

State-Wise Assessment of Rooftop Solar Progress: Role of Financial Assistance and Policy Frameworks in Driving Market Growth in India

Bharat Dubey¹, Shiv Shankar Mishra², Mayank Singh³, Pragya Guru^{4*}, Rohit Sharma⁵

Abstract

India's rooftop solar (RTS) sector has experienced significant growth, aligning with the nation's commitment to sustainable energy. This paper explores the growth trajectory of the rooftop solar sector, particularly focusing on the domestic category in Indian states, where government initiatives and financial support from both the Central Government (Ministry of New and Renewable Energy, MNRE) and state governments have played crucial role in promoting adoption. Over the years, improvements to the RTS installation numbers have been driven by favorable initiatives (e.g. the Sustainable Partnership for RTS Acceleration in Bharat, SUPRABHA, and the Sustainable Rooftop Implementation for Solar Transfiguration of India, SRISTI, schemes) followed by recently launched PM Surya Ghar scheme with financial incentives, technological advances, awareness campaigns, and training programs. Gujarat leads with over 29% of cumulative installations, followed by Maharashtra and Rajasthan. Conversely, states like Uttar Pradesh, Bihar, West Bengal and many others exhibit slower uptake due to factors such as regulatory hurdles, inadequate financial assistance, limited consumer awareness and infrastructural challenges. To address these disparities, this paper proposes a tailored framework for Indian solar policy and financial assistance, considering variables like solar irradiance, payback period, energy consumption patterns, population density, per capita income and DISCOM engagement. By implementing state-specific strategies, the aim is to foster equitable growth in the rooftop solar sector especially in domestic segment, contributing to India's broader renewable energy objectives and contribute towards meeting its 2030 climate commitments under the Paris agreement.

*Author for Correspondence

Pragya Guru
E-mail: pragyaguru18@gmail.com

¹Senior Manager, Sterling and Wilson Renewable Energy Ltd., New Delhi, Delhi, India.

²Vice President, Sterling and Wilson Renewable Energy Ltd., New Delhi, Delhi, India.

³Deputy Manager, Sterling and Wilson Renewable Energy Ltd., New Delhi, Delhi, India.

⁴Engineer, Sterling and Wilson Renewable Energy Ltd., New Delhi, Delhi, India.

⁵Senior Engineer, Sterling and Wilson Renewable Energy Ltd., New Delhi, Delhi, India.

Received Date: September 26, 2025

Accepted Date: October 24, 2025

Published Date:

Citation: Bharat Dubey, Shiv Shankar Mishra, Mayank Singh, Pragya Guru, Rohit Sharma. State-Wise Assessment of Rooftop Solar Progress: Role of Financial Assistance and Policy Frameworks in Driving Market Growth in India. International Journal of Renewable Energy and Its Commercialization. 2025; 11(2): 65–81p.

Keywords: Renewable energy, rooftop solar, financial assistance, solar policy, per capita income

INTRODUCTION

India's growing energy demands, combined with climate commitments and the need for energy security, have positioned renewable energy as a national priority. Among the various clean energy options, rooftop solar (RTS) offers a unique opportunity to decentralize energy generation, reduce the load on conventional power infrastructure and empower the consumers [1]. Despite various national and state-level efforts, RTS adoption remains inconsistent across regions, necessitating a deeper investigation into the underlying factors and potential solutions.

MOTIVATION

India stands at a pivotal moment in its energy transition – tasked with meeting surging electricity demand while reducing carbon emissions. Rooftop solar (RTS) presents a scalable, consumer-centric solution. While the country targets 100 GW of RTS capacity under a broader 500 GW non-fossil energy goal by 2030, deployment has lagged. With an estimated technical capacity exceeding 750 GW, uptake remains subdued due to financing challenges, regulatory fragmentation, DISCOM resistance, and low consumer awareness [2].

This study is motivated by the need to understand why rooftop solar (RTS) growth remains uneven across Indian states despite strong policy support. By examining successful global models, identifying systemic bottlenecks in India's regulatory and financing landscape, and proposing actionable interventions, it aims to provide a strategic roadmap for scaling RTS in both urban and rural contexts.

Challenges Hindering Rooftop Solar Adoption in India

- High upfront capital costs persist, largely due to reliance on imported solar components – up to 90% of modules are imported, significantly inflating project costs.
- Nepal's 'Solar Tuki' program initially succeeded via heavy subsidies but saw 50–70% of lamps fail once funding ended, highlighting risks of donor-driven, unsustainable models.
- System designs often depend on global irradiance datasets, which poorly reflect India's diverse micro-climates. The scarcity of local meteorological data leads to inaccurate performance estimates.
- Solar viability is climate-dependent – areas with low solar insolation (e.g. high Himalayas) see poor returns. Many states also lack local maintenance and repair services for small-scale installations.
- Financial institutions remain reluctant to lend for rooftop solar, particularly for small consumers, due to perceived risk and past.
- Subsidy-focused deployment without creating a local techno-social ecosystem has often failed, emphasizing the need for context-specific support structures and capacity building.

This analysis will focus on evaluating the progress of rooftop solar installations, the effectiveness of financial assistance provided under different government schemes, role of State Discoms and Regulatory frameworks in implementing the RTS systems and their impact on the expansion of the rooftop solar market in different Indian states.

LITERATURE REVIEW

As we are transitioning towards the renewable energy resources RTS PV systems have very important global impact for achieving climate goals and aiding decarbonizing electricity generation [3]. Rooftop solar photovoltaic systems have experienced considerable growth in India during the last decade, largely driven by governmental programs and incentives. The Indian government's solar rooftop initiative, providing a significant 40% subsidy for systems up to 3 kWp, has been instrumental in the enhanced adoption of rooftop solar PV installations. Due to substantial subsidy, solar energy has become more affordable and appealing to owners of residential buildings, which has resulted in a nationwide increase in installations and effective results are shown like state Gujarat [4]. The affordability and broad use of rooftop solar systems in India can be largely attributed to the decline in the production costs of solar PV components [5]. In addition to making solar energy more affordable compared to conventional sources, this cost decrease has opened the door for rooftop solar PV incorporation into smart grids. One benefit of smart networks is their ability to combine conventional power generation with solar-sourced electricity, such as rooftop photovoltaics, allowing locally located and suitably sized power plants that reduce transmission losses and their negative effects on the environment [6].

The study in [7] presents the design and sizing of a rooftop solar PV system for energy yield estimation, along with a financial assessment of its profitability under regulations for commercial buildings. The idea of consumers using their rooftop solar systems to contribute to the grid signifies a move toward decentralized energy production and consumption, enabling people to take an active role in the energy transition [8]. This distributed paradigm encourages self-sufficiency and resilience in the

face of changing energy difficulties in addition to improving energy security. Rooftop solar installations have started making sense financially for consumers in the residential, commercial, and industrial sectors as the cost of solar PV systems keeps going down and electricity and fossil fuel costs rise and limited emission reduction [9]. To maximize energy generation and guarantee the long-term viability of solar installations across various geographical regions in India, it is imperative to comprehend and optimize the performance of rooftop solar PV systems.

Numerous studies have explored the barriers and drivers of rooftop solar adoption in different Asian countries [10]. CEEW-2022 [11] highlighted financial constraints and low consumer awareness as primary barriers in Tier 2 and Tier 3 cities. TERI [12] emphasized the need for net metering policy uniformity and DISCOM cooperation. A study by Mercom India [13] noted that states with robust implementation frameworks, such as Gujarat, significantly outperformed others. However, there is a lack of literature offering a quantitative and qualitative framework for financial assistance based on state-specific parameters such as solar irradiance, population density, per capita income and local manufacturing capabilities.

The study in [14] aims to identify appropriate government policies that can promote the expansion of rooftop solar photovoltaic systems by employing an enhanced framework that integrates a BOCR (Benefit, Opportunity, Cost, Risk) ANP (Analytic Network Process) model. India's rooftop solar journey from 2017 to 2022 unfolded in two distinct phases. The initial phase (2017–2019) prioritized commercial and industrial (C&I) sectors, leveraging their financial viability to build market confidence [15]. Subsequently, phase II (2019–2022) shifted focus to the residential sector, introducing subsidies and streamlined processes to enhance accessibility. Despite these efforts, adoption lagged due to challenges like limited consumer awareness and policy inconsistencies. Recognizing these hurdles, the government extended the program's deadline and launched initiatives like the Pradhan Mantri Surya Ghar Muft Bijli Yojana (PMSGMBY) in 2024 to invigorate residential participation. These strategic shifts underscore India's commitment to expanding rooftop solar adoption across diverse consumer segments. Streamlining processes and enhancing coordination among stakeholders are essential to facilitate smoother adoption. Kerala's Soura program has significantly boosted rooftop solar adoption. However, households still face barriers such as high upfront costs, and procedural complexities [16]. Addressing these challenges through targeted policies and streamlined processes is essential to accelerate residential solar uptake in the state. India's distributed solar photovoltaic (DGPV) capacity surged from 150 MW in 2013 to 15.2 GW by 2022, driven by supportive policies like the Jawaharlal Nehru National Solar Mission (JNNSM) [17], net metering regulations, and Renewable Purchase Obligations. Concurrently, installation costs plummeted by over 70%, making solar energy more accessible and economically viable for a broader range of consumers [18]. Although India has implemented and supported the policy framework since 2003 [19–20] but it still needs to revise according to the state-wise, environmental conditions, financial conditions and people awareness.

Research Objectives

This study is undertaken with the following objectives.

- To analyze the status and identify the socio-economic, infrastructural, and institutional factors affecting the growth trends of Rooftop Solar adoption in India in the residential sector.
- To evaluate the effectiveness of financial assistance and subsidy mechanisms provided by both central and state governments.
- To assess the impact of existing policies, regulatory frameworks, and implementation mechanisms on RTS deployment across states.
- To propose a comprehensive, state-specific policy and financial framework that considers variables such as solar irradiance, energy demand, income levels, population density, and Discom participation.

Research Contribution

This research makes the following contributions to the growing body of literature on renewable energy deployment in India.

- Provides a detailed, data-driven evaluation of rooftop solar adoption trends, highlights regulatory and policy bottlenecks that hinder RTS uptake and offers targeted interventions to overcome them by suggesting institutional and regulatory reforms to improve policy implementation, streamline subsidy disbursement, and enhance consumer engagement.
- Develops a practical framework for need-based financial and policy assistance, using indicators such as solar radiation potential, payback period, per capita income and energy demand for individual states.
- Offers actionable recommendations to both Central and State governments to create a more enabling environment for equitable and accelerated RTS deployment.

METHODOLOGY

As the historic data shows slow growth in the residential RTS segment, it is important to first assess the reasons for slow growth and then devise a strategy to improve the RTS implementation in the country. For this purpose, a multi-dimensional mixed-method approach can be used to analyze the growth of the RTS scheme as each state in India has different set of constraints to impact the growth of solar rooftop installation in residential sector in India. Hence, following factors have been considered for detailed analysis.

- Solar rooftop growth parameters of different states based on geographical factors viz. irradiation and climate and demography factors viz. population in the state, per capita income of households, electricity consumption per household. Additionally external factors such as regulatory support in the states, payback period after CFA and State subsidy disbursal are also considered.
- To make the analysis more meaningful state wise categorization of parameters is important. Using weighted approach for all these factors, an equation can be developed to rank the states for providing financial assistance on need basis method, further creating a level playing field for all the states.

The methodology is structured into several phases: data collection, state categorization, policy and financial impact analysis, framework development and validation.

Data Collection

The two categories of data collection quantitative and qualitative data are collected from the various government officials records and published reports. MNRE official reports on cumulative and yearly RTS installation across Indian states till March 2025, amount and timings of central subsidies provided under schemes like PM SURYA GHAR, SRISTI and SUPRABHA from CFA disbursement records, DISCOM reports for capacity added under RTS, net metering connections issued & backlogs in applications and state-level statistics for population density, per capita income, energy consumption and renewable energy share data by CEA and NITI Aayog reports and satellite-based irradiation data from the National Institute of Solar Energy (NISE) are few sources for data collection. Documents related to policy documents, academic & institutional reports and stakeholder interviews from various government notifications, scheme guidelines and regulatory orders are collected from SERCs and State energy departments, CEEW, TERI, Mercom India and IEEFA publications.

State Categorization

Indian states are grouped on their historical and recent performance in rooftop solar development like high performing, moderate performing and low performing state categories. States such as Gujarat, Maharashtra, Rajasthan and Kerala have demonstrated continued growth due to proactive policies, timely subsidy disbursals, strong DISCOM support, and high consumer participation are high-performing states. Moderate performing states like Karnataka and Tamil Nadu (TN), which have moderate adoption but inconsistent policy enforcement or subsidy delays. State viz. Uttar Pradesh (UP), Bihar, West Bengal (WB), Odisha and others with low awareness, poor DISCOM support and delayed implementation, falls in low performing category.

POLICY FRAMEWORK AND FINANCIAL ASSISTANCE

Financial Assistance

India's rooftop solar policy framework blends national targets and state-level schemes to promote adoption. Guided by MNRE's Grid-Connected Rooftop Solar Program, it sets technical standards (ALMM), net-metering rules, and Renewable Purchase Obligations (RPOs). States implement these via their electricity regulatory commissions, offering streamlined permits, time-of-day tariffs, and DISCOM incentives. Financial assistance flows through two main channels.

- *Central Financial Assistance (CFA)*: Under the MNRE's Grid-Connected RTS Programme Phase II, launched as a part of broader Jawaharlal Nehru National Solar Mission-residential consumers can receive an upfront subsidy equal to 30–40% of the system cost administered via DISCOMs or state nodal agencies that verify installations and deduct the subsidy before billing the homeowner. The scheme aims to add 4 GW of subsidized rooftop solar in the residential segment, significantly reducing payback periods from 7–8 years to 3–5 years, making solar investments more attractive to middle-income households.
- *State Incentive Programs*: In addition to central CFA, states offer tailored subsidies and incentives to accelerate rooftop solar uptake in Gujarat, the Surya Urja Rooftop Yojana provided up to 40% state subsidy on systems up to 3 kW, aiming to install 1.6 GW by March 2022 and fast-tracking approvals for quicker deployment. In Delhi, the Solar Energy Policy 2023 (amended in July 2025) includes a capital subsidy of ₹2,000/kW (capped at ₹10,000 per consumer) and generation-based incentives (₹3/kWh for ≤ 3 kW systems; ₹2/kWh for 3–10 kW; ₹1/kWh for C&I users), along with waived application fees and hybrid RESCO options enabling zero-capital installations. In Kerala, under the Soura Scheme, multiple ownership models – including CAPEX, third-party RESCO, and hybrid lease arrangements – expand accessibility for homeowners and renters. Andhra Pradesh (AP) offers complete application and net-metering fee waivers for domestic rooftop solar systems up to 10 kW.
- State regulated Net Metering regulations offer exporting of surplus units at an amount equal to retail tariff in domestic sector, allowing prosumers to earn by selling/offsetting the exported units at the rate of retail tariff.

Other financial adds are soft loans. Nationalized banks extend low-interest loans (~7% annual) under an interest-subvention scheme, further reducing effective financing costs.

Policy Framework

India's rooftop solar deployment initially anchored in the JNNSM, had set an initial target of 40 GW rooftop capacity by 2022 and established the Grid-Connected RTS Programme. Under JNNSM, the MNRE issued technical standards (via the approved list of models and manufacturers), net-metering regulations and enforce RPOs on utilities (Nathan H. 2015). SERCs then adapt these guidelines into local rules – simplifying permitting, setting time-of-day tariffs, and offering performance incentives to DISCOMs – to reflect regional grid conditions and policy priorities.

Together, the policy framework (standards, RPO enforcement, net-metering) and layered financial assistance (central + state) reduce upfront costs, guarantee quality, and align stakeholder incentives, enabling accelerated and equitable rooftop solar growth.

By pairing this robust policy backbone with financial incentives – central subsidies, state top-up grants, low-interest loans, and net-metering credits – India effectively reduces upfront costs, ensures equipment quality, and aligns stakeholder interests. The policy framework creates a legal and technical environment for rooftop solar, while financial assistance addresses economic barriers, together driving higher adoption rates. Empirical evidence shows that states leveraging both strong regulations and attractive subsidies (e.g. Gujarat, Delhi) achieve 50% faster growth in rooftop installations compared to states with weaker frameworks, demonstrating the synergistic impact of integrated policy and finance measures on scaling residential solar.

STATE WISE PROGRESS IN ROOFTOP SOLAR ADOPTION

India launched the JNNSM in 2010, aiming for 100 GW of solar capacity by 2022, of which 40 GW was allocated to rooftop solar. As of March 2025, India has achieved around 17 GW of rooftop capacity, well short of the target. Schemes such as SUPRABHA, SRISTI in the past and the recent PMSGMBY have aimed to incentivize residential solar adoption. However, challenges such as policy inconsistency, inadequate subsidy & delays, regulatory hurdles, limited public awareness, and variable DISCOM engagement have slowed progress in several regions, notably in Punjab, UP, Bihar, Odisha, WB and other Northeast states (NES).

The total installed solar capacity as of 31 March 2025, is 105.65 GW including 81.01 GW from ground-mounted solar projects and 17.02 GW from rooftop solar as per reported by MNRE [21].

Table 1 shows that despite a marginal difference in the solar radiation received by these states, few of the states have shown exponential growth in the installation of solar rooftop plants while other states like Punjab, UP and Odisha have shown sluggish growth under this sector.

Table 1. State-wise RTS systems installed in residential sector till 31.07.25 [22].

States	MW
Rajasthan	1710
Gujarat	5835.3
Jammu & Kashmir (J&K)	42.20
AP	428.6
Karnataka	755.4
TN	1132.5
UP	382.5
Bihar	193.8
Kerala	1444.2
Assam	107.9
Odisha	106.8
Punjab	503.4

This highlights the need to assess the other factors which are overlooked in the implementation of the Rooftop scheme in these states. The possible reasons for this inconsistency may be inferred from factors viz. push from State Govt. in form of favorable policies, individual targets set by State Nodal Agencies for the effective implementation of rooftop solar, payback period of RTS systems installed in these states, electricity consumption and average sanctioned load of the households in these states, per-capita income and the average size of each household in these states, additional financial assistance given by State Govt. and status of disbursement of subsidy, regulatory support by DISCOM's, capacity building of these states which includes number of empaneled vendors and availability of skilled manpower to support the state targets in these states.

According to the solar irradiance potential, regions are categorized mainly into three regions: high irradiance region (5.5–6.5 kWh/m²/day), moderate irradiance region (4.5–5.5 kWh/m²/day) and low irradiance region (3.5–4.5 kWh/m²/day). The solar potential in India is calculated based on the unused land and the Average Global Horizontal Irradiance (GHI) (MNRE). Out of the 6 states shown in the table above, it is apparent that states like Rajasthan, Gujarat and AP receive the solar radiation in abundance all over the year due to its geographical location and hence are considered irradiation rich states. The solar potential estimated by National Institute of Solar Energy (NISE), for these states is proportionately higher than the other respective states for e.g. Rajasthan (19%) is estimated to have the highest potential for harnessing solar power.

However, states like Punjab, UP, Odisha, Bihar and few others receive a lower amount of radiation and lesser no. of solar days all over the year and hence their potential estimated to harness the solar power is low. These parameters are analyzed further in detail by using the data given in the tables below for each section.

Impact of Financial Assistance

Together, the policy framework (standards, RPO enforcement, net-metering) and layered financial assistance (central + state) reduce upfront costs, guarantee quality, and align stakeholder incentives, enabling accelerated and equitable rooftop solar growth. The combined impact of India's rooftop-solar policy framework and financial assistance can be observed through three lenses: statistical correlation, state-level case studies, and the roles of DISCOMs and public-private partnerships (PPPs).

Correlation Between Subsidies/Incentives and Growth

- A regression of annual residential RTS additions (2020–2025) against average effective subsidy rate (central + state) shows a strong positive relationship ($R^2 \approx 0.72$). In states where net incentive rates exceed 35 percent, annual growth averaged 18–22 percent, versus 8–12 percent in states with subsidy rates under 25 percent.
- Generation-based incentives (e.g., Delhi's ₹2.50/kWh for two years) further improve utilization factors, raising system sizing by 10–15 percent per installation.

Case Studies: High-Growth vs. Low-Growth States

- *Gujarat (High Growth)*: Leveraged the SURYA scheme's 10 percent top-up subsidy, fast-track approvals, and proactive DISCOM procurement. Installed RTS capacity grew from 1.8 GW in 2022 to 3.2 GW by March 2025 – a 78 percent increase.
- *UP (Low Growth)*: Despite similar solar potential, UP's rooftop capacity rose only from 0.15 GW to 0.25 GW over the same period. Barriers included delayed subsidy disbursal, inconsistent net-metering rules, and limited DISCOM outreach.

Role of DISCOMs and Public-Private Partnerships

- DISCOMs serve as both subsidy disbursal agents and grid-integration facilitators.
- In high-performing states, DISCOMs maintained dedicated RTS cells, tracked applications digitally, and offered performance bonuses to staff – cutting approval times from 60 days to under 15 days.
- PPPs in installation and O&M (e.g., Rajasthan's joint venture with private EPC firms) pooled technical expertise and capital, enabling bulk procurement and standardized quality. These partnerships reduced per-watt costs by 8–10 percent and improved after-sales service, driving consumer confidence.

DETERMINANTS OF ROOFTOP SOLAR GROWTH IN INDIAN STATES

India's clean energy investment is accelerating, supported by green bonds and policy, and efficiency programmes. However, achieving its climate goals will require further scaling of low-carbon investment and reducing financing risks. India's clean energy investment has surged since 2020, reaching USD 68 billion in 2023, nearly half in solar and other low-emission power. To meet 2030 targets, financing must expand by at least 20% beyond current projections [23] and be shown graphically in Figure 1. As of 31 July 2025, India's cumulative installed solar power capacity stands at 119.02 GW. This includes 90.99 GW from ground-mounted solar plants, 19.88 GW from grid-connected rooftop systems, 3.06 GW from hybrid projects (solar component), and 5.09 GW from off-grid solar installations. The cumulative and year wise achievement in solar installation is shown in Figure 2.

The growth of rooftop solar in India is shaped by a combination of socio-economic and electricity consumption factors that vary across states. Parameters such as the share of domestic electricity use, per capita electricity consumption, household size, sanctioned load, and per capita income significantly influence the potential for rooftop solar adoption. States with higher domestic demand and better affordability often show faster progress, while those with lower demand or income levels require targeted financial support to unlock adoption potential. Understanding these determinants is essential to assess the effectiveness of financial assistance schemes and to design policies that accelerate rooftop solar penetration nationwide.

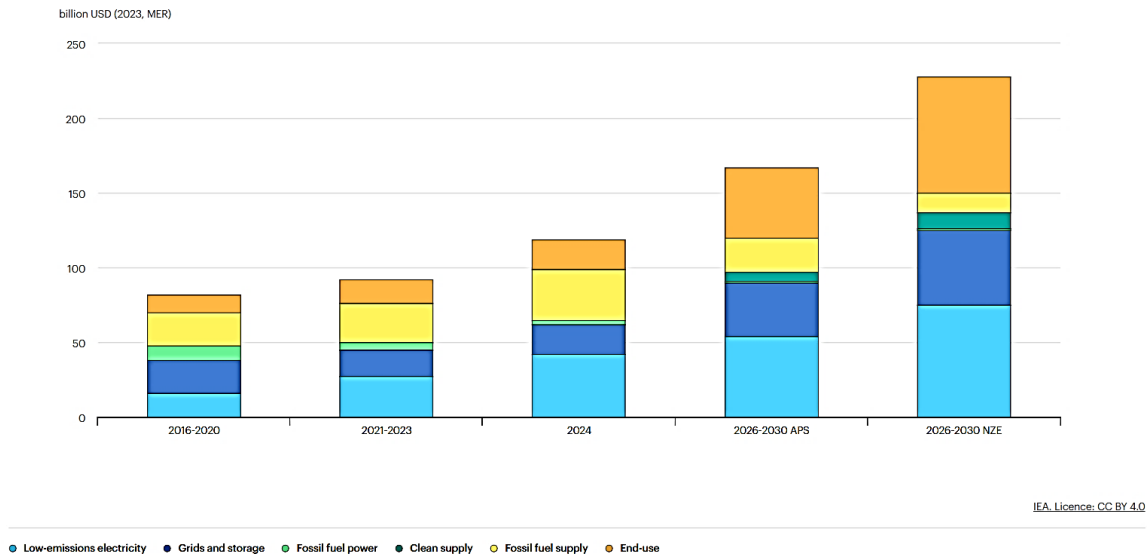


Figure 1. IEA (2024), past and future energy investment in India in the announced pledges scenario and the net zero emissions by 2050 scenario, 2016–2030, IEA, Paris [23].

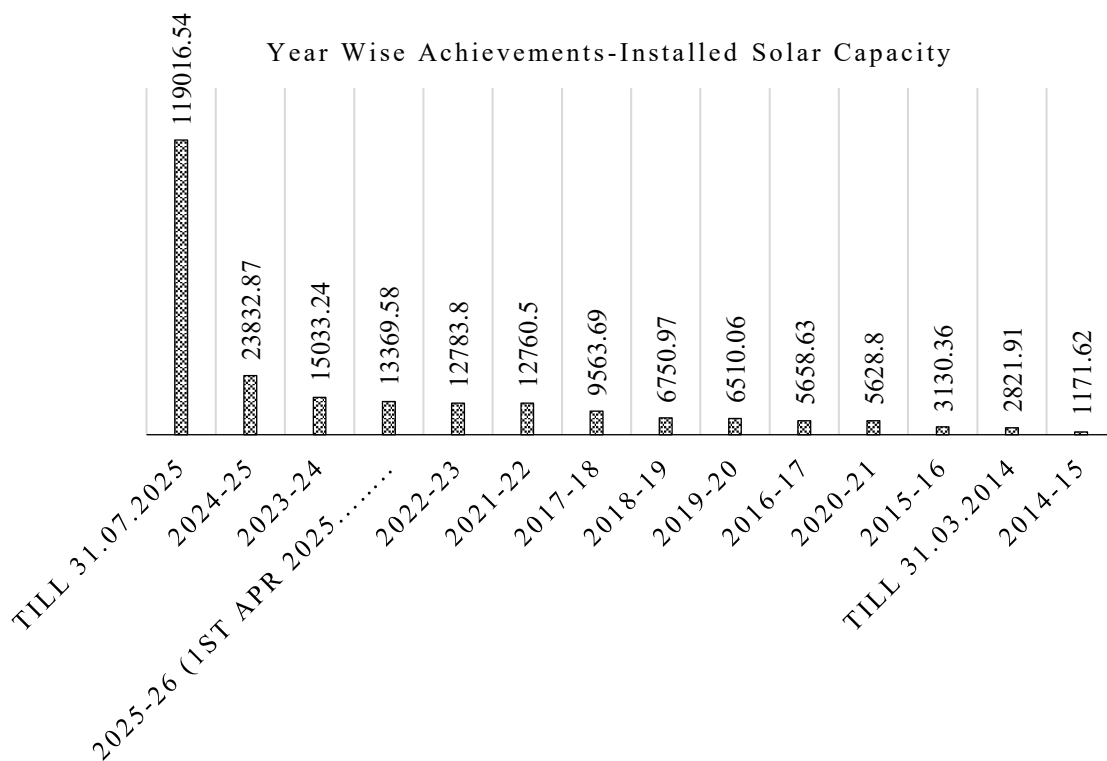


Figure 2. Year wise achievement in installed solar capacity.

Table 2 represents the categorization of the selected states according to the solar irradiation and generation of the electrical power [24]. Table 3 represents the state-wise solar potential and annual average global horizontal irradiance of selected states [25].

The progress of solar rooftop adoption is closely linked with state-wise electricity consumption patterns, per capita income, sanctioned load, and household size, which together define the potential for solar rooftop penetration.

Table 2. Categorization of selected states.

Category	States	Avg. irradiance (kWh/m ² /day)	Generation performance
High Irradiance – High Generation	Rajasthan	5.5–6.5	Excellent utilization of high solar potential.
	Gujarat		
High Irradiance – Low Generation	J & K	4.5–5.5	Underutilized due to terrain, grid, policy gaps.
	Himachal Pradesh (HP)		
Moderate Irradiance – High Generation	Karnataka	5.0–5.5	Strong policy push and grid connectivity.
	TN		
Moderate Irradiance – Low Generation	UP	4.5–5.5	Delayed approvals, subsidy issues.
	Bihar		
Low Irradiance – Low Generation	Kerala	3.8–4.5	Limited potential + logistical challenges.
	Assam		

Table 3. State-wise solar potential and annual average global horizontal irradiance.

State	Region	Solar potential capacity (In MW)	State solar potential against total solar potential in India	Annual average GHI (kWh/m ² /day)
AP	SR	38440	5.1%	5.5–6.0
Gujarat	WR	35770	4.8%	5.5–6.5
Odisha	ER	25780	3.4%	5.0–5.5
Punjab	NR	2810	0.4%	4.5–5.0
Rajasthan	NR	142310	19%	5.5–6.5
UP	NR	22830	3%	4.5–5.5

Figure 3 highlights the state-wise electricity consumption under the domestic category, comparing Central Electricity Authority (CEA) data for 2023 and 2024 [26]. States like U.P. (40.59%) and Punjab (26.31%) show a significant share of domestic electricity consumption, indicating higher residential dependency on grid electricity. Such states present a greater opportunity for solar rooftop adoption as domestic demand creates a strong incentive for cost-saving alternatives and renewable integration. In contrast, states like Odisha (11.98%) and Gujarat (12.55%) reflect comparatively lower domestic shares, suggesting a more balanced or industrial-dominated load pattern.

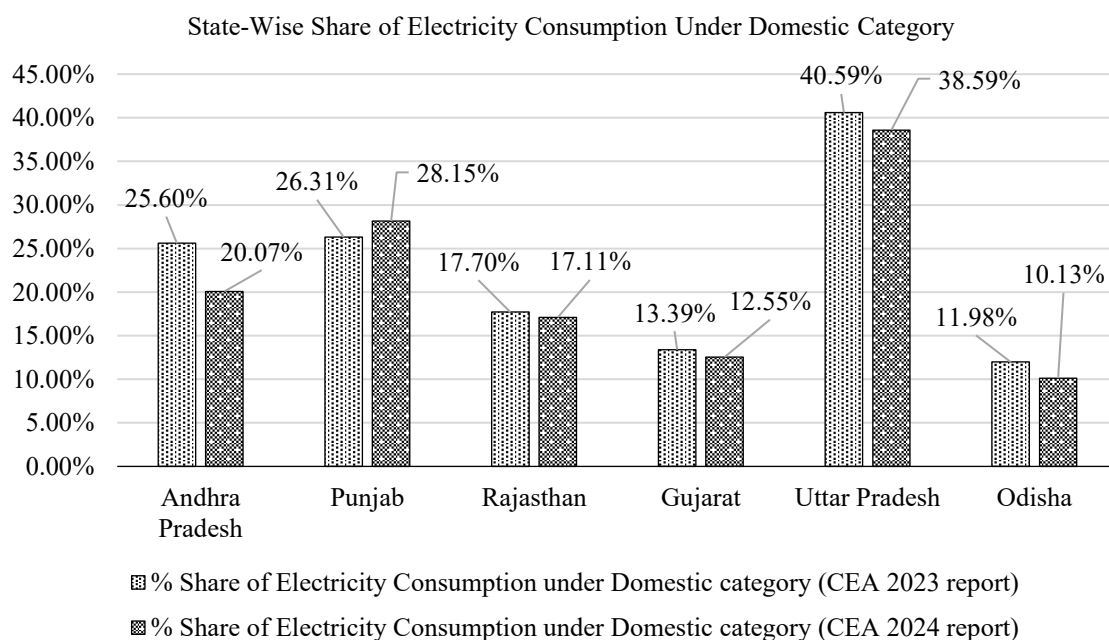


Figure 3. State-wise electricity consumption under domestic category.

Figure 4 provides the trend in per capita electricity consumption (kWh) across states for 2020–21, 2021–22, and 2022–23. Punjab and Gujarat consistently record higher per capita consumption, which aligns with their relatively better per capita incomes (as shown in Table 4). This higher consumption indicates both energy affordability and greater awareness, contributing positively to rooftop solar uptake, particularly when financial assistance or subsidies are available. States like Uttar Pradesh and Odisha, though recording lower per capita consumption, represent latent demand growth areas where financial incentives could accelerate adoption.

Table 4. State-wise per capita income vs average sanction load per household vs avg. size per household.

UP	1,48,416	1.5	5.1
Odisha	1,18,289	1.1	3.9
All India	–	1.3	4.3

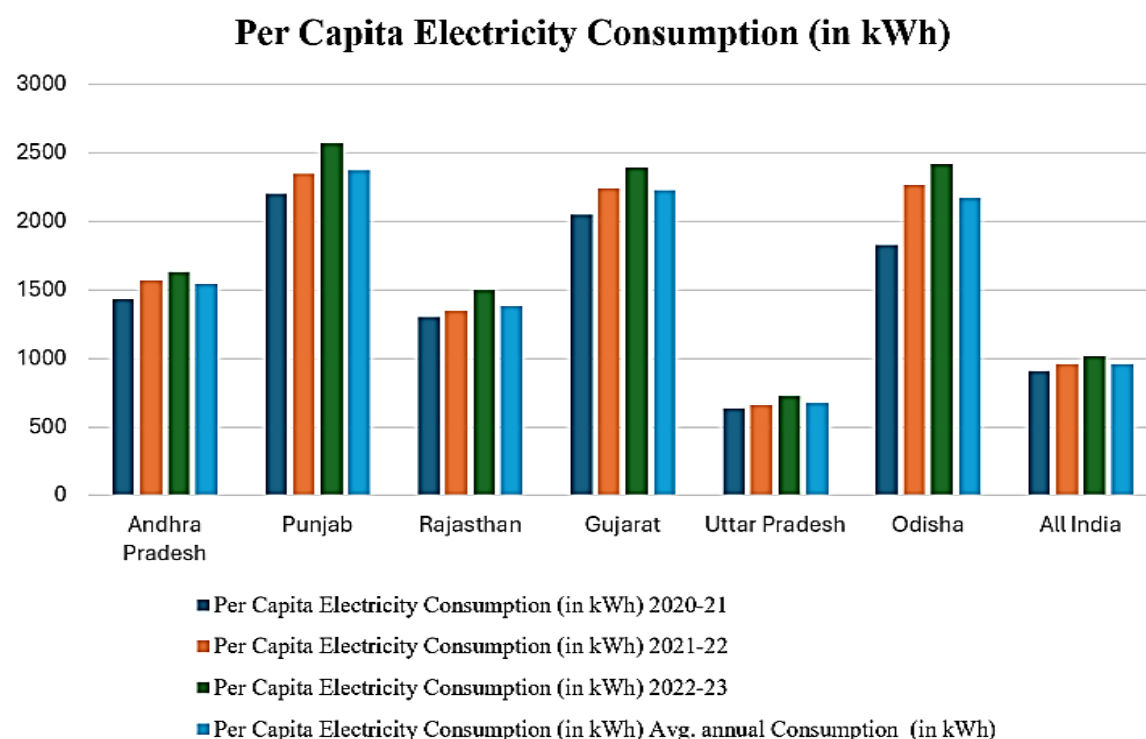


Figure 4. State-wise electricity consumption (in kWh).

Table 4 establishes the relationship between per capita income, average sanctioned load per household, and average household size. Rajasthan (₹2,47,892) and Gujarat (₹1,63,335) stand out with higher incomes, suggesting greater financial capacity for solar rooftop investment. Punjab also shows a relatively high sanctioned load (1.9 kW per household) despite moderate income, reflecting higher household electricity demand that can be offset through rooftop solar adoption. Conversely, states like Andhra Pradesh and Odisha, with sanctioned loads closer to 1.0–1.1 kW, exhibit limited household demand, but targeted subsidies and low-interest financing could make solar viable in such regions.

Figure 5 compares average sanctioned load with household size. Larger households in UP (5.1 members) and Rajasthan (4.8 members) correspond to higher electricity needs, though the sanctioned load per household remains moderate. This imbalance indicates an opportunity for rooftop solar to bridge the gap between household demand and sanctioned supply. States with smaller household sizes (e.g., AP with 3.4) have lower load requirements, yet solar rooftops can still reduce their dependence on conventional electricity tariffs, improving affordability.

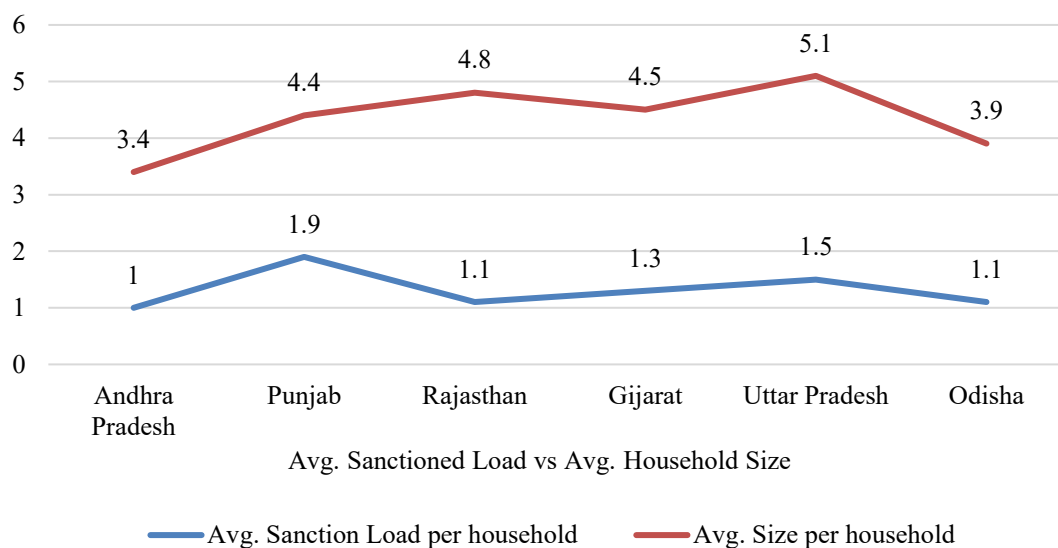


Figure 5. Average sanctioned load vs average household size.

Together, these analyses underline that the growth of solar rooftop businesses is strongly influenced by domestic consumption patterns, per capita incomes, household size, and sanctioned load levels. Financial assistance schemes, such as capital subsidies and net metering incentives, play a crucial role in bridging affordability gaps. High-consumption and high-income states demonstrate faster adoption, while states with lower household demand or income potential can achieve significant progress if policy support is effectively targeted. Thus, the interplay between state-level socio-economic parameters and electricity demand characteristics validates the importance of financial assistance in driving the expansion of solar rooftop systems across India, ultimately supporting the government’s renewable energy growth targets.

Table 5 provides an overview of state-wise financial assistance (subsidies) offered in addition to the Central Financial Assistance (CFA) [27] by MNRE. While all states uniformly receive the CFA of ₹78,000 (up to 3 kW), variations exist at the state level. For example, Uttar Pradesh provides an additional subsidy of ₹15,000 for systems up to 2 kW and up to ₹30,000 for higher capacities, while Odisha offers ₹25,000 for up to 2 kW and ₹60,000 for systems above 3 kW [28].

Table 5. State-wise financial assistance (subsidy) provided by state govt. in addition to CFA.

Name of the state	CFA by MNRE	Financial assistance (subsidy) provided by state govt.
AP	78,000/- upto 3kW max.	NIL
Punjab	78,000/- upto 3kW max.	NIL
Rajasthan	78,000/- upto 3kW max.	NIL
Gujarat	78,000/- upto 3kW max.	NIL
UP	78,000/- upto 3kW max.	15,000/- per kW max. up to 2 kW (i.e., Max. 30,000/- for 2kW and above)
Odisha	78,000/- upto 3kW max.	25,000/- per kW up to 2 kW and 10,000/- additionally for 3kW systems. (i.e., Max. 60,000/- for systems up to 3kW and above)

In contrast, states like Gujarat, Rajasthan, and Punjab do not extend any extra subsidy beyond the CFA. This variation highlights how proactive state-level financial support can significantly influence rooftop solar adoption, particularly in lower-income or high-demand states.

Table 6 examines the impact of subsidies on project economics by comparing scenarios with no subsidy, only CFA, and CFA plus state subsidy (as in Uttar Pradesh). Without subsidies, a 3 kW residential solar rooftop system has a payback period of around 6 years, whereas with CFA, it reduces to 4 years, and with combined CFA + state subsidy, it shortens further to just 3 years. This clearly validates the role of financial incentives in improving project viability and accelerating rooftop solar adoption.

Table 6. Project assumptions and impact of central & state subsidies on payback period.

Particulars	Unit	Project details considering NO subsidy	Project details considering only CFA	Project details considering CFA+ state subsidy (e.g.: U.P. State policy)
Plant Capacity	kW	3	3	3
Contract demand	kW	3	3	3
CUF	%	19%	19%	19%
O&M Cost (after 5 years)	%	1.00%	1.00%	1.00%
Degradation in PV performance	%	1.0%	1.0%	1.0%
DISCOM Tariff (Weighted)	Rs. per unit	6.50	6.50	6.50
Escalation in retail tariff (every year)	%	1.00%	1.00%	1.00%
Rooftop solar plant cost per kW	Rs. Per kW	60000	60000	60000
Project Cost w/o Subsidy	INR	180000	180000	180000
Project Cost after Subsidy	INR	180000	102000	72000
Payback	in Years	~6	~4	~3
Net returns after deducting CAPEX cost	INR	₹ 5,54,459	₹ 6,32,459	₹ 6,62,459

Table 7 details the generation, revenue, and cumulative net benefit of a residential rooftop solar project. Over 25 years, the system generates approximately 1.1 lakh kWh, resulting in a cumulative financial gain of ₹7.34 lakh after accounting for O&M costs and CAPEX. Importantly, the increasing cumulative benefit curve demonstrates that solar rooftop systems are not only cost-saving but also a source of long-term financial returns for households.

Table 7. Generation, revenue and net benefit calculation of a residential RFS.

Year (n)	Tariff	Total generation (kWh)	O&M cost	Net benefit (INR)	Cumulative benefit (INR)
1	6.5	4993.2	0.0	32455.8	32455.8
2	6.6	4943.3	0.0	32452.6	64908.4
3	6.6	4893.8	0.0	32449.3	97357.7
4	6.7	4844.9	0.0	32446.1	129803.7
5	6.8	4796.4	0.0	32442.8	162246.5
6	6.8	4748.5	2297.3	30142.3	192388.8
7	6.9	4701.0	2412.2	30024.2	222413.0
8	7.0	4654.0	2532.8	29900.3	252313.3
9	7.0	4607.4	2659.4	29770.4	282083.7
10	7.1	4561.4	2792.4	29634.2	311717.9
11	7.2	4515.8	2932.0	29491.3	341209.3
12	7.3	4470.6	3078.6	29341.5	370550.8
13	7.3	4425.9	3232.5	29184.3	399735.1
14	7.4	4381.6	3394.2	29019.5	428754.6
15	7.5	4337.8	3563.9	28846.5	457601.1
16	7.5	4294.4	3742.1	28665.1	486266.2
17	7.6	4251.5	3929.2	28474.7	514740.9
18	7.7	4209.0	4125.6	28275.0	543015.9
19	7.8	4166.9	4331.9	28065.5	571081.4
20	7.9	4125.2	4548.5	27845.7	598927.1
21	7.9	4084.0	4775.9	27615.0	626542.1
22	8.0	4043.1	5014.7	27373.0	653915.1
23	8.1	4002.7	5265.5	27119.0	681034.1
24	8.2	3962.7	5528.7	26852.5	707886.6
25	8.3	3923.0	5805.2	26572.8	734459.4
Total		1,10,938.2	75,962.6	7,34,459.4	

Figure 6 highlights the availability of empaneled vendors across states, which directly impacts rooftop solar market penetration [29]. States like Uttar Pradesh (1830 vendors) and Gujarat (1235 vendors) have a strong vendor base, indicating higher institutional readiness and ease of project implementation. On the other hand, states such as Odisha (160 vendors) and Andhra Pradesh (245 vendors) show weaker vendor participation, which can slow down rooftop solar adoption despite subsidy availability. This emphasizes that alongside financial assistance, a robust vendor ecosystem is equally essential for scaling rooftop solar.

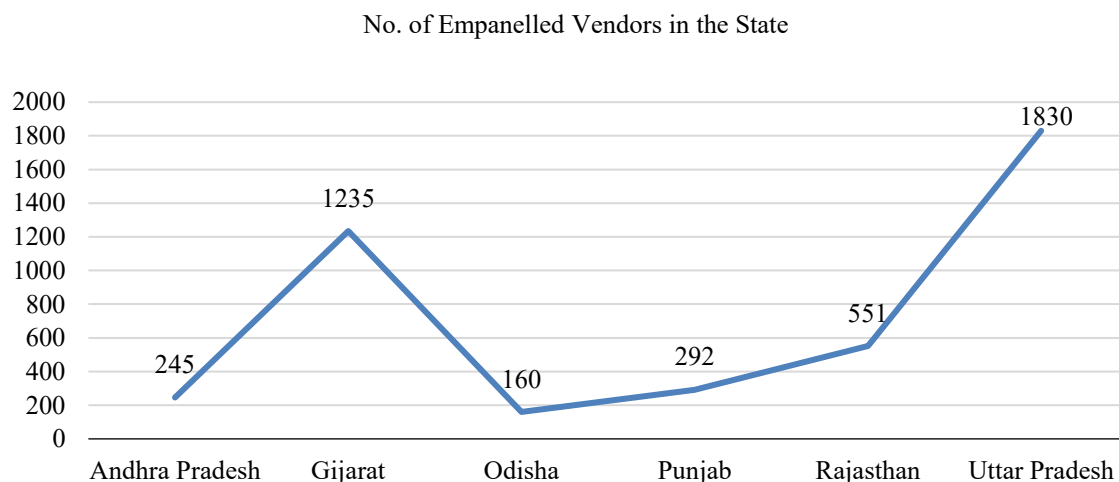


Figure 6. State-wise availability of empaneled vendors.

Figure 7 depicts the state-wise financial growth in rooftop solar over the last seven years (FY 2018–19 to FY 2024–25) [30]. The figure shows a clear upward trajectory in most states, though the growth is highly uneven. Gujarat demonstrates the strongest financial growth, consistently outpacing other states and crossing ₹5,000 crore by FY 2024–25, reflecting its robust policy support, higher consumer adoption, and strong vendor base. Uttar Pradesh follows with a steady rise, surpassing ₹1,500 crore, supported by state-level subsidies and the highest number of empaneled vendors. Rajasthan shows moderate but consistent growth, while Punjab, Odisha, and Andhra Pradesh exhibit relatively slow progress, with financial growth remaining below ₹500 crore even in the latest fiscal year. The Year-on-Year (YOY) growth bars further highlight the acceleration in Gujarat and Uttar Pradesh compared to stagnation in states with weaker policy or market ecosystems.

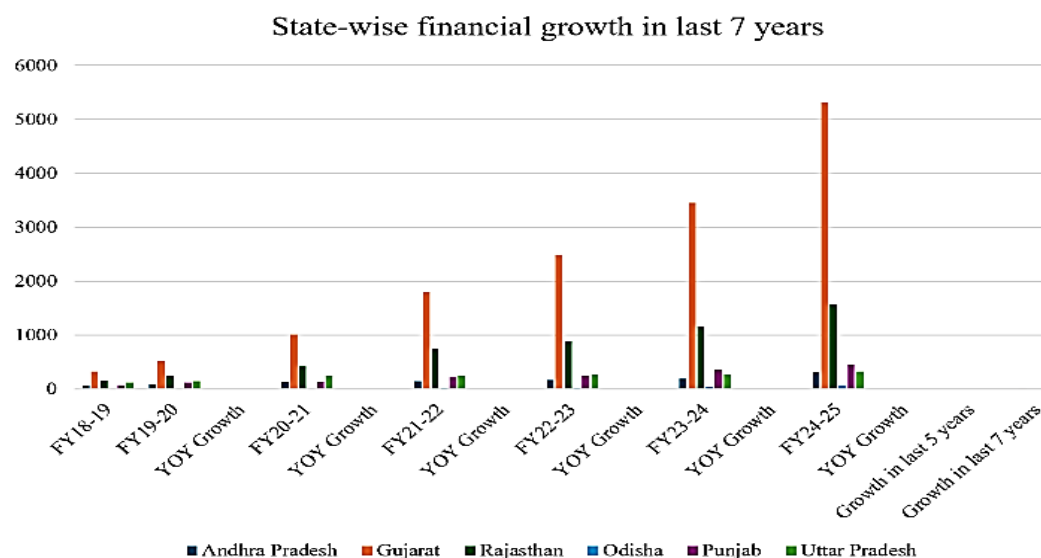


Figure 7. State-wise financial growth in last 7 years.

Overall, the data confirms that financial assistance mechanisms, coupled with vendor availability and supportive state policies, are key determinants of rooftop solar growth. States that combine central subsidies with additional financial incentives and maintain a strong vendor network show faster progress, while states lacking in either subsidy support or market readiness face challenges in scaling rooftop solar deployment.

OPPORTUNITIES AND RECOMMENDATIONS

The expansion of rooftop solar in India requires not only technological progress but also strong regulatory and financial support. Central and state governments play a pivotal role in shaping an enabling environment through clear policies, uniform regulations, and innovative subsidy mechanisms. This section highlights key opportunities and provides targeted recommendations to overcome existing barriers, enhance investor confidence, and accelerate the sustainable growth of rooftop solar across diverse states.

POLICY RECOMMENDATIONS FOR CENTRAL AND STATE GOVERNMENTS

- *Unified Net-Metering Regulations:* Harmonize net-metering rules across states – standardize feed-in tariffs, interconnection timelines, and meter specifications – to reduce regulatory confusion and speed approvals.
- *Performance-Linked Subsidies:* Shift from upfront capital subsidies to a mix of capital and generation-based incentives, rewarding actual performance (kWh generated) and ensuring long-term system reliability.
- *Ring-fenced Budget Allocations:* Mandate quarterly release of rooftop solar subsidy funds at both central and state levels to avoid “first-come, first-served” exhaustion and ensure year-round access.
- *DISCOM Accountability Framework:* Introduce key performance indicators (KPIs) for DISCOMs – such as average approval time, subsidy disbursal lag, and consumer grievance resolution – to align utility incentives with rooftop solar targets.

Innovations in Financing Models

- *RESCO (Renewable Energy Service Company) Model:* Expand third-party ownership structures where RESCOs install, own, and maintain systems, selling power to consumers via long-term power-purchase agreements (PPAs). This removes upfront cost barriers for households.
- *Leasing Systems:* Promote asset-leasing models that allow consumers to pay a fixed monthly lease instead of large capital outlays, with option to purchase at lease end.
- *Green Loans and Credit Lines:* Work with public sector banks to create dedicated “green credit” windows offering lower collateral requirements, fast-track approvals, and interest subvention for rooftop solar borrowers.

Role of Digital Platforms and Standardization

- *End-to-End Digital Portals:* Develop a unified national portal integrating application, technical feasibility checks, subsidy tracking, net-metering approvals, and grievance redressal to cut processing time from months to weeks.
- *Standardized Equipment and Installation Protocols:* Enforce strict adherence to ALMM-listed components and ISO installation guidelines. Publish state-wise dashboards tracking approved vendors, system performance, and warranty claims to boost transparency.
- *Data-Driven Monitoring:* Leverage IoT-enabled smart meters and cloud-based analytics to monitor generation, detect faults, and automate incentive disbursal based on verified performance.

Enhanced Loan Facilities

- *Interest Subvention Schemes:* Extend and deepen interest-subvention programs (e.g., 5–7 year tenure at subsidized rates) for residential and MSME rooftop projects.
- *Credit Guarantee Mechanisms:* Establish a government-backed credit guarantee fund to de-risk rooftop solar loans, enabling banks to lend without heavy collateral and reducing credit costs.
- *Bundled Financial Products:* Offer combined loan-plus-insurance packages covering system performance, theft, and weather damage, simplifying financing and enhancing consumer confidence.

By implementing these targeted policy, financing, digital, and regulatory measures, central and state governments can unlock the latent potential of India's rooftop solar market – accelerating capacity additions, democratizing access, and ensuring sustainable growth.

SUMMARY OF FINDINGS AND IMPLICATIONS

The launch of the PMSMBY in 2024 has been a landmark move, aiming to cover one crore households with rooftop solar systems, each capable of generating up to 300 units per month of free electricity. This initiative alone has led to a surge in demand, making solar energy more accessible to middle and lower-income households. The provision of up to 60% capital subsidy for systems up to 2 kW and 40% for additional capacity up to 3 kW has played a transformative role in making rooftop solar financially viable.

State governments have bolstered central initiatives with region-specific incentives and efficient implementation support, significantly boosting rooftop solar growth in states like Gujarat, Maharashtra, and Rajasthan. Gujarat leads the nation with about 82% of India's residential rooftop solar capacity – installing over 3.3 lakh rooftop systems under the PM Surya Ghar scheme, adding 1,232 MW and delivering 400% growth over five years. Maharashtra ranks second, accounting for around 13% of installations, with capacity rising from 1,000 MW in 2021 to nearly 2,000 MW by 2023. These states have achieved success through streamlined online portals, active DISCOM involvement, mobile apps for tracking progress, and district-level awareness campaigns – particularly in Maharashtra's Nagpur district, which alone hosts over 33,600 systems totaling 132 MW. By converting consumers into energy-producing prosumers, these policies advance decentralized grid greening and drive local employment, entrepreneurship, and skill development. Continued policy refinement, enhanced public-private partnerships, and sustained engagement will be key to meeting India's renewable energy ambitions and achieving inclusive energy transition.

The analysis shows integrated policy frameworks – covering ALMM technical standards, uniform net-metering, RPO enforcement, and layered subsidies – can accelerate rooftop solar adoption by up to 50% in proactive states like Gujarat, Maharashtra, and Rajasthan. In contrast, lagging regions such as UP and Bihar face subsidy caps, delays, and regulatory inconsistencies. Policymakers should streamline subsidy disbursement with quarterly ring-fenced budgets and enforce consistent interconnection rules for equitable growth.

DISCOMs that establish dedicated rooftop solar help desks, implement digital application tracking, and tie staff incentives to approval KPIs can reduce turnaround times from months to days. Promoting solar in Tier-2 and Tier-3 cities lowers theft-related losses, improves collection efficiency, and helps ease the cross-subsidy burden on state finances.

With combined central and state financial support, residential adopters can reduce solar payback periods from approximately 7–8 years to 3–5 years. Yet, awareness and trust deficits persist in Tier-2/3 and rural areas. Targeted consumer education, vendor transparency platforms, and bundled financing-insurance offerings are key to unlocking latent demand.

CONCLUSIONS AND FUTURE SCOPE

The study concludes that combined financial support from both central and state governments – and the creation of a consumer-focused ecosystem – has been pivotal in driving rooftop solar growth in India's residential segment. Since the launch of the PM Surya Ghar Muft Bijli Yojana in early 2024, rooftop solar capacity has increased by approximately 5.15 GW in FY 2024–25 – a 72% year-over-year growth – bringing total grid-connected rooftop capacity to 18.84 GW as of June 30, 2025. States such as Gujarat, Maharashtra, and Rajasthan have emerged as frontrunners in residential solar adoption, enabled by layered subsidies, streamlined approval systems, and active distribution company engagement. This surge demonstrates the effectiveness of well-structured policies, targeted incentives, and effective implementation mechanisms.

Looking ahead, future research and practice must focus on several critical areas: rigorous policy impact assessment using post-2025 data; piloting leasing and green-loan models with credit guarantees in underserved regions; integrating IoT-enabled smart meters for real-time performance tracking and automated incentives; conducting behavioral studies in low-uptake regions; and benchmarking against global models such as those in Germany and Australia. These measures will be crucial to achieving India's objectives of 30 GW rooftop solar by 2027 and 500 GW non-fossil capacity by 2030 – ensuring a resilient, inclusive solar transition.

REFERENCES

1. Goel M. Solar rooftop in India: Policies, challenges and outlook. *Green Energy Environ.* 2016;1(2):129–37.
2. Gulia J, Thayillam A, Sharma P, Garg V. Indian residential rooftops: A vast trove of solar energy potential. Institute for Energy Economics and Financial Analysis (IEEFA); 2022.
3. Odeh S, Nguyen TH. Assessment method to identify the potential of rooftop PV systems in the residential districts. *Energies.* 2021;14:4240.
4. Klima K, Apt J. Geographic smoothing of solar PV: Results from Gujarat. *Environ Res Lett.* 2015;10:104001.
5. Davidson C, Drury E, Lopez A, et al. Modeling photovoltaic diffusion: An analysis of geospatial datasets. *Environ Res Lett.* 2014;9:074009.
6. Kaur T. Solar PV integration in smart grid—Issues and challenges. *Int J Adv Res Electr Electron Instrum Eng.* 2015;4:5861–5.
7. Tarigan E. Techno-economic analysis of residential grid-connected rooftop solar PV systems in Indonesia under MEMR 26/2021 regulation. *Int J Energy Econ Policy.* 2024;14:412–7.
8. Srivastava R, Amir M, Ahmad F, et al. Performance evaluation of grid-connected solar powered microgrid: A case study. *Front Energy Res.* 2022;10:1044651.
9. Jewell J, McCollum D, Emmerling J, et al. Limited emission reductions from fuel subsidy removal except in energy-exporting regions. *Nature.* 2018;554:229–33.
10. Sakti AD, Ihsan KTN, Anggraini TS, et al. Multi-criteria assessment for city-wide rooftop solar PV deployment: A case study of Bandung, Indonesia. *Remote Sens.* 2022;14:2796.
11. Council on Energy, Environment and Water (CEEW). Residential rooftop solar market potential in Indian households. Available from: https://www.ceew.in/sites/default/files/residential-rooftop-solar-market-potential-in-indian-households_0.pdf.
12. TERI. India's role in global energy governance framework. 2025. Available from: https://www.teriin.org/sites/default/files/files/India_role_in_global_energy_GovernanceFram_work.pdf.
13. Mercom India. India solar market update Q3-2023. Available from: <https://www.mercomindia.com/product/q3-2023-india-solar-market-update>.
14. Satapathy A. BOCR/ANP framework to evaluate policies for adoption of rooftop solar PV. *Adv Consum Res.* 2025;2(1).
15. Mukherjee M. India's ongoing rooftop solar journey 2017-2022. OIES Paper ET No.18. Oxford Institute for Energy Studies; 2022.
16. Mathew TC, Pandian SN. Unveiling the shadows: A qualitative exploration of barriers to rooftop solar photovoltaic adoption in residential sectors. *Clean Energy.* 2024;8(5):218–28.
17. International Energy Agency (IEA). Jawaharlal Nehru National Solar Mission (Phase I, II and III). Available from: <https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii?technology=DistributedPV>.
18. Schetinger AM, Pereira de Lucena AF. Evaluating policy frameworks and their role in the sustainable growth of distributed photovoltaic generation. *Resources.* 2025;14(2):28.
19. Shidore S, Busby JW. What explains India's embrace of solar? State-led energy transition in a developmental polity. *Energy Policy.* 2019;129:1179–89.
20. Srivastava S. Policy framework for developing and promoting decentralised renewable energy livelihood applications. 1st ed. New Delhi: Ministry of New Renewable Energy; 2021. p. 1–19.
21. Ministry of New and Renewable Energy (MNRE). Physical achievements. Government of India.
22. Ministry of New and Renewable Energy (MNRE). Physical progress details. Available from: <https://mnre.gov.in/en/physical-progress/>.

23. International Energy Agency (IEA). Past and future energy investment in India in the Announced Pledges Scenario and the Net Zero Emissions by 2050 Scenario, 2016–2030. Paris: IEA; 2024. Available from: <https://www.iea.org/data-and-statistics/charts/past-and-future-energy-investment-in-india-in-the-announced-pledges-scenario-and-the-net-zero-emissions-by-2050-scenario-2016-2030>.
24. Pareek A, Niyaz HM, Kumar M, Gupta R. Categorizing Indian states based on operating condition of photovoltaic system. *Sol Energy Adv.* 2024;4:100052.
25. NITI Aayog. Solar energy potential in India. Available from: <https://iced.niti.gov.in/energy/fuel-sources/solar/potential>.
26. Central Electricity Authority (CEA). Annual report 2023. Available from: https://cea.nic.in/wp-content/uploads/fs__a/2024/07/Book_2023.pdf.
27. Ministry of New and Renewable Energy (MNRE). Press release. Press Information Bureau (PIB). Available from: <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2111106>.
28. Press Information Bureau (PIB). Press release 2025. Available from: <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2111106>.
29. Solar Rooftop Portal. Approved vendor list — state-wise. Available from: <https://api.solarrooftop.gov.in/VendorList/statewiseVendor>.
30. Ministry of Statistics and Programme Implementation (MOSPI). Energy Statistics India 2025. Available from: https://mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2025/Energy%20Statistics%20India%202025_27032025.pdf.