Post-Installation Experiences of Grid-Connected Residential Rooftop Solar PV Users in India: An Empirical Survey

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Abstract

Grid-connected residential rooftop solar PV (GRRPV) systems are being promoted worldwide through energy policies to increase the share of renewable energy as a part of climate change mitigation efforts and to enhance energy security. The post-installation experiences of end users remain under-reported despite a wide range of research exploring the adoption trends of, the barriers to, and the drivers responsible for the deployment of GRRPV systems. Promoting GRRPV systems assumes particular significance in the global south as the region witnesses a rising electricity demand amid prospective economic growth. This qualitative research aims to understand the factors influencing the adoption of GRRPV systems and to assess consumer satisfaction with their financial savings. In addition, it examines post-installation consumer experiences. The research data were gathered using a semi-structured questionnaire and analyzed using descriptive and thematic methods to identify the recurring patterns and themes within the collected data. The analysis of survey data reveals that high upfront costs and a lack of consumer knowledge and awareness are reported as barriers to the adoption of GRRPV systems, whereas savings on electricity bills due to high electricity prices are identified as key enablers. The study's findings revealed the need to streamline the subsidy disbursal process, expedite installation and commissioning, and ensure transparent communication between vendors and end-users regarding the operation of GRRPV systems during the pre-installation stages. This research provides evidence-based guidance for policymakers and regulators in countries with emerging rooftop solar PV markets, highlighting key barriers to adoption and focus areas for enhancing the consumer experience and policy delivery.

Keywords: Rooftop Solar, Consumer Adoption, Solar PV, Survey Research, India, Solar Rebound Effect

1. Introduction

The share of energy sources in the electricity mix of many countries has undergone rapid changes since the first decade of the 21st century, driven by rising electricity demand and the need to adopt renewable energy technologies (International Energy Agency, 2024). Solar PV systems are among the most popular renewable energy technologies due to their cost-effectiveness, stationary structure, and minimal maintenance requirements. Globally, governments are promoting grid-connected rooftop solar PV systems as part of their energy policies to enhance energy security and increase the share of renewable energy, which offers climate change mitigation.

The adoption of Grid-connected residential rooftop photovoltaic (GRRPV) systems is increasing due to their potential for renewable energy production and financial savings to consumers. Governments are promoting the adoption of the GRRPV systems by providing subsidies and enabling metering and billing mechanisms. A wide range of research explores the trends in, the barriers to, and the drivers responsible for the adoption of rooftop solar PV systems (Dutt, 2020; Mahadevan et al., 2023). The literature suggests that market forces, as well as economic, social, and political factors, influence consumer decision-making (Karakaya & Sriwannawit, 2015). Studies have shown that social and economic factors are more significant than environmental factors (Sommerfeld et al., 2017).

Existing research has extensively examined the factors influencing the adoption of solar PV systems. A

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systematic review of 146 studies on household solar PV adoption identified 127 factors across eight categories that influence consumer decisions. (Shakeel et al., 2023). A review of 95 studies, primarily focusing on small-scale solar energy installations in the residential sector, identified cost savings, environmental conservation, and increased social status as the most frequently cited reasons for PV adoption (Nag et al., 2024). A bibliographic study of 564 publications used co-citation and co-word analysis. It found that a significant share of studies focus on 'motivation to adopt solar panels' and 'determinants of renewable energy adoption' (Ashraf Fauzi et al., 2023).

The existing literature primarily focuses on pre-adoption factors that influence consumers' decision-making. However, there is a relative lack of empirical investigation into consumers' post-installation experiences, including their satisfaction and usage behavior. This creates a gap in understanding how consumer perceptions evolve after the adoption of solar PV systems.

The study of post-installation experiences of GRRPV consumers is crucial for assessing the long-term effectiveness of PV policies and the sustainability of the rooftop solar PV sector, as it provides valuable feedback on consumer satisfaction, service enhancements, and policy implementation. This research aims to bridge the existing knowledge gap by understanding the factors influencing adoption, assessing consumer satisfaction with financial savings, and exploring post-installation consumer experiences.

2. Methodology

A cross-sectional, qualitative survey of GRRPV users was conducted in 45 cities across 12 states and one union territory in India. The geographic distribution of survey respondents and the states represented in the sample are shown in Figure 1. A semi-structured questionnaire, comprising two sections, was developed. In the first section, user information and technical details of the GRRPV system were collected. In the second section, questions were asked regarding users' motivations, initial barriers, policy delivery, and post-installation experiences. Selected questions from the second part of the semi-structured questionnaire are shown in Table 1.

Table 1 Selected questions from the semi-structured questionnaire used for the consumer survey

Sr. No.	Selected Questions from Survey Questionnaire	Type of Question
1	What were the top reasons for you to consider solar energy?	Open-ended
2	How satisfied are you with the overall installation process?	Likert Scale (1 to 10)
3	Rate the responsiveness of the installer to the issues with your rooftop solar system since installation.	Likert Scale (1 to 10)
4	How satisfied are you with the financial savings you've experienced from the rooftop solar system?	Open-ended
5	In your opinion, what are the biggest challenges for residential consumers who are considering to install rooftop solar system?	Open-ended
6	What improvements would you like to see in future rooftop solar PV systems?	Open-ended

Descriptive statistical analysis was performed using the survey data to summarize and interpret information about respondent demographics, dwelling characteristics, and system parameters. A two-step thematic analysis was conducted to identify recurring patterns and themes within the qualitative data. In the first step, open coding to break data into concepts and labels (Strauss, 1987). In the second step, codes were analyzed and grouped into three themes, namely consumer satisfaction, service enhancements, and policy implementation (Clarke & Braun, 2017). The thematic analysis does not capture or summarize all the information collected; rather, it identifies key features of the data and interprets them to address the research question.

The questionnaire was administered to a sample of 96 GRRPV users between February 2025 and April 2025. The sample users were selected through convenience sampling, comprising 11 in-person surveys, 61 telephonic surveys, and 24 online surveys (Devi et al., 2018; Martin & Ryor, 2016). The mean age of survey respondents

was 47.5 years. Of 96 respondents, 87 were male, 8 were female, and 1 did not prefer to disclose their gender.

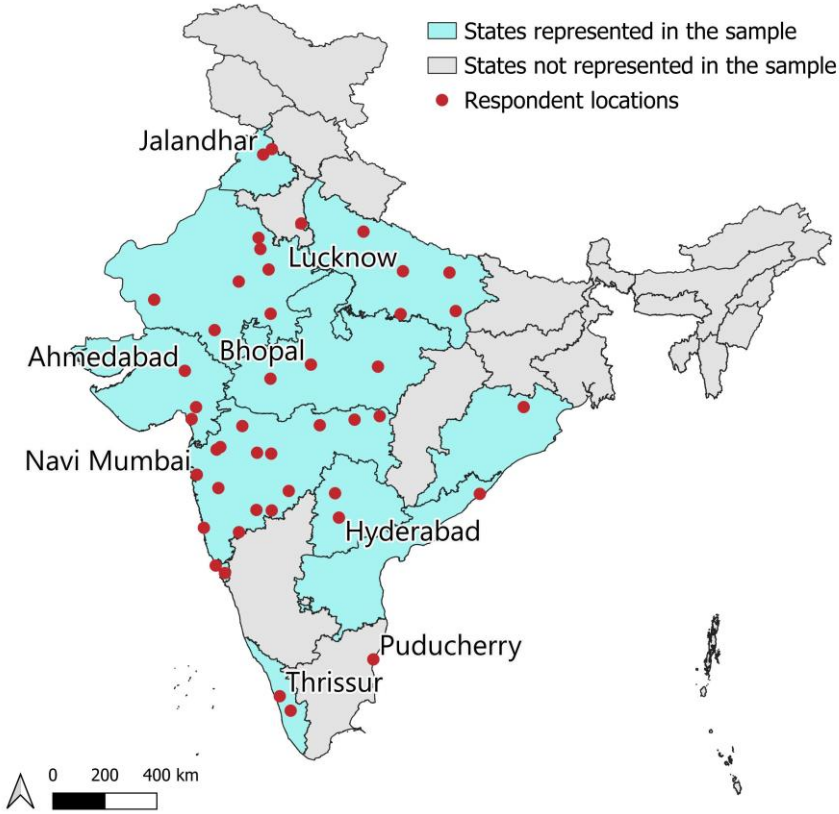

Figure 1: Map of India showing geographic distribution of survey respondents and the states represented in the sample

The installed capacities of the four housing society connections were 15 kW, 20 kW, 27 kW, and 175 kW, while the capacities of the remaining 92 GRRPV systems ranged from 1 kW to 15 kW, with a mean of 4.9 kW and a mode of 3 kW. Only 17 out of 96 GRRPV systems were integrated with battery storage. The systems, ranging in age from 5 months to 9.6 years, with a mean age of 2.8 years, were covered. Of the surveyed installations, 90 GRRPV systems were equipped with a net metering mechanism. Gross metering was employed in two systems, whereas four respondents were unsure about the type of metering and billing mechanism used.

A total of 83 GRRPV systems were installed on independent houses or bungalows. Six systems were installed on the private rooftops of apartment flats by the respective flat owners, four on the rooftops of housing society buildings for society-level electricity connections, and three on the rooftop of row houses. The physical placement of PV modules on rooftops showed that 49 respondents reported them to be easily accessible, 40 reported indirect access (where water can reach the modules), and 7 reported that the modules were not safely accessible.

Irrespective of their subsidy status, the majority of the GRRPV systems (83) were self-funded. The remaining 13 systems were financed through loans, with five funded using a combination of equity and debt. The loan tenures ranged from 3 to 5 years, and the annual interest rates ranged from 7% to 9% in the given survey sample. Figure 2 shows the status of availing subsidy by GRRPV end-users. The survey sample shows that government subsidies support one out of three installations.

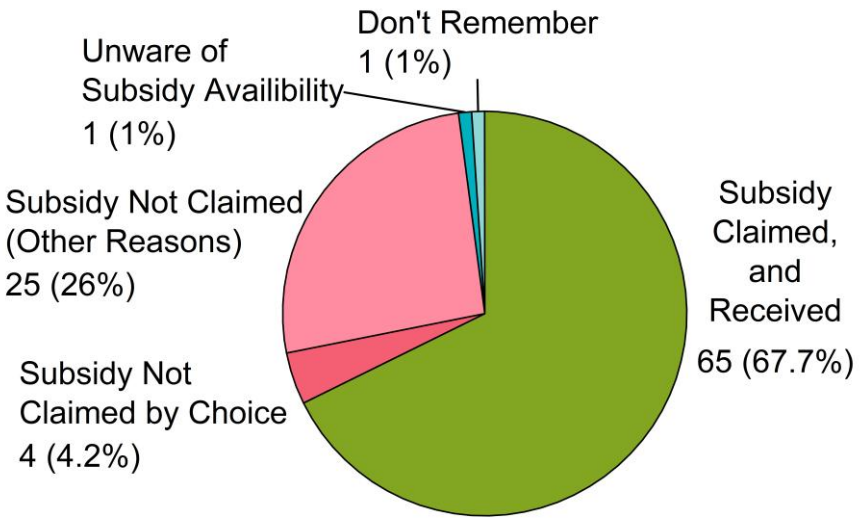

Figure 2 Distribution of survey participants by subsidy status for GRRPV Users (n=96)

3. Results and Discussion

Most respondents reported satisfaction with the installation process, including the quality of the installation and the time the installers took to install and commission the system. Consumers reported an average satisfaction rating of 8.5 out of 10 for the overall installation process.

Frequently reported influencing factors, including end-users' satisfaction with financial savings and their post-installation experiences, are presented and discussed. The responses related to the factors influencing deployment, both enablers and barriers, were grouped into six categories: economic, knowledge-attitude-behavior, technical, institutional, environmental, and market-based.

3.1 Factors Influencing the Adoption of GRRPV Systems in India

Figure 3 illustrates a prioritized list of enabling factors that contribute to consumer adoption of GRRPV systems. As reflected in 60 (about 62%) survey responses, potential financial savings in electricity bills due to high electricity prices are identified as the key enablers for the adoption of GRRPV systems. Improved financial viability, partly supported by capital subsidies from the central government and, in some cases, state governments, is cited as a major driver of the uptake of GRRPV systems. Studies conducted in Malaysia and Gujarat, India, revealed similar results, identifying electricity bill savings and return on investments as decisive factors of GRRPV adoption (Dave et al., 2025; Lam et al., 2025).

The influence of community on decision-making is evident among the respondents, as many stated they were inspired by the systems installed in the homes of their friends, relatives, and neighbors. The peer effect enhanced respondents' perceived credibility of technology and helped them assess the trustworthiness of installers, which ultimately influenced their decision-making.

Respondents stated that they envisioned GRRPV systems as a solution to frequent power outages on the centralized electricity grid. Consequently, energy reliability and autonomy emerged as the most frequently cited factor within the technical category. However, many users reported dissatisfaction after installation because GRRPV systems did not generate electricity during power outages, as they were required to follow anti-islanding protocols under regulatory obligations.

A consistent and stable policy is highlighted as the primary institutional driver. Respondents emphasized the environmental benefits of solar PV technology when discussing their motivation for installing GRRPV systems.

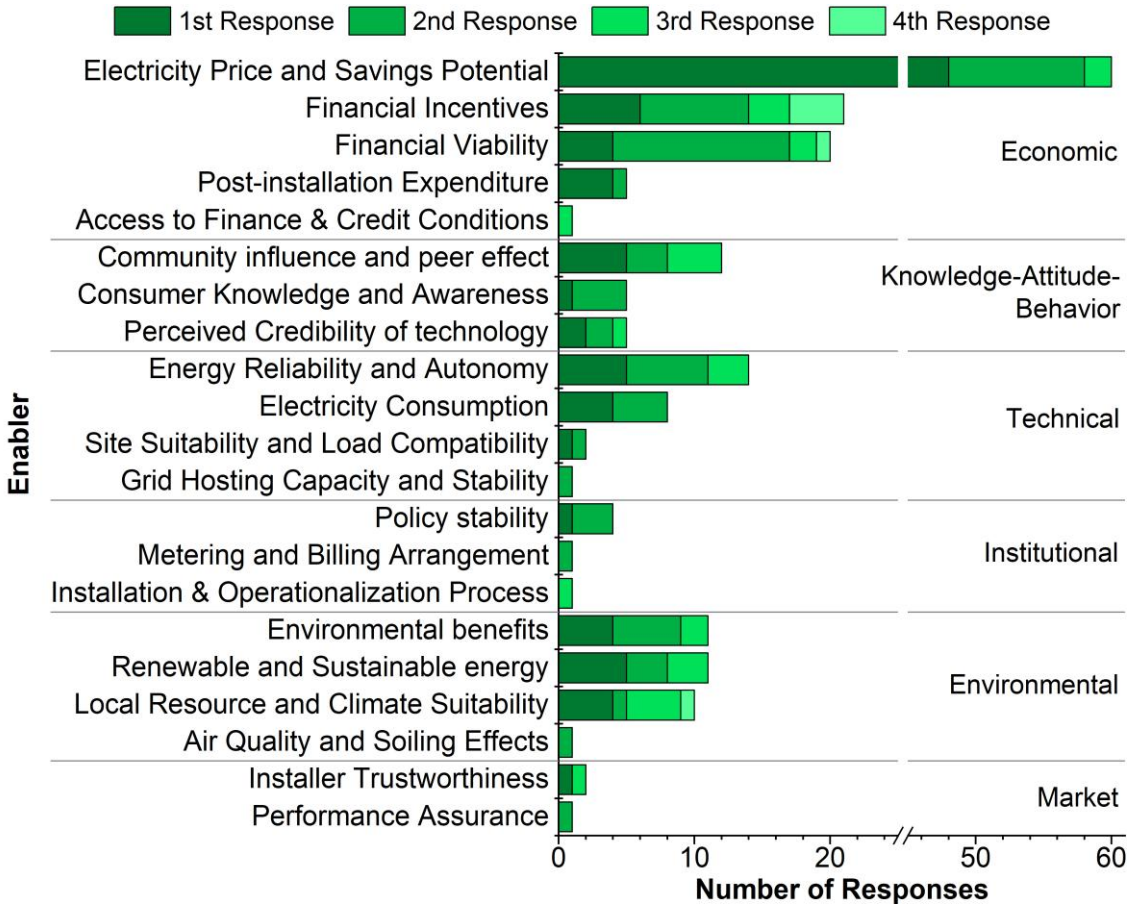

Figure 3 Enabling factors influencing consumer adoption of grid-connected residential rooftop solar PV systems in India, based on survey responses (n=96). Author's compilation.

Barriers to consumer adoption of GRRPV systems are illustrated in Figure 4. According to 50% of respondents, the high upfront cost is the most prominent deterrent to GRRPV system adoption. Limited access to finance and financial viability are the leading reasons for limited uptake. The consumer's knowledge and awareness about the technology, installation process, and related policies were identified by around 27% of respondents as the main factor under the knowledge-attitude-behavior category. These findings are consistent with contemporary studies conducted within the Indian context (CEEW, 2023; Dutt, 2020).

A lack of adequate rooftop space and insufficient electricity consumption were noted as key technical impediments. Concerns related to maintenance, such as the cost of replacing the inverter and battery storage, and panel cleaning, were frequently reported as technical factors discouraging users from installing a GRRPV system. Respondents indicated that non-adopters perceive issues such as delays in subsidy disbursement, a slow installation and commissioning process due to delays in approvals, and a lack of trust in installers as deterrents.

The respondents recognize financial viability as both an enabler and a barrier, indicating heterogeneity among them and context-specific economic conditions. Financial viability is shaped by income level, access to credit, policy awareness, and local electricity prices. Hence, further research is warranted to understand how financial viability varies across different segments of electricity consumers.

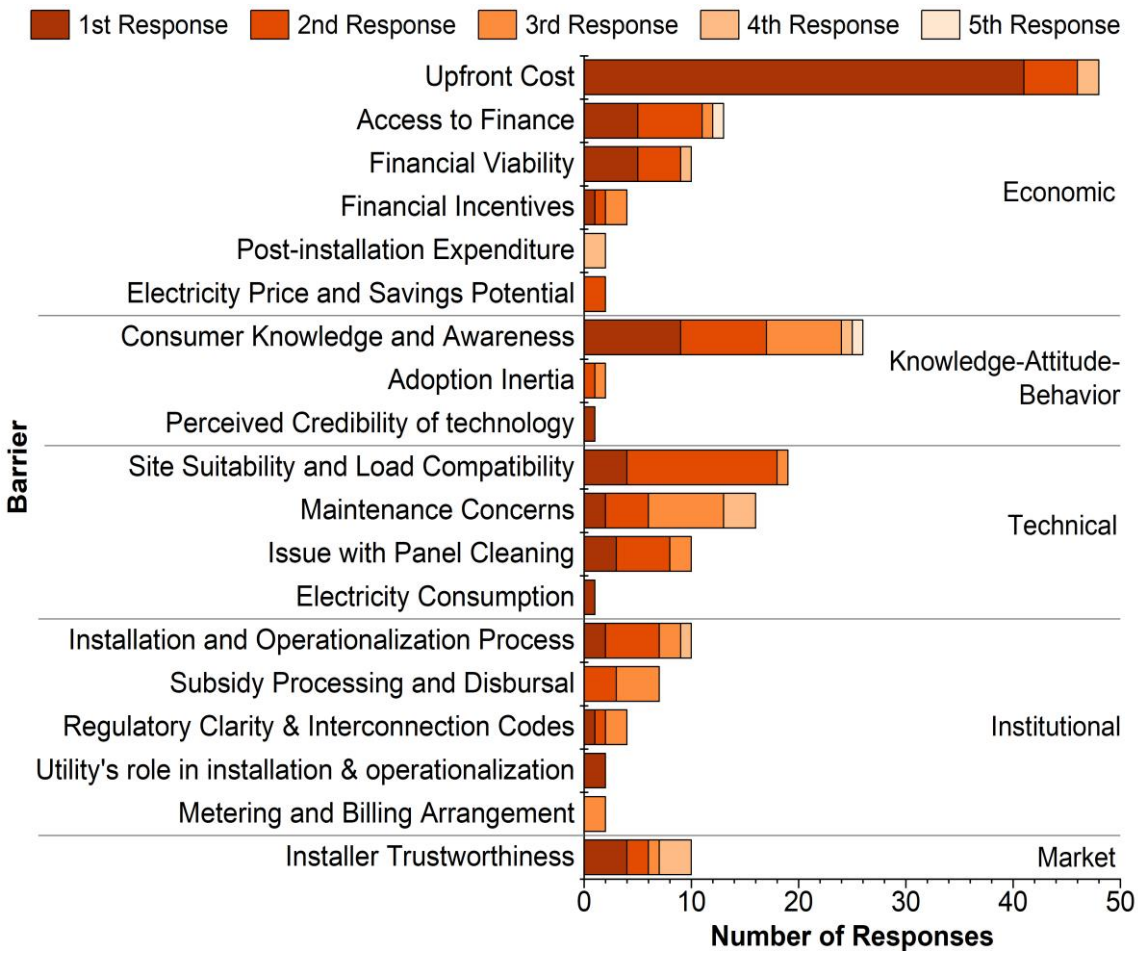

Figure 4 Barriers influencing consumer adoption of grid-connected residential rooftop solar PV systems in India, based on survey responses (n=96). Author's compilation.

3.2 User Satisfaction with Financial Savings

When asked about financial savings, respondents reported an average satisfaction level of 8.85 on a scale of 10 (n = 96). A total of 17 respondents reported achieving a 100% reduction in their electricity bill, while 19 users reported savings of 90% or more but less than 100%. A total of 29 users reported reductions of 50% to 90%, 18 reported savings of less than 50%, and 13 could not provide a definitive estimate of their bill reduction. Respondents generally considered the decision to install the GRRPV system to be wise and financially sound. In the surveyed sample, no specific relationship was observed between bill savings and factors such as subsidy availability, battery storage availability, or financing structure.

3.3 Post-Installation Experiences of GRRPV System Users

Only two respondents indicated a noticeable reduction in electricity consumption, while the majority reported differing consumption behaviors. Most people observed a marginal increase in their consumption; however, they noted that their families generally became more conscious about electricity use after installing GRRPV systems. For example, more electricity was used during the daytime to correspond with solar power generation. Households began using induction cookstoves for cooking, operated air coolers for extended periods, and purchased additional appliances, such as washing machines, refrigerators, and air conditioners. Some respondents further reported purchasing electric cars and bikes, as they perceived electricity to be more affordable after installing GRRPV systems. While individual experiences cannot establish causality, they provide insight into behavioral changes among users of GRRPV systems.

The observations from the present study regarding the possible presence of the solar rebound effect align with those of prior studies conducted in Australia and Belgium (Boccard & Gautier, 2021; Deng & Newton, 2017). A survey of 928 beneficiaries of Photovoltaic Poverty Alleviation Projects (PPAPs) in China examined post-installation satisfaction and trust in the electricity provider and found that perceived installation quality and the environmental friendliness of solar PV positively impacted PV users' satisfaction (Ding et al., 2021). A

qualitative study covering 350 households in India found high consumer satisfaction post-installation, attributed to savings in electricity costs and the reliable performance of the systems. However, a minority of consumers reported a need to improve maintenance service and technical support, as identified by this study as well.

A section of respondents raised concerns about delays in approvals from electricity distribution companies, which resulted in delays in the installation and commissioning of the systems. Respondents also reported delays in subsidy disbursal, linked to slow, complicated procedures, highlighting the need to expedite and streamline the subsidy disbursal process.

Users experienced minor technical issues during the early operational phase, including inverter tripping, inverter malfunction, battery cooling issues, wiring and connection faults, and meter reading errors. The users noted that most installers addressed these interruptions in due course.

Respondents expressed a strong interest in more space-efficient and affordable panel designs, as well as innovations in cleaning technology, to reduce the maintenance burden on consumers. A large section of respondents reported difficulty with periodic cleaning of PV modules due to limited accessibility, highlighting the need to educate both installers and users to adopt cleaning-friendly, accessible PV structures in future designs.

Many users expressed frustration over the inverter's inability to operate during power outages, as this limitation failed to address their concern about frequent power interruptions in the centralized electricity grid. This problem arose because users were generally unaware of the anti-islanding protocol mandated for grid-tied inverters. Integrating battery storage could resolve this issue, but it would entail additional cost, and users were often not informed of this prior to the installation of the GRRPV system.

4. Conclusion

This qualitative study presents the factors influencing the adoption of grid-connected residential rooftop photovoltaic (GRRPV) systems, consumer satisfaction with financial savings, and post-installation experiences. In the survey, 62% of respondents identified savings on electricity bills due to high electricity prices as the key reason for installing GRRPV systems. High upfront costs, followed by a lack of consumer knowledge and awareness about the technology, installation process, and related policies, are the most frequently reported barriers to adoption. Respondents identified financial viability as both an enabler and a barrier, indicating heterogeneity among respondents and a need for further research across different segments of electricity consumers.

Respondents largely considered the decision to install the GRRPV system to be wise and financially sound, as around 43% of those who provided estimates of monthly bill savings reported achieving a 90% or more reduction in their electricity bills. Many respondents observed a marginal increase in electricity consumption and increased appliance use after GRRPV installation, indicating a potential solar rebound effect facilitated by the lower marginal cost of electricity generated from GRRPV systems.

The study identified several areas where policy and service improvements are needed to enhance consumer satisfaction and sustain long-term adoption of GRRPV systems. First, the subsidy process should be streamlined. Second, communication between the vendor and end-users should be improved, as it has often lacked clarity about the operation of GRRPV systems during power interruptions in the centralized electricity grid.

There is a need for expedited policy delivery and expanding the scope of existing policy frameworks beyond installation by including provisions to safeguard end-users' expectations. Broadening the scope of policies could encourage people to recommend GRRPV technology to others, ultimately promoting its adoption.

4.1 Limitations and future scope:

The study is limited to qualitative, cross-sectional data from mostly urban respondents, which may not represent all consumer segments. Hence, the findings should be interpreted with caution, as they may not be statistically representative of the overall population. Further investigation with a larger sample size, including users in semi-urban and rural areas, is recommended to validate the present findings and gain broader insights.

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