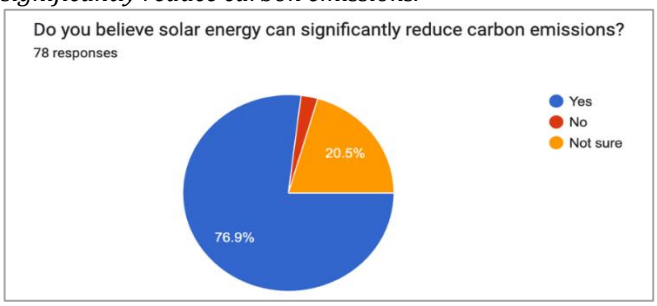


8. Perceived Environmental Impact (n = 78)

This indicates strong social acceptance and alignment with national mitigation targets.

Figure 11

The chart shows that most people believe solar energy can significantly reduce carbon emissions.

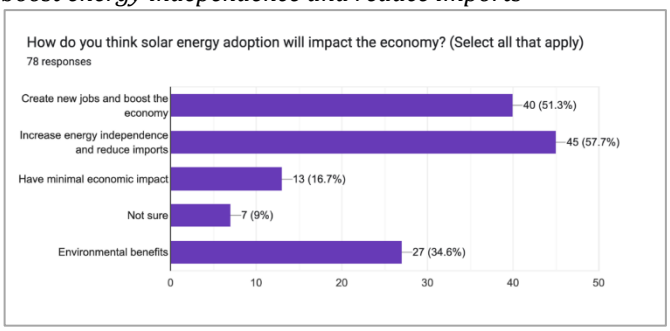


9. Perceived Economic Impact (n = 78, multi-select)

The expectation that solar enhances national energy security underlines an important narrative for public communication and policymaking. This belief mix supports policies that localize value capture e.g., incentives tied to local assembly/content, accredited installer training, and MSME-friendly procurement while ensuring stable market demand via net-metering and clear interconnection rules.

Figure 12

The chart shows that people think solar energy will mainly boost energy independence and reduce imports



The result of this study is that Pakistani individuals are very much aware and familiar with the rooftop solar photovoltaic systems. Most of the respondents shows that they understand the benefits of adoption. They give positive feedbacks. Yet despite of high awareness, the adoption of solar seems difficult. It is because of the barriers that include high initial financial cost, limited supporting infrastructure, lengthy procedural requirements. These challenges decrease the consumers willing to install solar plates.

Since awareness satisfactory levels are high, government should focus on the basic awareness campaigns and more reducing financial barriers. Financial incentives include, low interest loans, and tax exemptions. It can help to address the cost concerns. Also working on improving the grid infrastructure, and approval procedure can increase the adoption rates.

CONCLUSION

The questionnaire helped us assess public awareness and adoption intent regarding solar systems in Pakistan. It was distributed among individuals from different age groups, educational backgrounds, and professional sectors. The individual includes university students, academic staff, and members of the general public. Their responses provide insights into their attitudes and perceptions. The most important finding of the study is that most of the participants are well aware of solar energy. They are aware of its benefits, yet are unable to adopt rooftop solar PV systems. It is due to limited financial resources, infrastructure constraints, and procedural and bureaucratic challenges. The results of the questionnaire show that rooftop solar adoption in Pakistan is mainly adopted by working-age households. Respondents aged 26–35 form the largest group planning to switch to solar. This age group combines awareness of environmental issues with growing financial capacity. Overall, the findings show that rooftop solar adoption among Pakistani individuals is shaped by awareness, affordability, and institutional support. Reducing upfront costs and expanding targeted awareness initiatives can accelerate adoption. Although this study has several limitations. First, the sample size is relatively small and may not be representative of individuals from all regions of Pakistan. Second, using a survey limits the analysis to self-reported behavior.

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