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The Last Mile of a Subsidy: Household Frictions in Rooftop Solar Adoption in Karnataka, India: A Qualitative Study

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ABSTRACT

Despite one of India's most progressive distributed solar policy environments and the substantial capital subsidies available under the Pradhan Mantri Surya Ghar: Muft Bijli Yojana (PMSGY), residential rooftop solar adoption in Karnataka remains well below its technical potential. This study examines why adoption stalls between policy and people by analysing the "household friction" that willing consumers encounter across the adoption journey. Using a qualitative exploratory design, semi-structured interviews and questionnaires were administered to 70 households in Karnataka, predominantly in the Bengaluru metropolitan region, comprising 24 adopters and 46 non-adopters, between June and July 2026. Responses were examined through thematic analysis and triangulated with national evidence, principally the CEEW pan-India survey of 17,094 households and a qualitative study of Kerala households. Findings reveal that anticipated complexity substantially exceeds experienced complexity: adopters rated expected complexity at a mean of 5.1 out of 10 before installation but actual complexity at only 2.2 after installation, a 57 per cent reduction. Space and roof-ownership constraints ranked as the leading barrier among non-adopters, followed by information gaps and upfront cost. Environmental concern ranked as the leading motivation among adopters, and 45.8 per cent of adopters reported they would have adopted even without the subsidy, while others described a "subsidy paradox" in which panel restrictions, vendor empanelment, and paperwork diluted the subsidy's value. The paper proposes testable policy interventions to reduce procedural, informational, structural, and perception-related friction in the last mile of subsidy delivery.

Keywords: distributed solar photovoltaics , energy policy, household friction, Karnataka, PM Surya Ghar, rooftop solar, solar subsidy

1. Introduction

India's energy transition has entered a critical phase in which decentralised renewable energy is expected to play an increasingly important role in meeting growing electricity demand, reducing

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carbon emissions, and improving energy security. Among distributed energy technologies, rooftop solar photovoltaic (RTS) systems occupy a unique position because they enable households to become active participants in electricity generation while simultaneously reducing dependence on centralised power systems. Compared with utility-scale renewable energy projects, rooftop solar offers several additional benefits, including reduced transmission and distribution losses, better utilisation of existing built infrastructure, lower land requirements, increased consumer participation, and greater local employment generation in installation and maintenance services [1]. These characteristics have made residential rooftop solar an important element of India's long-term clean energy strategy.

Recognising this potential, the Government of India has introduced a series of policies and incentive mechanisms to accelerate rooftop solar deployment over the last decade. The most significant recent intervention has been the Pradhan Mantri Surya Ghar: Muft Bijli Yojana (PMSGY), launched in February 2024, which combines capital subsidies, concessional financing, digital application processing, and awareness campaigns to promote residential rooftop solar adoption [2]. The scheme has contributed to rapid growth in the sector, helping India reach nearly 11.9 GW of residential rooftop solar capacity across approximately four million households by May 2026 [1]. However, despite this progress, achieving the government's target of ten million solarised households by March 2027 requires substantially faster adoption rates than those currently observed. The challenge facing policymakers is therefore no longer solely one of technology deployment, but of scaling household participation. Although awareness levels of rooftop solar have increased significantly across India, a substantial gap continues to exist between policy availability and household adoption.

The Council on Energy, Environment and Water (CEEW), in one of the largest consumer-side studies conducted on residential rooftop solar in India, found that 57 per cent of surveyed households were aware of rooftop solar, and 26 per cent expressed willingness to consider installation. However, only 5 per cent had initiated the installation process and just 1.4 per cent had completed adoption [1]. These findings reveal a substantial gap between policy availability and consumer action. Rather than simply asking why households are unaware of rooftop solar, attention must shift toward understanding why willing households fail to proceed with adoption.

The existing literature shows that rooftop solar adoption is influenced by a complex interplay of economic, informational, institutional, technical, and behavioural factors. Complementing these findings, Mathew and Pandian's qualitative study in Kerala found that financial barriers, information deficits, technical concerns, and regulatory issues collectively inhibit household adoption despite generally positive attitudes toward solar energy [3]. These barriers do not operate independently but often reinforce one another across the household decision-making process.

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Karnataka provides an especially relevant context for examining this phenomenon. As one of India’s leading renewable energy states, Karnataka has historically promoted rooftop solar through net-metering arrangements and supportive renewable energy policies. Recent regulatory reforms introduced by the Karnataka Electricity Regulatory Commission (KERC) have expanded the concept of rooftop solar into broader Distributed Solar Photovoltaic (DSPV) systems and introduced mechanisms such as Virtual Net Metering (VNM) and Group Net Metering (GNM) to address physical and ownership constraints that often prevent adoption [4]. BESCOM and other distribution companies have also established digital platforms to facilitate applications, approvals, and subsidy processing [5]. Nevertheless, the existence of progressive policy frameworks does not automatically translate into widespread household adoption. Despite these enabling policy measures, residential adoption remains significantly below the state’s estimated technical potential, raising important questions regarding the effectiveness of existing implementation frameworks from the consumer perspective.

This disconnect between policy intent and household behaviour highlights the need to examine rooftop solar adoption through the lens of household friction. Household friction refers to the collection of procedural, financial, informational, technical, behavioural, and institutional obstacles that prevent willing consumers from progressing through the adoption journey. These frictions may include uncertainty regarding subsidy eligibility, lack of knowledge about application procedures, difficulty accessing financing, concerns regarding vendor credibility, net-metering complexity, approval delays, structural limitations of rooftops, and uncertainty regarding long-term performance and maintenance. Even when these barriers appear individually minor, their cumulative effect can significantly discourage adoption. Rather than viewing solar adoption as a simple economic decision, this perspective recognises adoption as a multi-stage process involving awareness, evaluation, financing, application, installation, and long-term use. Each stage introduces potential friction points that can delay, discourage, or completely prevent adoption.

The importance of investigating such frictions has grown with the expansion of government support programmes. Recent policy developments indicate continued efforts to simplify adoption through reforms such as expanded metering options, virtual net-metering frameworks, group net-metering models, and procedural simplifications under PM Surya Ghar. The Ministry of New and Renewable Energy (MNRE) recently introduced a 10 per cent flexibility in approved DC system capacity after reports that rooftop solar applications were being delayed or rejected because of minor mismatches between installed solar panel capacity and inverter ratings [6]. Such examples illustrate how seemingly small administrative or technical requirements can create significant friction in the household adoption journey.

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Against this backdrop, this study seeks to examine why rooftop solar adoption stalls between policy and people in Karnataka. Drawing on both primary household-level research and secondary evidence from national surveys, academic literature, policy documents, and regulatory analyses, the study aims to identify the key friction points that prevent households from progressing from awareness and intention to installation and sustained use.

By focusing on the household experience rather than solely on policy design, this research seeks to contribute to the growing literature on distributed renewable energy adoption and provide actionable insights for policymakers, distribution companies, financial institutions, solar vendors, and local governance bodies. The study positions household friction as a critical explanatory framework for understanding the persistent gap between rooftop solar policy ambition and actual adoption outcomes in Karnataka.

2. Literature Review

The literature demonstrates that rooftop solar adoption is rarely constrained by technology alone. Instead, adoption is shaped by a combination of financial, informational, technical, regulatory, and behavioural frictions. Subsidies and supportive regulations create necessary conditions for adoption, but they do not guarantee installation. The evidence suggests that the most significant challenge lies in converting household willingness into action. Therefore, understanding how households experience the "last mile" of subsidy delivery is essential for designing policies that move beyond availability and toward actual adoption. This insight forms the conceptual foundation for the present study of rooftop solar adoption in Karnataka.

2.1 Rooftop solar as a household-level distributed energy transition

Rooftop solar systems are increasingly understood not merely as a renewable-energy technology, but as a distributed energy transition that shifts households from passive electricity consumers to "prosumers" (producers and consumers). The literature identifies rooftop solar as a critical route to decarbonising electricity demand, reducing grid dependence, improving household energy security, and utilising built urban surfaces for clean energy generation [3].

The environmental and economic benefits associated with rooftop solar have resulted in strong policy support across many countries, including India. India's residential rooftop solar transition has gained new urgency after the launch of the Pradhan Mantri Surya Ghar: Muft Bijli Yojana in February 2024. The CEEW 2026 survey reports that the scheme nearly doubled India's residential RTS growth rate from a CAGR of 45 per cent in 2017–2023 to 85 per cent in 2024–2026, with 11.9 GW installed across about 4 million households as of 31 May 2026 [1]. Nevertheless, residential rooftop solar still accounts for only a small fraction of the country's

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technical potential, suggesting that barriers extend beyond technology availability and financial incentives.

Unlike utility-scale solar, where the state, developers, and utilities drive deployment, residential solar adoption depends on household decisions shaped by awareness, affordability, roof ownership, vendor trust, subsidy procedures, financing access, and post-installation experience. CEEW explicitly argues that consumer behaviour "forms the backbone" of residential RTS adoption, complemented by institutional factors such as DISCOM processes, financing institutions, state nodal agencies, and policy design [1].

2.2 Theoretical perspectives on rooftop solar adoption

The literature applies two behavioural theories to explain household adoption of rooftop solar technologies: the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory.

The Technology Acceptance Model argues that adoption depends primarily on perceived usefulness and perceived ease of use. In the rooftop solar context, usefulness is reflected in expected electricity-bill savings, energy independence, and environmental benefits, while ease of use is determined by installation procedures, financing accessibility, policy clarity, and maintenance requirements.

Diffusion of Innovations theory emphasises the importance of observation, trusted information, peer validation, and communication channels. Since households cannot typically "trial" rooftop solar before committing to installation, they rely heavily on trusted information sources, neighbours, friends, community groups, and successful adopters to reduce uncertainty [1].

The CEEW survey found that government departments and officials were trusted by nearly 71 per cent of unaware households as credible sources of information on new government schemes, and around 70 per cent of unaware households preferred in-person visits as the channel of communication [1]. This finding is highly relevant for Karnataka, where DISCOMs, gram panchayats, urban local bodies, resident welfare associations, and local vendors could act as trusted intermediaries. CEEW similarly finds that satisfied adopters are underutilised conversion assets: more than 90 per cent of adopters reported positive post-installation experience, especially bill savings and system performance, and 87 per cent were willing to recommend their solar vendors [1].

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2.3 Financial barriers to rooftop solar adoption

Multiple studies identify high upfront capital costs, long payback periods, uncertainty regarding return on investment, and limited financing access as major deterrents to household adoption. The Kerala study by Mathew and Pandian found financial concerns to be the most prominent category of barriers identified by respondents [3]. Affordability concerns often outweigh environmental motivations when consumers evaluate rooftop solar investments. The CEEW survey finds that affordability concerns are not necessarily about cost alone, but also about lack of awareness of financing options: among aware but uninterested households who perceived RTS as expensive, 73 per cent were unaware of available financing options [1]. This finding suggests that financial literacy and awareness are often as important as subsidy levels themselves.

The financial attractiveness of rooftop solar is also strongly influenced by policy design. Subsidies under PM Surya Ghar provide up to INR 78,000 for systems of 3 kW and above, significantly reducing initial investment requirements [2]. On the other hand, rising equipment costs associated with domestic content requirements and ALMM regulations may partially offset these benefits for price-sensitive consumers [1].

2.4 Information and awareness barriers

The literature consistently identifies information asymmetry as a major barrier to rooftop solar adoption. Awareness of rooftop solar does not necessarily translate into understanding the practical steps required for adoption. Households often lack information regarding where to apply, system sizing, vendor selection, financing options, subsidy eligibility, application procedures, and net-metering mechanisms. According to the CEEW 2026 survey, while 57 per cent of households were aware of rooftop solar, only 12 per cent knew the first step required to begin adoption; furthermore, 68 per cent of willing but non-initiating households reported uncertainty about how to proceed [1]. This indicates a major gap between awareness and actionable procedural knowledge.

2.5 Technical and structural constraints

A key gap in the rooftop solar literature concerns households that are formally interested but structurally unable to install systems. Technical barriers include insufficient roof space, shading, structural weaknesses, inadequate sanctioned load, grid connectivity limitations, metering delays, and concerns regarding maintenance and performance [3]. Urban areas face particular challenges due to apartment housing, shared rooftops, tenancy arrangements, rented dwellings, and ownership disputes. The CEEW survey reported that roof-space constraints and roof-ownership issues remain significant obstacles, particularly in dense urban environments [1].

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Karnataka’s urban landscape, especially Bengaluru, presents these challenges acutely. Increasing apartment-based living reduces the feasibility of conventional rooftop installations for many households. Karnataka’s 2025 DSPV reforms directly address some of these constraints through virtual net metering and group net metering [4].

2.6 Regulatory and institutional barriers

Regulatory and policy barriers arise when households face complex administrative procedures, uncertain rules, slow DISCOM approvals, net-metering delays, vendor empanelment ambiguity, uncertain subsidy timelines, cumbersome documentation, changing policy frameworks, or inconsistent interpretation of technical requirements.

The CEEW survey reveals that procedural bottlenecks frequently arise during application submission, vendor selection, financing approvals, net-metering approvals, and installation stages. Among households that initiated the adoption process, a majority reported experiencing friction within these intermediate steps: CEEW finds that among households that initiated installation, 59 per cent were stuck in intermediate stages, including application, vendor selection, financing, registration, documentation, and installation [1].

In Karnataka, BESCOM’s DSPV portal shows multiple digital entry points, including PM Surya Ghar, non-subsidy applications, virtual net metering, group net metering, application status, load enhancement, and commissioning or synchronisation [5]. While this indicates institutional readiness, it also raises a research question: do households experience this architecture as streamlined support or as fragmented digital complexity? Recent MNRE interventions further illustrate how institutional processes themselves can create adoption barriers. A July 2026 advisory was issued after applications under PMSGY were delayed because DISCOMs rejected systems with minor mismatches between module DC capacity and inverter AC capacity. The decision to permit a 10 per cent tolerance was intended specifically to reduce procedural delays and regulatory friction [6].

2.7 Trust, social influence, and behavioural factors

Trust also shapes the effectiveness of information dissemination. The literature suggests that direct engagement through government departments, DISCOMs, local institutions, community organisations, resident welfare associations, and peer networks may be more effective than mass communication campaigns alone. The CEEW survey found that nearly 71 per cent of unaware households reported trusting government institutions as information sources, and that in-person communication and peer interactions were viewed as more effective than purely digital outreach methods [1]. Importantly, the CEEW survey reports very high satisfaction levels among existing

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adopters, with over 90 per cent reporting positive experiences and 87 per cent willing to recommend rooftop solar to others [1].

2.8 Karnataka's policy environment: enabling architecture with persistent household friction

Karnataka has historically been a leading state in solar energy and was among the early movers in net metering. Current BESCOM information shows that Karnataka's Renewable Energy Policy 2022–2027 allows grid-connected rooftop solar PV projects under net-metering and gross-metering arrangements, with BESCOM inviting applications from residential, commercial, industrial, educational, and other consumers [7]. BESCOM also provides routes for PM Surya Ghar subsidy applications, non-subsidy applications, virtual net metering, group net metering, load enhancement, application tracking, and commissioning or synchronisation [5].

A major development in Karnataka's policy landscape is the move from conventional "solar rooftop PV" framing toward Distributed Solar PV (DSPV). The Karnataka Electricity Regulatory Commission's 2025 reforms expanded eligible installation surfaces beyond conventional rooftops to include elevated ground-mounted systems, facade-integrated panels, and virtual and group net-metering arrangements [4]. These reforms are intended to democratise access for consumers who lack viable roof space, such as apartment residents, institutional users, and households facing structural constraints.

This policy architecture appears progressive, but the literature suggests that enabling rules do not automatically translate into household adoption. Policy may create formal eligibility, yet people still need understandable processes, trusted vendors, financing clarity, DISCOM responsiveness, and confidence in long-term service quality. Therefore, Karnataka provides a strong case for studying the "policy-to-people" gap: the state has supportive regulations and DISCOM portals, but adoption may still stall at the household interface where policy is experienced as paperwork, uncertainty, cost risk, and procedural delay [4].

2.9 Financial value, subsidy design, and financing awareness

Financial savings are consistently the strongest motivator for household RTS adoption. CEEW reports that 81 per cent of aware households cited reduction in electricity bills as the primary reason that would convince them to consider RTS installation, while only 19 per cent cited environment-friendly electricity as a motivator [1]. This implies that household adoption is primarily driven by perceived private economic value rather than climate or environmental benefits.

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The PM Surya Ghar subsidy design has strengthened this value proposition. The scheme offers central financial assistance up to INR 78,000 for systems of 3 kW and above, and the CEEW report notes that the 3 kW subsidy cap appears to shape system-size decisions, with 52 per cent of adopters choosing 3 kW systems. The subsidy cap remains INR 78,000 despite new ALMM List-II sourcing requirements, although ALMM compliance may increase upfront costs by an estimated INR 3,000 per kW [1].

However, financing awareness remains weak. CEEW finds that financing awareness increases as households move along the adoption journey: 31 per cent among aware-not-interested households, 59 per cent among non-initiator households, and 82 per cent among in-process households [1].

2.10 Low-consumption households

Low-consumption households are another important segment. CEEW finds that 63 per cent of aware-not-interested households fall into the low electricity-consumption category, where affordability concerns may reflect a genuine mismatch between installation cost and expected bill savings [1]. For such households, standard rooftop solar messaging based on immediate bill savings may be less persuasive, and alternative models such as shared solar, utility-led community solar, or bundled welfare-linked installations may be more appropriate.

3. Materials and Methods

3.1 Research design

This study adopts a qualitative exploratory research design to investigate the barriers and frictions influencing residential rooftop solar adoption in Karnataka. The study focuses on understanding the “last mile” of policy implementation by examining the lived experiences of households that have either adopted rooftop solar systems or seriously considered doing so. The study also included households that have not yet adopted rooftop solar in order to understand their awareness, inhibitions, and perceptions. The approach is guided by the premise that adoption decisions are shaped not only by economics and technology but also by perceptions, trust, procedural complexity, and household-specific circumstances. The study uses a household friction framework, viewing rooftop solar adoption as a multi-stage process involving awareness, consideration, initiation, installation, and post-installation experience. Particular attention is paid to points where households encounter obstacles or delays that may discourage adoption despite positive attitudes towards solar energy.

3.2 Study area

The study focuses on households located in Karnataka, with a majority of respondents residing in the Bengaluru metropolitan region. Karnataka was selected as the study location because it has historically been one of India's leading solar-energy states and has introduced several enabling policies for distributed solar generation, including net metering, virtual net metering, group net metering, and Distributed Solar PV (DSPV) reforms [4], [7]. Despite this supportive policy environment, residential rooftop solar penetration remains significantly below its technical potential, making Karnataka an appropriate setting for investigating the gap between policy availability and household adoption. The urban character of Bengaluru also provides a useful context for examining emerging challenges such as apartment living, roof-ownership constraints, shared infrastructure, and household decision-making in dense metropolitan settings.

3.3 Sampling strategy

A non-probability snowball sampling approach was employed. Participants were initially identified through personal networks, family contacts, neighbours, and community connections. These respondents subsequently referred other individuals who had either installed rooftop solar systems or had considered installation. Snowball sampling was considered appropriate because rooftop solar adopters represent a relatively small and specialised population, making random identification difficult within the constraints of the study. A total of 70 households participated in the study; the sample consisted of 24 households that had already installed rooftop solar systems and 46 households that had not (Table 1). While the sample size is small and not statistically representative, qualitative research prioritises depth of understanding rather than statistical generalisation. The objective was to obtain rich descriptions of household experiences and identify recurring themes that may help explain broader adoption patterns.

3.4 Data collection

Data were collected through semi-structured interviews and a structured questionnaire administered between June and July 2026. Semi-structured interviews were used because they provide flexibility to explore household experiences while ensuring consistency across respondents, and they yielded more natural and insightful responses. The instrument covered the following aspects: type of residency; awareness of rooftop solar technology; awareness and perception of the PM Surya Ghar (PMSGMBY) website; awareness and utilisation of the government subsidy scheme; reasons for considering or not considering rooftop solar; expected and actual benefits and concerns; sources of information and advice; perceived and actual complexity of the adoption process; obstacles and frictions faced during the adoption journey; overall experience of the adoption process; and suggestions to make solar adoption easier and

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more widespread. Adopters rated the complexity they expected before installation and the complexity they actually experienced, each on a 10-point scale; non-adopters rated how complicated adoption feels to them on the same scale. Respondents also ranked five common reasons for adoption (adopters) or non-adoption (non-adopters) from 1 (most prominent) to 5 (least prominent).

3.5 Data analysis

The interview data were analysed using thematic analysis. The analysis followed an inductive process involving four steps. Familiarisation: interview notes were reviewed multiple times to identify recurring observations and patterns. Initial coding: statements and observations were coded according to common themes emerging from respondent experiences. Theme development: related codes were grouped into broader categories representing key household frictions. Interpretation: themes were interpreted in relation to existing literature and compared with findings from the CEEW national survey [1] and the Kerala rooftop solar study by Mathew and Pandian [3]. For the ranking questions, ranks were summed across respondents so that a lower total score indicates a more prominent reason. Direct quotations and examples were used where possible to preserve respondent perspectives and reduce researcher interpretation bias. Although the study does not claim statistical generalisability, triangulation with findings from the CEEW national survey and other published research increases confidence in the relevance of the identified themes.

4. Results

The findings from this study reveal that rooftop solar adoption in Karnataka stalls not because households reject the technology, but because friction accumulates at multiple points in the adoption journey from awareness to installation and post-installation experience. Although Karnataka has one of India's most progressive distributed solar policy frameworks, household-level evidence shows that adoption remains constrained by informational gaps, procedural complexity, structural limitations, and perceived financial risk. These findings closely mirror national patterns documented in the CEEW 2026 survey, which found that while 57 per cent of households were aware of rooftop solar, only 5 per cent initiated installation and just 1.4 per cent completed adoption [1]. The qualitative evidence from Karnataka helps explain why this conversion gap persists.

The total sample comprised 70 households: 24 households (34.3 per cent) that have adopted rooftop solar and 46 households (65.7 per cent) that have not (Table 1).

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Table 1. Sample composition (N = 70)

Category	Households (n)	Share of sample (%)
Adopters	24	34.3
Non-adopters	46	65.7
Total	70	100.0

Source: Primary survey and interviews, June–July 2026.

4.1 Importance of the subsidy

Of the 24 adopter households, 4 (16.7 per cent) did not use the subsidy, 9 (37.5 per cent) reported that the subsidy was a major factor in their decision and that they would not have adopted without it, and the remaining 11 (45.8 per cent) reported that they would still have adopted solar without the subsidy (Table 2). The subsidy is therefore decisive for a substantial minority of adopters, but nearly half of the adopters in this sample were motivated strongly enough to have proceeded even in its absence.

Table 2. Role of the PM Surya Ghar subsidy in the adoption decision (adopters, n = 24)

Response	Households (n)	Share (%)
Would not have adopted without the subsidy (subsidy was a major factor)	9	37.5
Would still have adopted without the subsidy	11	45.8
Did not use the subsidy	4	16.7
Total	24	100.0

Source: Primary survey and interviews, June–July 2026.

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4.2 Time taken to receive the subsidy

Twenty of the 24 adopters used the subsidy; of these, 3 were unsure of the time taken. Among the 17 subsidy users who reported a timeline, 6 (35.3 per cent) received the subsidy within one month, 8 (47.1 per cent) within two months, and 3 (17.6 per cent) after more than two months (Table 3). While most subsidy transfers were completed within two months, respondents' accounts in Section 4.4 indicate that the wait for the subsidy was only one of several institutional delays experienced, alongside net-metering approvals and DISCOM processes.

Table 3. Time taken to receive the subsidy (subsidy users reporting a timeline, n = 17)

Time to receive subsidy	Households (n)	Share (%)
Within 1 month	6	35.3
Within 2 months	8	47.1
More than 2 months	3	17.6
Total	17	100.0

Note: A further 3 subsidy users could not recall the timeline and are excluded. Source: Primary survey and interviews, June–July 2026.

4.3 Reasons for solar adoption

Adopters ranked five common reasons for adoption from 1 (most prominent) to 5 (least prominent); ranks were summed across respondents, so a lower total score indicates a more prominent reason. On this measure, environmental concern emerged as the leading reason for adoption, followed closely by long-term cost saving and increasing electricity prices, with the government subsidy fourth and neighbourhood or peer influence a distant fifth (Table 4).

Table 4. Ranked reasons for adoption (adopters; lower total score = more prominent)

Rank	Reason for adoption	Total score
1	Environmental concern	39
2	Long-term cost saving	43

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Rank	Reason for adoption	Total score
3	Increasing electricity prices	44
4	Subsidy from government	50
5	Influence from neighbourhood / friends	74

Source: Primary survey and interviews, June–July 2026.

Non-adopters ranked five common reasons for non-adoption on the same basis. Space availability and roof-ownership issues ranked as the most prominent barrier, followed by lack of information about how rooftop solar works and the perception that the upfront cost is too high (which tied on total score), the perception that the process is too complicated and time-consuming, and finally not finding a need to switch (Table 5). The ordering maps closely onto the barrier categories in the literature: technical and structural constraints, information and awareness barriers, financial barriers, and regulatory and institutional barriers.

Table 5. Ranked reasons for non-adoption (non-adopters; lower total score = more prominent)

Rank	Reason for non-adoption	Total score	Barrier category
1	Space availability problems / roof-ownership issues	72	Technical and structural
2	Not enough information about how it works	87	Information and awareness
2	Upfront cost feels too high	87	Financial
4	Process seems too complicated and time-consuming	97	Regulatory and institutional
5	No perceived need to switch to solar	117	Behavioural

Source: Primary survey and interviews, June–July 2026.

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4.4 Major frictions in solar adoption

Fear of complexity is greater than actual complexity. Across interviews and survey responses, households consistently rated the expected complexity of rooftop solar adoption far higher than the complexity actually experienced by adopters. Before installation, adopters expected a mean complexity of 5.1 on a 10-point scale; after installation, the same households rated the actual complexity at a mean of 2.2, a reduction of 57 per cent (Table 6). Non-adopters' perception of complexity (mean 5.1) closely matches adopters' pre-installation expectations, suggesting that non-adopters anticipate a far more difficult process than adopters actually experience. Respondents' comments reflected this: "less complicated than I thought" and "the whole process was not as complicated".

Table 6. Perceived versus experienced complexity of solar adoption (10-point scale)

Measure	Respondent group	Mean score
Expected complexity before adoption	Adopters (n = 24)	5.1
Actual complexity experienced after adoption	Adopters (n = 24)	2.2
Perceived complexity of adoption	Non-adopters (n = 46)	5.1

Note: 1 = least complicated; 10 = most complicated. The gap between expected and experienced complexity among adopters represents a 57 per cent reduction. Source: Primary survey and interviews, June–July 2026.

Structural barriers in urban Karnataka. The most consistent barrier among non-adopters in Bengaluru was lack of roof access. Apartment residents repeatedly cited shared roof ownership, society approval challenges, limited terrace space, shading from adjacent buildings, and uncertainty about feasibility in multi-storey complexes. Survey respondents remarked: "no idea how it works in an apartment setup"; "space issue — tall buildings around reduce sunlight"; "society approval is difficult"; and "rented apartment — no opportunity to explore".

Financial barriers. Electricity-bill savings were cited as an important motivator for adoption; however, many households expressed confusion about payback periods, ROI calculations, the impact of net metering, long-term maintenance costs, and the effect of changing BESCOM tariffs. Even high-income households expressed hesitation when ROI was unclear, suggesting that financial literacy, not financial capacity, is a limiting factor. Households also mentioned

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high upfront capital costs, long payback periods, uncertainty regarding return on investment, and limited financing access.

Information barriers. Awareness exists, but actionable knowledge does not. A striking pattern across the Karnataka sample is that awareness of solar is high, but awareness of the process is low. Survey responses included "not sure how to start", "unaware of documents required", and "need more clarity on steps". Respondents also provided feedback on the PM Surya Ghar website: some noted that awareness of the website and the scheme needs to be increased, especially in rural areas, while others felt the website lacks clear information about eligibility, cost, timelines, capacity requirements, payback period, warranty, and maintenance.

Institutional delays and procedural barriers. Most respondents were aware of the PM Surya Ghar subsidy, but procedural delays and complications emerged as friction points. Respondents reported: "the BESCOM bill was generated for a few months, but the subsidy was pending"; "it took a long time for the vendor to get all parts"; "getting net metering done from BESCOM was time-consuming and complicated"; "with the government you need enough patience"; and "BESCOM-related processes took a lot of time".

4.5 Other findings

Several additional findings emerged from the interviews and open-ended survey responses. First, respondents described a hidden downside of the subsidy: it restricts households to particular (ALMM-approved) panel types and empanelled vendors, and because choice is restricted, these panels and vendors are sold at higher prices, reducing the effective saving delivered by the subsidy. Second, people trust peers and word of mouth; in villages, respondents reported that people are more influenced by the sarpanch than by government websites. Third, some respondents felt there is limited information available for selecting a vendor ("I did not know which vendor to trust"). Fourth, surplus solar electricity generated by households is procured by BESCOM at a very low unit rate, which respondents felt reduces ROI; however, pairing solar with an electric vehicle changes the economics — some respondents charge their EVs from solar generation, avoiding spending on petrol or diesel.

5. Discussion

The purpose of this section is to interpret the findings of this household-level study in Karnataka and situate them within the broader evidence base. Although the sample size of this study is small and drawn through snowball sampling, the friction patterns observed align closely with large-scale research, particularly the CEEW 2026 survey of 17,094 households [1] and the qualitative Kerala study by Mathew and Pandian [3]. This convergence strengthens the credibility of the findings and suggests that the barriers identified are structural rather than incidental.

5.1 Karnataka households mirror national friction patterns

Respondents in this study frequently cited obstacles such as BESCOM/DISCOM delays, documentation complexity, and uncertainty about net-metering approval wait times. These match CEEW's identification of the same friction points, including application submission, vendor selection, and net-metering approvals [1]. This alignment is important: it indicates that Karnataka's challenges are not random, but part of a broader national pattern. Even motivated households hesitate or drop out, not because they lack interest, but because the adoption pathway is procedurally heavy and institutionally slow. In this sense, the "last mile of a subsidy" is not the subsidy itself, but the institutional interface through which households must navigate to access it.

5.2 Fear of complexity versus actual complexity

Another major finding of this study is the gap between perceived and actual complexity. Before installation, adopters expected a mean complexity of 5.1 out of 10; after installation, the same households rated actual complexity at a mean of only 2.2 — a 57 per cent reduction (Table 6). Non-adopters' mean perceived complexity of 5.1 mirrors adopters' pre-installation expectations, indicating that the fear deterring non-adopters is largely anticipatory rather than grounded in adopters' lived experience. This pattern is consistent with CEEW's finding that over 90 per cent of adopters report a positive experience and 87 per cent would recommend their vendor [1]. The Kerala study also identifies psychological barriers — fear of paperwork, fear of roof damage, fear of hidden costs — as major deterrents [3].

This suggests that rooftop solar adoption is shaped not only by economic or procedural factors but by anticipatory anxiety. In Karnataka, this fear is amplified by fragmented digital portals, multi-step procedures, inconsistent vendor coordination, and the absence of simple unified guidance. The perception of complexity is a barrier independent of actual complexity, and reducing this perception requires communication strategies, not only procedural reform.

5.3 The subsidy paradox

A notable insight from this study is the subsidy's downside. Several adopters reported that the subsidy pushed them toward ALMM-approved panels, which are more expensive; toward empanelled vendors, which had slower service; and toward paperwork that was slow and unclear. A few respondents even chose to skip the subsidy, stating that the paperwork and delays outweighed the financial benefit (4 of 24 adopters in this sample did not use the subsidy). This aligns with CEEW's observation that affordability concerns are often linked not to cost itself but

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to lack of awareness of financing options — 73 per cent of households who find solar "expensive" are unaware of financing pathways [1]. The Kerala study similarly notes that regulatory uncertainty — unclear documentation, inconsistent interpretation of rules, and unpredictable timelines — discourages adoption even when subsidies exist [3].

In Karnataka, the subsidy paradox is intensified by the state's transition to DSPV rules and the introduction of virtual and group net metering. While these reforms expand eligibility, they also introduce new categories, new forms, and new approval pathways. For households, this can feel like "more rules" rather than "more access" [4].

5.4 Trust and peer influence as decisive factors

Across interviews, households repeatedly emphasised trust in vendors, friends, neighbours, and community leaders (including sarpanches in rural areas). This matches CEEW's finding that 71 per cent of unaware households trust government departments and prefer in-person guidance, and that adopters are powerful promoters [1]. The Kerala study also highlights social and psychological barriers, showing that rooftop solar diffusion depends heavily on peer validation because households cannot "trial" the technology before purchase [3]. In Karnataka, this is especially relevant for apartment residents, who face structural constraints and therefore rely on society-level decisions, RWA guidance, and collective trust. This suggests that rooftop solar diffusion in Karnataka is not only an economic or regulatory process but a social learning process, where peer networks reduce uncertainty more effectively than websites or advertisements alone.

5.5 Karnataka's unique friction profile: policy readiness versus household readiness

Karnataka's policy environment is supportive and progressive. BESCOM offers multiple digital routes (PM Surya Ghar, non-subsidy DSPV, virtual net metering, group net metering) [5], and KERC's 2025 reforms expand installation surfaces beyond rooftops [4]. Yet adoption remains below technical potential. This study suggests that the friction profile in Karnataka is shaped by a misalignment between policy readiness and household readiness. Policy offers multiple pathways; households experience them as fragmented. Policy expands eligibility to increase access; households struggle to interpret which option applies to them. Policy emphasises digital processes; households prefer in-person guidance. Policy assumes roof ownership; urban households increasingly live in apartments. Thus, in Karnataka, the translation of policy architecture into household-friendly pathways is itself a distinct friction.

5.6 Divergence from national evidence

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While most findings in this study align with CEEW [1] and the Kerala study [3], two divergences are notable. First, apartment-related constraints received far greater emphasis in this sample. Because the sample includes many urban respondents, apartment residents were over-represented, and many believed rooftop solar "does not apply to apartments" even though DSPV rules allow shared systems — suggesting a communication gap specific to Karnataka's urban context. Second, whereas CEEW finds that 81 per cent of aware households nationally cite bill reduction as the primary motivator and only 19 per cent cite environmental benefit [1], adopters in this sample ranked environmental concern marginally ahead of long-term cost saving (Table 4). This divergence should be interpreted cautiously: the two cost-related reasons (long-term cost saving and increasing electricity prices) scored almost identically to environmental concern and would jointly dominate if combined, and the largely urban, higher-income profile of this snowball sample may over-represent environmentally motivated early adopters. Nevertheless, it indicates that for the segment sampled here, environmental identity is a genuine and rankable motivation rather than an afterthought.

6. Recommendations

The recommendations below are based on the survey findings and suggestions from respondents. They collectively aim to reduce friction across the entire household adoption journey and to accelerate residential rooftop solar adoption under PM Surya Ghar. They are framed as testable interventions for policymakers rather than settled prescriptions.

Reduce institutional friction by standardising and accelerating approvals. Institutional delay — particularly net metering, documentation, and subsidy processing — was a prominent barrier in this study. Policymakers should test whether a standardised, time-bound approval window (for example, 21 days) increases adoption and reduces drop-out rates; whether a single-window digital and in-person support system improves completion rates by reducing confusion and procedural anxiety; and whether automatic net-metering installation after commissioning reduces delays.

Simplify subsidy access and reduce its unintended friction. The subsidy paradox — where subsidy-based financial support itself increases friction — was a distinctive finding. Policymakers should test whether enabling end-users to apply directly for the subsidy (instead of vendor-mediated applications) increases transparency and reduces delays; whether a simplified, step-by-step, checklist-based subsidy form reduces confusion; and whether revising ALMM requirements for residential systems reduces cost anxiety and improves affordability without compromising quality.

Address perception friction through targeted communication. Since fear of complexity was greater than actual complexity in the study sample, policymakers should test whether a “solar is simpler than you think” campaign — using real adopter testimonials, before/after complexity scores, and simple visuals explaining the process — reduces anticipatory anxiety; whether hyperlocal outreach through RWAs, gram panchayats, and BESCOM field staff increases awareness and trust; and whether demonstration sites in apartments and villages accelerate adoption, since rooftop solar cannot be “trialled” and visible installations reduce uncertainty.

Improve financial literacy and strengthen the economic value proposition. Affordability concerns often stem from lack of financing awareness, not cost alone. Policymakers should test whether a standardised “Solar Finance Kit” — including EMI options, payback-period calculators, bill-reduction estimates, and panel cost comparisons — improves decision-making; whether increased partnerships with banks and micro-finance institutions increase financing uptake; and whether models designed for low-consumption households (shared solar, community solar, utility-led solar subscription models) improve perceptions of ROI.

Expand access for apartment residents through DSPV awareness and facilitation. Apartment constraints were the most prominent structural barrier in this Karnataka sample. Policymakers should test whether RWA-level facilitation cells — providing information and training on virtual net metering, group net metering, and shared rooftop systems — increase adoption; whether a dedicated “Apartment Solar Pathway” — including feasibility templates, cost-sharing models, guidance on rooftop ownership, and vendor lists specialising in apartment systems — reduces confusion and increases adoption in apartments; and whether mandating solar readiness — pre-laid conduits, designated solar zones, and rooftop access provisions — in new apartment buildings accelerates long-term adoption.

Leverage peer networks and adopter experience as a conversion engine. Data from this study and from CEEW show that adopters are powerful advocates and promoters [1]. Policymakers should test whether a “Solar Champions” programme — solar open houses hosting demonstrations, guiding neighbours, sharing experiences, and explaining ROI, together with platforms for peer-to-peer information sharing — accelerates adoption; and whether community-based solar workshops involving trained adopters and government officials increase procedural confidence and reduce fear of complexity.

Align policy architecture with household behaviour. Karnataka’s policy environment is advanced, but households often find it fragmented. Policymakers should test whether a unified “Karnataka Solar Adoption Framework” — consolidating PM Surya Ghar, DSPV rules, virtual net metering, group net metering, apartment guidelines, financing options, progress dashboards, and status updates — improves clarity; whether a single-window framework for the entire

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process of solar adoption and subsidy improves acceptance; and whether behavioural nudges — such as highlighting money lost on utility bills over past years or displaying community adoption statistics and maps showing neighbouring homes with solar — increase adoption.

Create a specific task force for rural adoption. Rural regions have limited access to digital media. Policymakers should test whether differentiated approaches and awareness programmes for rural areas increase adoption, and whether working with local rural authorities and leaders (for example, the sarpanch) improves awareness, influence, and trust.

In addition, the following respondent suggestions merit testing by policymakers: providing benefits in direct taxation or property tax for adopters; increasing the subsidy limit beyond the current INR 78,000 cap for larger systems; state-government top-up subsidies (as some other states provide); allowing consumers to select vendors and panels of their choice without restriction; providing higher rates for exported solar electricity; and promoting EV adoption alongside solar to enhance ROI (household electricity, EV charging, induction cooking, and similar uses). Respondents also proposed specific improvements to the PM Surya Ghar website: making it available as a mobile application; making it more intuitive and streamlined; separating information required by prospective adopters from other content and news; providing clearer and simplified information about eligibility, cost, timelines, capacity requirements, payback period, warranty, and maintenance; and using more infographics and visuals for ease of understanding.

7. Limitations and Future Research

Although this study provides meaningful insights into household-level frictions in rooftop solar adoption in Karnataka, several limitations must be acknowledged. These limitations do not weaken the value of the findings; instead, they clarify the scope of the study and point toward future research that can build on this work. First, the sample consists of only 70 households and therefore cannot represent all households in Karnataka; although the study collected numerical data, the sample size was too small for robust statistical inference, and the study therefore emphasises qualitative patterns, not quantitative modelling. Second, snowball sampling may introduce selection bias because respondents are drawn from interconnected social networks. Third, interviews rely on self-reported experiences and recollections, which introduces potential biases — recall bias, subjective interpretation of "complexity", and emotional influence on perceptions of vendors or DISCOMs; however, self-reported experiences are appropriate for friction-based research, where perceptions themselves shape behaviour. Fourth, many respondents were located in or around Bengaluru, limiting the ability to generalise findings to rural Karnataka.

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Despite these limitations, the study provides valuable insights into how households experience rooftop solar adoption and where friction occurs between policy design and implementation. By focusing on lived experiences, it complements large-scale quantitative studies and contributes a household-level perspective to the growing literature on residential rooftop solar adoption in India. Several avenues for future investigation follow from this work: identifying which specific procedural steps create the longest delays; evaluating the effectiveness of DSPV models (virtual and group net metering) for apartment residents; testing how behavioural nudges influence adoption; examining the role vendors play in shaping household decisions; and exploring how rooftop solar adoption differs for small businesses.

8. Conclusion

This study set out to explain why rooftop solar adoption stalls between policy and people in Karnataka. The evidence shows that adoption is not a single decision but a multi-stage friction journey: households hesitate or drop out not because of one barrier, but because multiple small frictions accumulate across awareness, evaluation, financing, application, installation, and post-installation stages. Even households that overcome the first few frictions can be deterred by those that follow. The CEEW national survey indicates that the greatest opportunity lies not in creating demand but in enabling action [1], and the Kerala study confirms that barriers are interconnected and cumulative rather than isolated [3]. In Karnataka, the "last mile of a subsidy" is therefore not the subsidy itself but the household experience of navigating policy, procedures, and the associated friction points. The shortfall in adoption relative to potential does not indicate unwillingness; rather, the pathway from willingness to installation is filled with small, persistent frictions — and it is these frictions, more than the level of financial support, that policy must now address.

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