Power on the Roof: Reviewing Rooftop Solar Adoption in India

Saithu Mohammed., P. Maheswari

Faculty of Management, SRM Institute of Science and Technology, Kattankulathur

DOI: https://doi.org/10.51584/IJRIAS.2025.100900041

Received: 27 September 2025; Accepted: 03 October 2025; Published: 12 October 2025

ABSTRACT

Rooftop solar (RTS) represents a critical component of India's clean energy transition, offering decentralized generation, reduced transmission losses, and potential resilience benefits. Yet, despite ambitious national targets and substantial technical potential, RTS adoption has lagged behind expectations. This narrative review synthesizes peer-reviewed literature (2019–2025), government program documents, and policy reports to examine the trends, barriers, enablers, economics, regional signals, stakeholder outcomes, and policy implications shaping rooftop solar adoption in India. Findings indicate that commercial and industrial consumers have historically dominated the sector due to favorable tariffs and access to credit, while residential uptake accelerated only after the launch of flagship initiatives such as PM Surya Ghar. Persistent barriers include high upfront costs, affordability gaps, regulatory uncertainty, procedural delays, information asymmetries, and built environment constraints. At the same time, innovations such as simplified subsidy pipelines, digitalized approval portals, DISCOM performance incentives, vendor certification, and emerging business models including RESCO/OPEX and group or virtual net metering demonstrate viable pathways to expand adoption. The review identifies future research needs in program evaluation, financial innovation, grid integration, apartment governance, and quality assurance, and emphasizes the importance of stable regulatory frameworks, inclusive finance, and community-oriented models.

Keywords: Rooftop solar, Renewable energy, Adoption barriers, Business models, Policy innovation, India

INTRODUCTION

Rooftop solar (RTS) systems represent one of the most promising pathways for India to achieve its clean energy and decarbonization goals. By generating power closer to the point of consumption, RTS not only reduces electricity bills for households and firms but also minimizes transmission and distribution losses, thereby improving overall grid efficiency [2]. In addition, RTS offers resilience benefits by diversifying energy sources and reducing dependence on centralized fossil-fuel-based generation.

Despite these advantages, rooftop deployment has lagged behind expectations. While utility-scale solar witnessed exponential growth after 2015, enabling India to emerge as a global leader in large-scale renewable capacity, the rooftop segment fell significantly short of the ambitious 40 GW target set for 2022 under the National Solar Mission [2]. Recognizing this shortfall, policymakers initiated a series of post-2022 reforms, including enhanced subsidy structures, performance-based incentives for distribution companies (DISCOMs), and digitalized application processes. These interventions, along with the launch of flagship programs such as the PM Surya Ghar: Muft Bijli Yojana, have contributed to renewed momentum in the residential sector [7].

Nevertheless, adoption remains highly uneven across states, consumer classes, and urban forms. Variations in state-level regulatory frameworks, differences in credit access, and heterogeneity in built environments shape the pace and scale of RTS diffusion. For example, while states such as Gujarat and Maharashtra have recorded substantial growth, others continue to face persistent barriers in financing, consumer awareness, and utility engagement [7].

This review synthesizes recent empirical and policy evidence to examine the enablers and constraints shaping RTS adoption in India. By systematically analyzing financial mechanisms, regulatory structures, stakeholder roles, and regional case experiences, the paper identifies the structural drivers of adoption and highlights emerging innovations. Finally, it outlines a forward-looking research and policy agenda to guide the effective scaling of rooftop solar as a key pillar of India's energy transition.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

Policy And Regulatory Landscape

A. National Programs

The Ministry of New and Renewable Energy (MNRE) has implemented several flagship initiatives to accelerate rooftop solar (RTS) deployment. The Grid-Connected Rooftop Solar Programme (Phase II) was an early intervention that provided central financial assistance for residential consumers and introduced performance-based incentives to align distribution companies (DISCOMs) with installation targets. While uptake under this scheme was moderate, it laid the foundation for subsequent reforms [3].

In 2024, the government launched the PM Surya Ghar: Muft Bijli Yojana, representing a major policy milestone in India's clean energy transition. Targeting one crore households by 2027, the scheme incorporated an integrated digital portal to streamline application processes, standardized subsidies to reduce ambiguity, and collateral-free loans to address affordability concerns [6]. Early evidence suggests that these reforms significantly reduced transaction barriers and triggered a surge in applications and installations, particularly in the residential segment.

B. Metering and Tariff Structures

Metering frameworks are central to the economic attractiveness of RTS. Net metering, which allows consumers to offset consumption with rooftop generation, continues to be the most decisive factor influencing household payback periods. The Electricity (Rights of Consumers) Rules, 2020, mandated net metering for systems up to 500 kW, bringing greater uniformity. However, several states adopted variations such as net billing and gross metering for larger capacities, creating regulatory uncertainty and inconsistent financial returns [3].

Recent innovations, such as group net metering and virtual net metering, are gradually being introduced to address constraints in apartments and shared-roof contexts. Yet, their operationalization remains uneven across states, with only a handful demonstrating effective implementation [7]. This heterogeneity underscores the need for harmonized regulatory frameworks that balance DISCOM concerns with consumer incentives.

C. State-Level Regulations and Discom Incentives

State-level regulations play a decisive role in shaping adoption outcomes. Decisions on capacity caps, interconnection procedures, and consumer eligibility vary widely, producing contrasting adoption patterns across regions. Evidence indicates that when DISCOMs are offered performance-linked incentives and clear service benchmarks, application approval timelines shorten, consumer experiences improve, and system reliability increases [8].

Conversely, states without such alignment often face systemic challenges, including long delays in site inspections, limited meter availability, and procedural bottlenecks. These frictions create consumer dissatisfaction and discourage prospective adopters [1]. The contrast highlights that effective policy design must not only focus on subsidies but also on institutional incentives and accountability mechanisms for DISCOMs, which remain the most critical intermediaries in rooftop solar diffusion.

Adoption Trends

Rooftop solar adoption in India has historically been concentrated in the commercial and industrial (C&I) sector, where higher electricity tariffs, larger rooftop availability, and greater access to institutional credit created favorable economic conditions. By contrast, the residential segment remained marginal through the early 2020s despite capital subsidies, primarily due to affordability constraints, limited credit access, and lower levels of consumer awareness [8, 2]. The cumulative effect of these structural barriers was a slow pace of residential diffusion; even as C&I users drove steady expansion in the overall rooftop segment.

A major shift occurred in 2024 with the launch of the PM Surya Ghar: Muft Bijli Yojana, which combined substantial central subsidies with streamlined digital processes, vendor empanelment, and performance-based incentives for distribution companies. This intervention catalyzed residential adoption across multiple states, with Gujarat and Maharashtra registering the most significant growth, aided by their relatively mature regulatory

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

frameworks and supportive state-level programs [6]. Nonetheless, India's cumulative rooftop capacity by early 2025 was estimated at only 16.3 GW, well below both the 40 GW target initially set for 2022 and the technical potential of over 200 GW [3].

The geographical distribution of adoption remains highly uneven. Five states, Gujarat, Maharashtra, Rajasthan, Kerala, and Tamil Nadu, account for nearly 70 percent of all rooftop capacity, underscoring the concentration of diffusion in particular regions [7]. Gujarat stands out for its aggressive Surya Gujarat program, which enabled the state to account for more than 60 percent of India's cumulative residential rooftop capacity by FY2022 [1]. By contrast, several populous states such as Uttar Pradesh and Bihar have continued to lag due to limited policy innovation, bureaucratic bottlenecks, and weaker vendor ecosystems [9].

The South Indian states present a particularly instructive case in the diversity of adoption trajectories. Tamil Nadu has historically emphasized utility-scale solar projects, but rooftop adoption has grown only modestly, with urban centers such as Chennai and Coimbatore leading deployment. Regulatory charges and intermittent policy uncertainty have constrained wider adoption, although recent announcements, including a plan to install 10 GW of solar capacity by 2030, signal greater commitment to distributed systems [4]. Karnataka has witnessed more substantial C&I adoption, particularly in Bengaluru's technology parks and industrial estates, though household uptake remains limited. The state has begun piloting virtual net metering models for multi-tenant buildings, yet these remain in their infancy [7].

Andhra Pradesh has prioritized utility-scale solar parks such as the Kurnool Ultra Mega Solar Park, while rooftop systems remain underdeveloped. Initiatives targeting agricultural feeders and public institutions have emerged, but residential adoption continues to face challenges related to awareness and procedural delays [8]. Telangana, meanwhile, has recorded moderate growth, especially in institutional and educational buildings around Hyderabad, though overall diffusion is constrained by limited installer networks and slower uptake in peri-urban and rural areas [7]. Kerala represents a distinct case. Despite relatively high consumer awareness, the state faces structural constraints such as small roof sizes, shading, and monsoon-heavy conditions that reduce effective generation potential. The Kerala State Electricity Board's SOURA program, which installs and manages rooftop systems directly on consumer premises, represents an innovative model aimed at overcoming consumer hesitancy. Yet qualitative evidence suggests that households remain concerned about long-term maintenance and reliability, which continues to dampen adoption despite favorable attitudes [5].

In synthesis, while residential adoption has accelerated under recent national programs, rooftop solar in India remains unevenly distributed and heavily reliant on state-level policy and institutional capacity. Western states such as Gujarat and Maharashtra continue to lead, while South Indian states illustrate the heterogeneity of adoption pathways: Tamil Nadu and Karnataka demonstrate stronger C&I diffusion, Kerala highlights the promise and pitfalls of utility-led programs, and Andhra Pradesh and Telangana remain in earlier stages of household-level adoption. The emerging literature underscores that the alignment of central subsidies with stable state regulatory frameworks, coupled with improved DISCOM incentives and consumer outreach, will be critical to expanding adoption beyond current hotspots [7, 2].

Barriers to Adoption

The literature consistently identifies a set of interlinked financial, regulatory, procedural, informational, and structural barriers that constrain the widespread diffusion of rooftop solar in India. Although the nature and severity of these barriers vary across consumer segments and states, together they create a persistent gap between technical potential and realized capacity.

A. Finance and Affordability

High upfront costs remain the most significant obstacle for residential households. Even after accounting for central financial assistance and state-level subsidies, many low- and middle-income consumers report affordability gaps, often due to limited access to low-interest or collateral-free credit [1]. For small and medium-sized enterprises (SMEs), balance sheet constraints and heightened contract risk under third-party models such as renewable energy service company (RESCO) agreements exacerbate financing challenges [8]. While concessional loans and capital subsidies have reduced payback periods to more attractive ranges, survey evidence indicates that cost remains the most cited deterrent to adoption among prospective household users [1].

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

B. Regulatory Uncertainty and Charges

Policy and regulatory instability are another critical barrier. Frequent shifts in net-metering thresholds, the imposition of additional grid support charges, and capacity caps tied to sanctioned load or distribution transformer limits increase perceived investment risk and discourage both households and businesses from committing to rooftop solar [3]. The C&I segment, in particular, has faced disincentives when favorable net-metering arrangements were replaced with less attractive net-billing or gross metering models. Such regulatory uncertainty not only undermines investor confidence but also complicates financial planning and contract negotiations [7].

C. Procedural Frictions

The process of securing rooftop solar installations is frequently hampered by bureaucratic and logistical inefficiencies. Empirical studies highlight delays in application approvals, shortages of bi-directional meters, inspection backlogs, and inadequate coordination among utility staff as common pain points [1]. These frictions contribute to consumer frustration and can erode trust in both distribution companies and government-led schemes. The resulting uncertainty increases the likelihood of drop-offs between initial application and final commissioning, limiting the impact of otherwise well-designed subsidy programs.

D. Information and Trust

Information asymmetries and consumer perceptions further inhibit adoption. Households often lack reliable knowledge about installation costs, subsidy entitlements, procedural requirements, and the long-term maintenance needs of rooftop systems. Misconceptions about roof damage, structural integrity, and technical complexity persist, particularly in states where demonstration projects are limited [5]. Qualitative evidence indicates that even among consumers aware of the financial benefits, doubts about installer credibility and post-installation service quality constrain uptake [1]. Trust deficits in both vendors and utilities therefore remain a central barrier, especially in the residential sector.

E. Built Environment Constraints

Finally, the built environment imposes structural limitations on feasible capacity. Shading from vegetation or adjacent buildings, limited rooftop space, and the prevalence of rental housing reduce the number of households able to install viable systems. In urban areas, high-rise apartments and shared roofs present particular challenges, since technical and legal frameworks for allocating rooftop generation are underdeveloped [7]. While models such as group or virtual net metering offer a potential pathway for multi-tenant buildings, these remain at an early stage of experimentation and adoption in most states.

Taken together, these barriers demonstrate that rooftop solar diffusion in India is not constrained by technological feasibility but by a combination of affordability, regulatory consistency, institutional efficiency, and consumer confidence. Addressing these bottlenecks will be central to achieving the ambitious targets set under the PM Surya Ghar program and subsequent state-level initiatives.

Enablers and Program Innovations

While the barriers to rooftop solar adoption in India remain significant, recent programmatic innovations have introduced a series of enablers that are beginning to shift adoption dynamics. These enablers operate at multiple levels, policy design, institutional incentives, market development, and consumer engagement, and collectively demonstrate the importance of integrated approaches to distributed renewable energy.

One of the most effective enablers has been the move toward simple, slab-based subsidy structures. Under the PM Surya Ghar: Muft Bijli Yojana, households are offered transparent and predictable subsidy amounts, linked to system size, thereby reducing confusion and variability in vendor quotations. The simplicity of this design lowers decision-making costs for consumers and helps mitigate distrust that often arises from opaque subsidy calculations [6].

The establishment of digital portals has also proven transformative. By integrating the processes of application,

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

vendor empanelment, inspection scheduling, meter provisioning, and grievance redress, these platforms minimize transaction costs and reduce dropout between application and commissioning. Evidence suggests that streamlined digital pipelines not only accelerate installations but also enhance transparency by allowing consumers to track their applications and payments in real time [6].

Another critical innovation lies in the introduction of performance-linked incentives for distribution companies (DISCOMs). Historically, DISCOMs were reluctant to support rooftop solar due to concerns over revenue erosion. By linking central incentives to DISCOM performance on parameters such as timely application approvals and verified system commissioning, policymakers have created a mechanism that aligns utility interests with consumer adoption [8]. This institutional realignment is widely regarded as essential to scaling decentralized solar.

Program designs have also emphasized the importance of vendor empanelment and quality assurance. Requiring vendors to meet minimum technical standards, undergo training, and provide after-sales service guarantees addresses the consumer trust deficit that has long constrained residential adoption. Standardized contracts and warranties, coupled with the public disclosure of vendor ratings on national portals, further reinforce accountability and consumer confidence [6].

Finally, credit access for households and micro, small, and medium enterprises (MSMEs) has emerged as a key enabler. Policies promoting collateral-free loans, concessional interest rates, and credit guarantees are helping to extend adoption beyond wealthier households and large firms. These financial mechanisms lower the upfront burden and distribute costs across predictable repayment schedules, making rooftop solar more inclusive and socially equitable [8].

Taken together, these programmatic enablers represent a shift from fragmented, subsidy-only approaches to integrated policy architectures that recognize the interplay of financial, institutional, and informational constraints. By simplifying consumer choices, aligning utility incentives, strengthening vendor ecosystems, and expanding financial access, India’s recent programs provide a replicable model for distributed renewable energy deployment in other emerging economies.

Economics And Business Models

The economics of rooftop solar in India are shaped not only by capital costs, tariffs, and subsidies, but also by the choice of business model through which systems are deployed. Three principal models dominate the Indian context: consumer-owned capital expenditure (CAPEX), third-party owned operating expenditure (OPEX/RESCO), and collective or virtual arrangements. Each model distributes costs, risks, and benefits differently across households, businesses, utilities, and developers.

A. CAPEX (Ownership)

The CAPEX model remains the most common approach for residential consumers and is also used by a subset of commercial and industrial (C&I) adopters. Under this model, the consumer makes the upfront investment, typically using savings, bank loans, or government-subsidized financing, and retains full ownership of the rooftop system. When coupled with stable net-metering policies, CAPEX systems generate substantial lifetime savings by offsetting high grid tariffs and enabling export credits. However, adoption under CAPEX is highly sensitive to the expected payback period. Empirical analyses show that when policy interventions such as subsidies or concessional loans reduce the payback horizon into the four-to-six-year range, adoption rates increase significantly [8]. For many households, however, the upfront capital requirement remains prohibitive, underscoring the importance of complementary financing instruments.

B. OPEX/RESCO (Third-Party)

The OPEX or RESCO model transfers ownership and operational responsibility to a third-party developer, who installs and maintains the rooftop system and sells electricity to the consumer through a long-term power purchase agreement (PPA) or lease. This model substantially lowers entry costs for consumers and shifts performance and maintenance risk to the developer, making it particularly attractive to C&I consumers with

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

large and predictable loads. Indeed, the majority of OPEX deployments in India to date have been concentrated in the C&I sector, where system sizes are sufficiently large to justify developer interest and creditworthiness is relatively higher [8]. By contrast, the residential segment has seen limited OPEX penetration due to small system sizes, higher transaction costs, and consumer credit risk. Scholars and policy analysts have argued that the expansion of this model to small enterprises and apartment complexes would require standardized PPAs, streamlined contractual procedures, and mechanisms such as credit guarantees to mitigate counterparty risk [8].

C. Collective and Virtual Models

More recent innovations include collective and virtual deployment models, designed to address the constraints of shading, limited rooftop space, and tenancy. Group net metering allows the generation from a single rooftop system to be apportioned across multiple consumer accounts, while virtual net metering enables consumers to subscribe to a share of an off-site solar installation and receive credits against their electricity bills. Community solar projects and utility-aggregated offerings fall within this category, pooling demand and spreading both costs and benefits across multiple participants. These models have been piloted in states such as Delhi and Uttarakhand, and they are particularly relevant for high-density urban areas and apartment housing, which dominate the built environment in many Indian cities. However, the successful scaling of such models requires clear and transparent settlement rules, robust metering infrastructure, and consumer protection frameworks to safeguard participant rights and ensure equitable distribution of benefits [7].

Collectively, these business models illustrate the diversity of pathways through which rooftop solar can be deployed in India. While CAPEX continues to dominate the residential landscape, OPEX models are crucial for scaling in the C&I segment, and collective and virtual approaches represent a frontier for expanding adoption into urban and rental-dominated housing markets. Policy alignment that supports all three models, through subsidy design, credit facilitation, and regulatory clarity, will be essential to broaden access and accelerate rooftop solar deployment nationwide.

Regional Case Signals

State-level experiences in India highlight the diversity of approaches to rooftop solar adoption and underscore the importance of aligning incentives, institutional capacity, and consumer engagement. Gujarat, Maharashtra, Kerala, and Uttar Pradesh provide illustrative examples of distinct trajectories.

Gujarat remains the benchmark for residential rooftop solar adoption. Through its Surya Gujarat program, the state combined generous state-level subsidies with central financial assistance, offering 40 percent support for systems up to 3 kW and 20 percent for larger residential units. This was complemented by streamlined procedures, a robust vendor empanelment system, and active outreach campaigns by distribution companies. The result was outsized residential additions: by FY2022, Gujarat accounted for more than 60 percent of India’s cumulative residential rooftop capacity, demonstrating the effectiveness of transparent subsidies, simplified approvals, and a competitive installer ecosystem [7].

Maharashtra presents a contrasting pattern. The state has seen substantial uptake in the commercial and industrial (C&I) segment, where high tariffs and large load profiles supported strong economic returns. However, its trajectory also illustrates the risks of regulatory instability. The introduction of additional grid charges and net-billing provisions dampened investor confidence and slowed new adoption, particularly in the residential sector. Although Maharashtra retains one of the highest cumulative rooftop capacities, policy volatility has been associated with significant fluctuations in annual additions, suggesting that stable regulatory frameworks are as critical as favorable economics for sustained growth [7].

Kerala represents an innovative but mixed case. The SOURA initiative launched by the Kerala State Electricity Board (KSEB) allowed the utility to lease consumer rooftops for solar generation, an approach designed to align utility and consumer interests. The state also introduced interest rate rebates on solar loans to improve household affordability. Despite these measures, adoption has been tempered by persistent informational and maintenance-related concerns. Qualitative evidence suggests that households remain wary about roof integrity, after-sales service, and the reliability of installer networks, even while expressing positive attitudes toward solar energy in

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

principle [5]. Kerala's experience underscores the importance of coupling innovative utility-led models with stronger consumer assurance mechanisms.

Uttar Pradesh illustrates the difficulties of scaling rooftop solar in price-sensitive and less urbanized markets. Despite being India's most populous state, its rooftop adoption has lagged considerably. Scholars identify a combination of policy gaps, implementation bottlenecks, and weak stakeholder coordination as major constraints [9]. Building an enabling ecosystem outside metropolitan areas remains a critical challenge. Recent efforts have included the launch of a dedicated rooftop solar portal and campaigns under the PM Surya Ghar scheme, which signal attempts to overcome these structural disadvantages. Nevertheless, the case of Uttar Pradesh highlights that affordable technology and subsidies are insufficient without parallel investments in vendor capacity, consumer outreach, and post-installation services.

Together, these regional cases demonstrate that rooftop solar adoption in India is shaped as much by subnational institutional choices and local ecosystem strength as by national policy frameworks. Gujarat exemplifies the potential of combining clear subsidies with market depth, Maharashtra highlights the destabilizing effect of regulatory volatility, Kerala shows the promise and limitations of utility-led approaches, and Uttar Pradesh underscores the importance of ecosystem development in markets beyond urban centers.

Stakeholders and User Outcomes

The experience of rooftop solar adopters in India reveals both the promise and the limitations of current program design. Households and C&I users consistently report high satisfaction with reductions in electricity bills and the technical performance of installed systems. However, evaluations also show lower satisfaction with the broader service experience, particularly in relation to utility processes, subsidy disbursements, and after-sales support. This divergence suggests that while the economic rationale for rooftop solar is compelling, gaps in customer service and institutional responsiveness remain a critical drag on adoption [1].

Vendors play a central role as the "last mile" of policy implementation. Their ability to deliver timely installations, maintain quality standards, and guide consumers through application procedures directly shapes adoption outcomes. Evidence indicates that structured interventions, such as training programs, installer certification, and predictable subsidy reimbursement cycles, help sustain vendor quality and consumer trust. Without these measures, risks of system underperformance, misinformation, and reputational damage to the sector increase.

The role of distribution companies (DISCOMs) is undergoing a notable transition. Historically perceived as reluctant gatekeepers due to concerns over revenue erosion and grid management, DISCOMs have increasingly shifted toward becoming active partners in rooftop solar diffusion. This change has been facilitated by performance-linked incentives, the integration of service standards into regulatory frameworks, and the digitization of approval pipelines. When financial and operational incentives are aligned, DISCOMs are more willing to streamline application approvals, ensure timely metering and grid connections, and support grievance redressal mechanisms [8].

Overall, the relationship between adopters, vendors, and DISCOMs illustrates that rooftop solar diffusion is not only a matter of technology and policy design but also of service ecosystems. Enhancing user outcomes requires systematic investment in vendor capacity and consumer protection, coupled with the institutional alignment of distribution companies to facilitate, rather than obstruct, adoption.

Research Gaps and Future Agenda

Despite significant progress in rooftop solar adoption, important research gaps remain that limit both scholarly understanding and policy design. One area requiring deeper investigation is the causal evaluation of specific program features. While policy briefs often highlight the role of DISCOM incentives, digital application portals, and grievance redressal mechanisms, there is little rigorous evidence on their direct effects in converting applications into commissioned projects. Controlled or quasi-experimental studies could shed light on which design elements most effectively reduce procedural frictions and accelerate adoption.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

Another important frontier lies in the domain of finance innovations. Current evidence on concessional loans and subsidies suggests affordability gaps persist, especially among low- and middle-income households and small and medium enterprises. Yet systematic evaluations of interest subvention schemes, credit guarantees, or on-bill financing mechanisms remain scarce. Future studies should examine not only repayment performance but also broader welfare outcomes, including impacts on household energy security and small business resilience.

Grid integration is also an underexplored research area. The expansion of rooftop solar raises pressing technical questions about feeder-level hosting capacity, voltage fluctuations, and load balancing. More empirical work is needed on the role of smart metering, time-of-day tariffs, and distributed storage in enhancing the stability and cost-effectiveness of grid operations while scaling rooftop capacity.

A fourth gap concerns the apartment and collective housing market, which represents a large but underutilized segment of India's urban energy landscape. While models of group net metering and community solar have been piloted, little is known about the governance mechanisms, cost-sharing arrangements, and consumer protections that can enable wider adoption in multi-family dwellings. Comparative case studies across states could provide valuable insights into effective institutional designs.

Finally, there is limited empirical evidence on quality assurance and system performance. Concerns over warranty compliance, installer credibility, and real-world generation performance continue to hinder trust among prospective adopters. A stronger evidence base that integrates installer grading systems, warranty enforcement mechanisms, and transparent access to generation data could play a pivotal role in reducing perceived risk and sustaining consumer confidence.

Implications For Policy and Practice

The evidence from India's rooftop solar experience highlights several implications for both policy design and implementation practice. A first priority is the stabilization of regulatory frameworks. Frequent shifts in net-metering rules, settlement timelines, and grid charges have undermined investor confidence and slowed diffusion. Establishing durable and transparent net-metering provisions, alongside enforceable service standards for utilities, would provide the predictability necessary for households, firms, and financiers to commit to rooftop solar investments at scale.

Equally important is the simplification and reliability of financial support. Subsidy mechanisms have been central to household adoption, but their impact is maximized when disbursements are simple, timely, and predictable. Predictability reduces consumer hesitation and enhances vendor liquidity, both of which are critical for sustaining adoption momentum. Partnerships between DISCOMs, financial institutions, and vendors can further expand access to credit, reduce procedural frictions, and address balance-sheet risks that constrain small enterprises and middle-income households.

At the state level, program design should broaden its focus to include collective and community-oriented models, particularly in the context of urban apartments and rental housing. Group net metering and utility-aggregated offerings represent viable solutions for consumers otherwise excluded by roof or tenancy constraints. Effective governance and consumer protections will be essential to ensuring their credibility and scalability.

Therefore, adoption is not only a question of affordability and regulation but also of social acceptance and behavioral change. Targeted awareness campaigns, neighborhood-level demonstrations, and transparent dissemination of performance data can help convert latent interest into actual installations. By aligning regulatory stability, financial accessibility, programmatic innovation, and consumer engagement, India can accelerate rooftop solar adoption in a manner that is both socially inclusive and operationally sustainable.

Limitations

This review is based on a synthesis of peer-reviewed studies, government reports, and program documents available through early 2025. While the evidence provides a comprehensive overview of adoption drivers, barriers, and outcomes, several limitations must be acknowledged. First, rooftop solar policy in India is highly

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

dynamic, with frequent revisions in net-metering rules, subsidy structures, and state-level program operations. As such, the insights presented here may not fully capture subsequent regulatory changes or emerging programmatic innovations. Second, the available literature is uneven across states and consumer segments, with a disproportionate focus on a few leading states such as Gujarat and Maharashtra. Finally, as this is a narrative rather than a systematic or meta-analytic review, it emphasizes breadth and synthesis over statistical aggregation. Practitioners and policymakers are therefore advised to verify the most current regulations and contextual factors before drawing operational or investment decisions from this analysis.

CONCLUSION

India's rooftop solar sector stands at a pivotal juncture in its energy transition. While adoption has accelerated in recent years, particularly with the launch of PM Surya Ghar and state-level programs, deployment continues to fall short of the country's ambitious targets and its substantial technical potential. The review highlights that adoption has been concentrated among C&I consumers with access to capital and favorable tariffs, while residential uptake, though growing, remains constrained by affordability, information gaps, and regulatory uncertainty.

Barriers such as high upfront costs, inconsistent metering rules, procedural bottlenecks, and limited consumer awareness continue to impede wider diffusion. At the same time, a set of enabling innovations, including simplified subsidy pipelines, digitalized approval systems, vendor certification, and DISCOM performance incentives, demonstrates pathways to overcoming these obstacles. Emerging business models, from collective net metering to third-party ownership, offer further promise in addressing built environment and credit-related constraints, especially in urban and small enterprise contexts.

Regional case signals suggest that rooftop adoption flourishes when states combine predictable policies, streamlined processes, and broad-based ecosystem support. Conversely, abrupt regulatory shifts or weak service delivery can erode confidence and stall momentum. For India to realize the full potential of rooftop solar, policy must move toward stability, inclusivity, and institutional alignment, while vendors and utilities strengthen their roles as facilitators rather than obstacles.

Looking forward, research and practice must focus on evaluating program design, innovating in finance, integrating rooftop systems into smart grids, and ensuring quality assurance. These directions are critical not only for scaling rooftop adoption within India but also for offering replicable lessons to other emerging economies pursuing distributed renewable energy transitions. By aligning regulatory clarity, consumer trust, financial innovation, and institutional incentives, rooftop solar can become a cornerstone of India's sustainable, decentralized, and equitable energy future.

ACKNOWLEDGEMENT

This study was supported by funding from the Indian Council of Social Science Research (ICSSR), New Delhi, India.

REFERENCES

1. [Adesh B. D., R. R. Gajjar, and P. Shah, "Assessing consumer adoption and awareness of rooftop solar integration: A case study of the distribution system," International Journal of Environmental Sciences, vol. 11, no. 23S, pp. 2041–2054, 2025.]
2. [Gulia J., V. Garg, and A. Thayillam, "Rooftop solar lagging: Why India will miss its 2022 solar target," IEEFA Report, 2022.]
3. [Gulia J. and V. Garg, "The impact of the 10-kW net metering limit on India's rooftop solar market," IEEFA Report, 2021.]
4. [Institute for Energy Economics and Financial Analysis, "India's rooftop solar outlook: Overcoming policy and financing barriers," Briefing Note, 2024.]
5. [Mathew T. C. and S. N. Pandian, "Unveiling the shadows: A qualitative exploration of barriers to rooftop solar PV adoption in residential sectors," Clean Energy, vol. 8, no. 5, pp. 218–228, 2024. doi:10.1093/ce/zkad066]

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

6. [Ministry of New and Renewable Energy, "PM Surya Ghar: Muft Bijli Yojana – Targeting 1 Crore Solar Installations by 2027," Press Information Bureau, Govt. of India, Dec. 5, 2024.]
7. [Patil A., K. Ramesh, and B. Tyagi, "How are Indian states enabling rooftop solar adoption? Analysing subnational policies and regulations," CEEW, 2025.]
8. [Sarangi G. and F. Taghizadeh-Hesary, "Rooftop solar development in India: Measuring policies and mapping business models," ADBI Working Paper 1256, 2021.]
9. Tiwari A., R. K. Mall, and M. Rupakheti, "Upscaling residential solar rooftop in Uttar Pradesh: Review of policy, practices and stakeholders' perspective," SSRN, 2025.