Rethinking Policy: Post-installation Experiences of Grid-connected Residential Rooftop PV Users in India

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***Abstract*—Grid-connected rooftop PV (GRPV) 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. A wide range of research explores the adoption trends of, barriers to, and drivers responsible for the deployment of GRPV systems. However, the post-installation experience of end users remains under-reported. The promotion of GRPV systems assumes particular significance in the global south as the region witnesses the rising electricity demand amid prospective economic growth. This qualitative research study is aimed to understand consumer satisfaction regarding financial benefits, policy delivery, system installation, postinstallation service, and the impact of GRPV systems on consumer electricity consumption. The data for the research was gathered through semi-structured questionnaires administered in two cities and one town in western India. The thematic analysis was performed to identify recurring patterns and themes within the collected data. Key findings from the study revealed the need for streamlining the subsidy disbursal process, pragmatic commitments from service providers, and improvement in the post-sale service offerings. It is observed that significant reductions in electricity bills play a pivotal role in the positive reception of GRPV systems. Geographic disparities in consumer satisfaction with service delivery have been noted, with urban areas reporting higher levels of satisfaction. The users reported minimal or no issues with the technical reliability of GRPV systems. The results underscore the need for expedited policy delivery and expanding the ambit of the existing policy frameworks beyond installation by including provisions to safeguard end users' expectations. Broadening the policy scope could encourage people to recommend the technology to others, ultimately promoting the adoption of PV systems. The research offers insights for policymakers and regulators to make informed decisions and support the development of effective policies for GRPV systems.**

***Index Terms*—Energy Transition, Rooftop Solar, PV Deployment**

1. INTRODUCTION

The share of energy sources in the electricity mix of many countries has rapidly changed since the first decade of the 21st century due to the rising electricity demand and a need to adopt renewable energy technologies (International Energy Agency, 2024). Solar PV systems are popular among all renewable energy technologies due to their cost-effectiveness, stationary structure, and minimal maintenance. The grid-connected rooftop PV (GRPV) systems facilitate on-site electricity generation, reducing the reliance on the grid. Moreover, the GRPV systems offer advantage in densely populated areas by efficiently used existing rooftop space, thereby minimizing the need for extensive land acquisition. Globally, governments are promoting GRPV systems as a part of the energy policy to enhance energy security and increase the share of renewable energy, which offers climate change mitigation.

The adoption of residential GRPV systems is rising due to their potential for renewable energy production and financial savings to consumers. Governments support the adoption of rooftop PV systems by providing subsidies and enabling metering and billing mechanisms. A wide range of research explores the adoption trends of, barriers to, and drivers responsible for the adoption of GRPV systems (Dutt, 2020; Mahadevan et al., 2023). The literature indicates that market forces and economic, social and political factors influence consumer decision-making (Karakaya & Sriwannawit, 2015). Studies have

indicated that economic factors are more important than others (Sommerfeld et al., 2017). The existing literature predominantly focuses on pre-installation motivations, resulting in a limited understanding of the post-installation experiences of a consumer. This research intends to bridge the existing knowledge gap by assessing GRPV consumer satisfaction with financial benefits, policy delivery, system installation, post-installation service, and the impact of GRPV systems on consumer electricity consumption.

The study of post-installation experiences of GRPV consumers is vital for determining the long-term efficacy of GRPV policies and the sustainability of rooftop PV sector by providing feedback about consumer satisfaction, product design and service enhancements, and policy delivery improvement. These results provide actionable insights for informing future policies and encouraging the long-term adoption of rooftop PV systems in line with India's energy transition.

2. METHODOLOGY

The study employs a cross-sectional qualitative research approach to collect data from residential grid-connected photovoltaic (GRPV) system consumers in one town and two cities in western India. The selected approach allows for capturing experiences from urban, semi-urban, and rural consumers. The particulars of towns/cities are presented in Table 1.

Table 1 Particulars of town and cities selected for the survey (Ministry of Home Affairs, 2024)

Sr. No.	Town/City (State)	Population as per the 2011 census	Level of urbanization	Mode of data collection	Number of samples collected
1	Niphad (Maharashtra)	20,249	Rural	In-person survey	6
2	Nashik (Maharashtra)	14,86,053	Semi-urban	In-person survey	9
3	Vadodara (Gujarat)	16,70,806	Urban	Telephonic survey	13

The data was collected in April 2024. A semi-structured questionnaire was developed and administered to a sample of 28 individuals selected through convenience sampling (Devi et al., 2018; Martin & Ryor, 2016). The questionnaire was divided into three key sections: user motivations and initial barriers, experiences with policy and regulatory frameworks, postinstallation service quality, and economic impacts.

Descriptive analysis is used to analyze quantitative data, and a thematic analysis was conducted to identify recurring patterns and themes within the qualitative data. The results are discussed in the subsequent section.

3. RESULTS

While analyzing financial benefits, system installation, and energy consumption behaviors offers insightful findings, consumer feedback regarding policy delivery and post-installation service provides valuable perspectives.

3.1 Financial Benefits

The observations related to the motivation for adopting GRPV systems indicate financial savings being the most common reason across all three regions, with most respondents citing 'reduction in monthly electricity bill' as the reason for adoption. Consumers cited energy independence (reducing reliability on the distribution grid) and the sustainable nature of solar PV technology as other motivations to install GRPV systems. The leading reasons behind consumer decisions to install rooftop PV systems across three localities are shown in Figure 1.

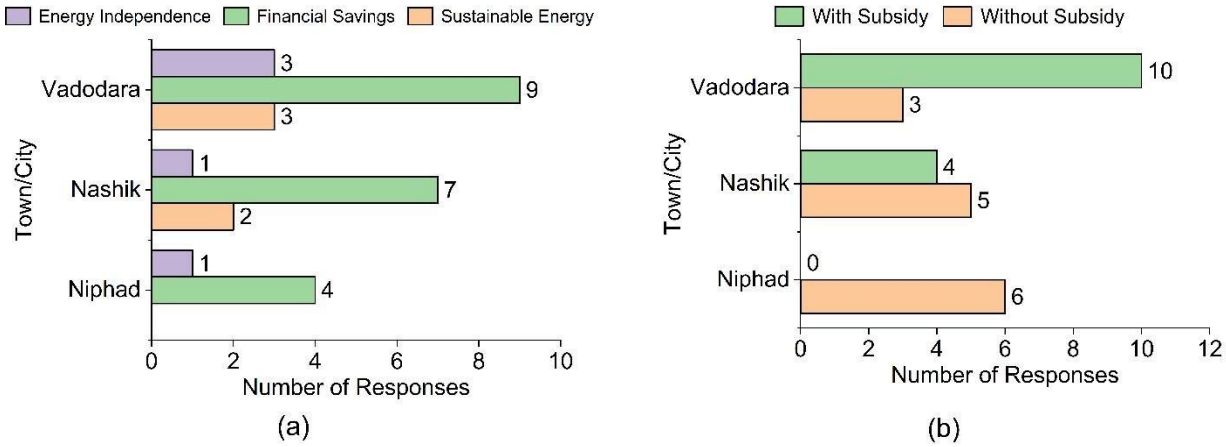

Figure 1 (a) Leading Reasons Behind Consumer Decisions to Install Rooftop PV Systems; (b) Subsidy Status.

This financial motivation was a decisive factor across all three localities, with over 66% of consumers in each locality citing it as the primary reason for installing the GRPV system. While 10 out of 13 consumers in Vadodara claimed to have received the benefit of capital subsidy, none of the respondents in Niphad indicated they received such benefit. The response was mixed for Nashik.

Respondents from Vadodara, Nashik, and Niphad reported average monthly bill reductions of 68%, 87%, and 82%, respectively. The average financial satisfaction is closely correlated with the reduction of bills in each locality. The average financial satisfaction ratings for Vadodara, Nashik, and Niphad were 82%, 95%, and 86%, respectively. The Average monthly bill reduction and financial satisfaction, as reported by respondents, is shown in Figure 2.

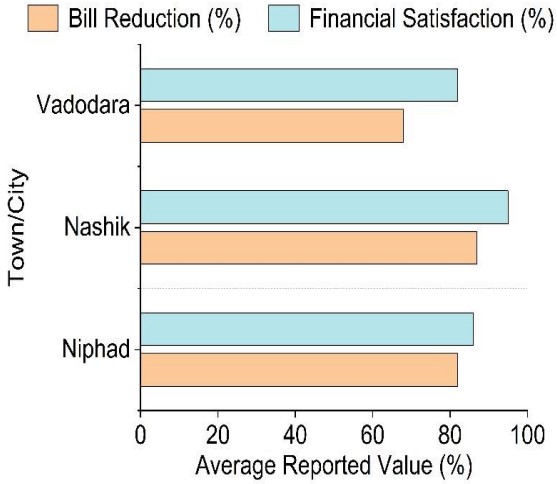

Figure 2 Average monthly bill reduction and financial satisfaction, as reported by respondents

3.2 Policy Delivery

One of the outcome of the study was the disparity in subsidy awareness and utilization between regions. In Vadodara, a well-developed urban area, most respondents had utilized government subsidies to offset the cost of their solar installations. In contrast, Nashik and Niphad residents reported lower engagement levels with subsidy programs. Many consumers in these localities cited slow and complicated processes for receiving subsidies, with some still waiting for their disbursements long after installation, indicating promoting and streamlining the subsidy disbursal process.

The study revealed several areas where policy and service improvements are needed to enhance the long-term adoption and satisfaction with GRPV systems. First, the subsidy process must be streamlined and more user-friendly, particularly in rural areas. There is also a need for more transparent communication among stakeholders, such as communication between vendor and distribution company, which was frequently criticized for its lack of responsiveness and clarity regarding net metering and compensation for excess power generation.

Regarding technological advancements, respondents expressed a strong interest in more spaceefficient and affordable panel designs, as well as innovations in cleaning technology to reduce the maintenance burden on consumers. Finally, consumers called for more reliable off-grid solutions, particularly in areas with frequent grid outages, and suggested that tax incentives for GRPV adoption could further enhance the financial appeal of solar systems.

3.3 Pre- and post-installation services

Respondents in all the localities reported satisfaction with the installation process, including the installation quality and time required to commission the system. Consumers in Niphad reported delays in service delivery and limited access to skilled labor, which may have contributed to the slightly lower satisfaction ratings compared to the Vadodara and Nashik, as shown in Figure 3.

The majority of respondents reported no significant technical issues in the GRPV system's performance, affirming the technology's robustness and efficiency. However, consumers reported dust accumulation on panels and occasional power outages as some of the challenges with the existing setup.

The average rating of vendor post-installation responsiveness remained closely similar (8.2 to 8.3) among all three localities, as shown in Figure 3. In Niphad, respondents were generally satisfied with post-installation services, though some noted frustration with delays caused by the limited availability of local vendors. They expected vendors to fulfill their commitments by providing faster and more reliable solutions to the problems related to the GRPV system.

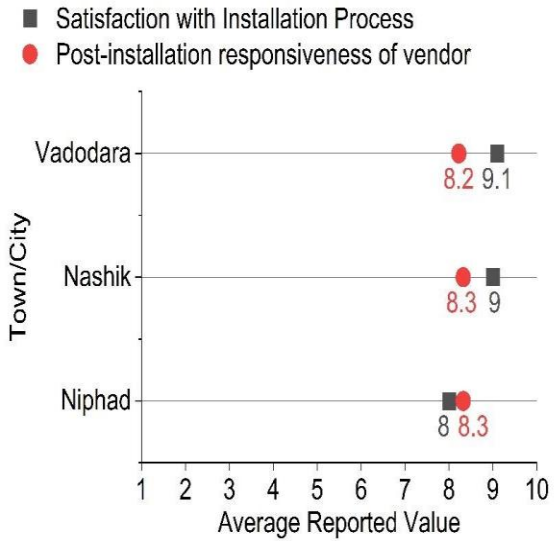

Figure 3 Satisfaction with the installation process and post-installation responsiveness of the vendor

3.4 Changes in Electricity Consumption

The respondents stated that they experienced the rebound effect, wherein their electricity consumption increased after the installation of GRPV systems. This observation is consistent with the presence of the rebound effect, which is documented in the academic literature (Qiu et al., 2019; Toroghi & Oliver, 2019). In both Vadodara and Nashik, several respondents reported increased electricity usage, attributing to the perception that electricity is now less expensive or free due to their solar installations. Some users even noted that they had purchased electric vehicles (EVs) to take advantage of the excess energy generated by their systems, indicating a shift toward eco-friendlier practices enabled by solar energy. Conversely, other respondents became more conscious of their electricity consumption post-installation, particularly in Niphad, where consumers were more conservative in their electricity use despite the presence of GRPV systems.

4. CONCLUSION

This qualitative research studies GRPV consumer satisfaction with financial benefits, policy delivery, system installation, post-installation service, and the impact of GRPV systems on consumer electricity consumption. The survey results, which were conducted in two cities and one town in western India, are presented.

Key observations from the study reveal the need to promote and streamline the subsidy disbursal process, to ensure pragmatic commitment from service providers, and to improve postinstallation service offerings. It is observed that significant reductions in electricity bills play a pivotal role in the positive reception of GRPV systems. Geographic disparities in consumer satisfaction with service delivery have been noted, with urban areas reporting higher satisfaction. The users reported minimal or no issues with the technical reliability of GRPV systems.

The need for expedited policy delivery and expanding the ambit of the existing policy frameworks beyond installation by including provisions to safeguard end users' expectations could be examined by conducting experiments to strengthen the argument. Broadening the policy scope could encourage people to recommend the technology to others, ultimately promoting the adoption of PV systems.

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