ADVANCING DISTRIBUTED, EQUITABLE SOLAR ENERGY IN TAMIL NADU

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Acknowledgment

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Acronyms

AAY	Antyodaya Anna Yojana
ARR	Average Revenue Requirement
BESS	Battery Energy Storage System(s)
BPL	Below Poverty Level
BTM	Behind the Meter
C&I	Commercial & Industrial
CAG	Comptroller and Auditor General
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CFA	Central Financial Assistance
CHBP	Cheaper Home Batteries Program
CMSPGHS	Chief Minister's Solar Powered Green House Scheme
DER	Distributed Energy Resource
DISCOM	Distribution Company
DT	Distribution Transformer
FPO	Farmer Producer Organization
FTE	Full-Time Equivalent
FY	Financial Year
GISS	Grid Interactive Solar System
GW	Gigawatt(s)
GWh	Gigawatt hour
HH	Household(s)
HTF	High Tension Feeder
₹	Indian National Rupees
IPS	Individual Pump Solarisation
kV	Kilo Volts
kW	Kilowatt(s)
kWh	Kilo Watt Hours
LCOE	Levelised Cost of Energy
LPG	Liquified Petroleum Gas
MU	Million Units
MW	Megawatt(s)
NCT	National Capital Territory (of Delhi)
NEM	National Electricity Market (Australia)
NSFA	National Food Security Act
O&M	Operations & Maintenance
P2P	Peer-to-Peer
PACS	Primary Agriculture Credit Societies
PFC	Power Finance Corporation
PHH	Priority Household
PIB	Press Information Bureau
PM KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan
PMAY	Pradhan Mantri Awas Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research & Development
RESCO	Renewable Energy Service Company
RPO	Renewable Purchase Obligation
RTS	Rooftop Solar Photovoltaics
SEPAP	Solar Energy for Poverty Alleviation Program
SECC	Socio-economic caste census
SHS	Solar Home System
SL	Sanctioned Load
ToD	Time-of-Day (tariff)
TWh	Terawatt hour
UMW	Ultra-Megawatt
WUA	Water Users Association

Executive Summary

Tamil Nadu's power sector has long been guided by a welfare-first approach that expanded access and inclusion. In the last decade, this has come at an increasingly rising fiscal cost. With rising consumption, cost of supply and cross-subsidies failing to close the revenue gap, DERs, especially rooftop solar and solar for agriculture, could offer a pathway to ease subsidy pressures, defer grid and capacity investments, cut technical losses, and improve local reliability.

International examples from rooftop solar leaders demonstrate that large-scale DER adoption is best achieved through targeted policy measures, tailored financial incentives, and hands-on consumer support—strategies that together stimulate DER demand, reduce grid pressure, strengthen energy security and address energy poverty issues. These insights argue for adoption-focused goals rather than capacity (MW) alone. Adoption-focused goals emphasize increasing the number of actual distributed energy resource (DER) users—such as households and businesses—rather than simply aiming for higher installed capacity in megawatts. This approach recognizes that the real value of DER lies in its ability to directly impact energy access and social outcomes. By prioritizing widespread adoption, policy can ensure solar and other distributed energy solutions reach a broader segment of the population, including vulnerable, helping to alleviate energy poverty.

The solar DER uptake has remained limited in Tamil Nadu. The state's rooftop potential is enough to meet around 47% of projected demand in 2030–31, yet installed rooftop capacity is less than 2% of the potential as of mid-2025 (Auroville Consulting, 2025). Two solar DER programs, PM Surya Ghar Portal for households, and PM KUSUM-C (IPS) for farmers, in particular, show promise to significantly advance solar DER uptake in Tamil Nadu while simultaneously addressing social, environmental and fiscal goals. While the PM Surya Ghar has received over 99,000 applications, less than 40% have resulted in installations, with only 136.38 MW commissioned as of July 2025 (MNRE, n.d). Similarly with KUSUM-C (IPS), since its introduction in 2021, the state has seen zero uptake among the farmers (GOI, 2025c). Low or zero uptake for Surya Ghar and KUSUM-C (IPS) in the state persists despite universal net metering and integrated application portals. Key barriers include free or subsidised electricity, network charges, low consumer awareness, and concerns about agricultural metering.

Rooftop solar modelled in the report shows unsubsidized levelized cost of energy (LCOE), e.g. cost of generated solar unit, range from ₹3.88–₹5.25/kWh, falling to ₹1.84–₹3.20/kWh with the current capital subsidies provided under PM Surya Ghar and PM KUSUM-C (IPS); if network charges apply, effective LCOE rises to ₹4.20–₹5.57 for unsubsidized and to ₹2.16–₹3.52 for subsidized systems. This compares unfavourably with the LCOE for large-scale ground-mounted solar systems in the range of from ₹2.32–₹3.87/kWh. However, an LCOE comparison only misses out on DER upstream grid benefits, which include avoided costs, giving scope for investment deferral. If further does not account for the potential to reduce the subsidy and cross subsidy burden, and other non-monetised benefits such as job creation, land use impact, resilience and enhanced energy security.

Tamil Nadu's electricity subsidy has increased from ₹5,600 crore in 2014–15 to over ₹16,000 crore in 2025–26. Most of this subsidy goes to domestic and agricultural users. However, current data show that targeting could improve, as mid and high-income households now receive a higher share of the subsidy than low-income households (Auroville Consulting, 2023a). Evidence from national and international programmes suggests that precise beneficiary identification and direct support for low-income households and marginal farmers improve both equity and uptake. Targeted rooftop solar programs with precise beneficiary identification promise similar benefits. This report explores different delivery mechanisms or business models for PM Surya Ghar and PM KUSUM-C (IPS) and assesses these against its potential to simultaneously meet the states and the DISCOMS' fiscal needs while providing a winning proposition to the consumers. The business models explored are: Market-Driven (Consumer-Driven), Build Operate Transfer (BOT), Full Subsidy, Peer to Government (P2G),Super RESCO and Zero Intrest Finance.

Tamil Nadu needs a balanced approach, not a choice, between utility-scale solar and DER. Utility-scale projects provide cheap bulk power, while DERs help cut subsidies, create jobs, ease land conflicts, and boost grid resilience and energy security. With the right policies, business models, and targeted reforms—focused on adoption—Tamil Nadu can advance welfare, fiscal health, and clean energy goals together.

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01 Introduction

Tamil Nadu has significant untapped potential to transform its power sector and foster inclusive growth by rapidly scaling distributed solar—especially rooftop systems—across urban, rural, and agricultural settings. This can be achieved by leveraging strong policy frameworks and targeted programs to create jobs, enhance grid reliability, and deliver social equity benefits to households and farmers.

Tamil Nadu stands on the cusp of a transformative shift in its power sector, with distributed solar energy—especially "behind-the-meter" solutions such as rooftop solar—emerging as a central pillar for the state's renewable energy transition, socio-economic progress, and climate resilience. Urban rooftops, agricultural pumps, and community buildings now serve not only as sources of electricity but as a means to democratize energy generation. This empowers households, businesses, and farmers to participate directly in and benefit from the state's green growth trajectory.

Globally, distributed solar solutions help reduce grid losses, boost reliability, and support the large-scale integration of variable renewables. Australia's experience—where rooftop PV supplies over 11% of electricity demand and installed capacity exceeds 20 GW—demonstrates how citizen-owned solar can reshape power systems (Clean Energy Council, 2025). Tamil Nadu, with a technical rooftop solar potential of over 60,479MW (annual generation potential: 95TWh, nearly half the projected demand for 2030–31), holds unique promise (Auroville Consulting, 2025). The benefits of distributed solar extend well beyond decarbonisation.

Employment generation: Evidence shows each MW of distributed solar creates two to five times more jobs than grid-scale projects (CEEW, 2017, 2022) (Auroville Consulting 2019a), sustaining skilled and semi-skilled employment across installation, operations, and maintenance—especially beneficial for both urban and rural economies.

Technical grid benefits: Behind-the-meter solar reduces distribution losses, flattens local demand peaks, enhances power quality, and relieves substation pressure. Coupled with energy storage and demand response, it plays a crucial role in balancing the "duck curve" and strengthening grid resilience.

Social equity: Distributed solar, when targeted at low-income households and marginal farmers through schemes like the PM Surya Ghar Yojana (offering up to 60% subsidy on rooftop systems) and PM-KUSUM-C (IPS) (incentivizing solarization of agriculture pumps), directly addresses energy poverty, curbs electricity bills, and improves rural incomes.

The policy landscape in Tamil Nadu aligns state and national ambitions. The state government's net zero target (by 2050) is supported by an ambitious renewable energy purchase obligation (RPO) framework (PIB, 2024a). For 2025–26, 2.10% of total electricity consumption must come specifically from distributed renewable sources—with targets progressively increasing each year (TNERC, 2025b). The latest draft regulations define distributed renewable energy as projects under 10MW, primarily enabled by net and gross metering and regulated by the Tamil Nadu Green Energy Corporation (TNERC, 2025b).

Key national programs lay the groundwork for Tamil Nadu to go further. The PM Surya Ghar: Muft Bijli Yojana, launched in 2024, offers central financial assistance up to ₹78,000 (covering up to 60% of the benchmark cost up to 2kW system and 40% for the next 1kW for residential rooftop systems), aiming to enable more than 1 crore households nationwide to access affordable solar power (PIB, 2024b). Meanwhile, the PM KUSUM-C (IPS) scheme supports farmers by subsidizing solar irrigation pumps (up to 60% subsidy with a mix of central and state support) and facilitating decentralized power generation on agricultural land, allowing surplus power to be sold to the grid (MNRE, 2024).

By customizing and scaling these schemes in Tamil Nadu's context, the state can fast-track distributed solar adoption for low-income and marginalized groups, integrate electrification with welfare and farm support, and streamline consumer participation via Tamil Nadu Green Energy Corporation Limited (TNGECL) and Tamil Nadu Power Distribution Corporation Limited (TNPDCL) (formerly TANGEDCO). Strategies such as aggregated procurement for small households and cooperative, community-led models for farmers will help guarantee that the clean energy transition becomes a genuinely inclusive, people-centric development story.

In this report, DER, rooftop solar (RTS), and behind-the-meter (BTM) are used interchangeably to refer to grid-interactive distributed solar. It may be noted that in 2024, the Tamil Nadu Generation and Distribution Company Limited (TANGEDCO) was trifurcated into three entities: Tamil Nadu Power Generation Corporation Limited (TNPGCL), Tamil Nadu Power Distribution Corporation Limited (TNPDCL), and Tamil Nadu Green Energy Corporation Limited (TNGECL). Most references to TANGEDCO in this report refer to the newly established TNPDCL. Further, the activities and responsibilities of the Tamil Nadu Energy Development Agency (TEDA) have been taken up by TNGECL.

02 Global Lessons, Local Power: Adapting Distributed Solar for Tamil Nadu

Distributed solar, including rooftop and small agricultural systems installed behind-the-meter, helps ease grid demand, lowers losses, boosts reliability, and supports job creation and renewable energy targets.

Rooftop Solar Penetration: A Global Benchmarking Exercise

For this report, distributed solar generation primarily refers to behind-the-meter (BTM) solar energy systems, such as rooftop solar installations on residential, commercial, or industrial buildings, and small on-grid systems powering individual agricultural pumps. These systems are typically located close to the point of consumption and are distinct from large-scale, utility-connected solar parks. This focus reflects the growing importance of decentralised energy solutions in enabling energy access, enhancing grid reliability, and supporting the broader energy transition through more resilient and participatory electricity systems.

As countries accelerate their transition to cleaner energy systems, rooftop solar photovoltaics (RTS) have emerged as a key pillar of distributed renewable electricity generation. Rooftop solar offers the potential to reduce grid demand, lower household electricity costs, and empower energy consumers. However, comparing rooftop solar penetration across countries is not straightforward, as metrics vary in definition and coverage. This chapter presents a comparative analysis of countries with high rooftop solar adoption, using a set of standardised indicators to evaluate deployment and impact. These include the proportion of households equipped with rooftop solar systems (Percentage of rooftop homes), the share of national electricity generation sourced from rooftop solar, the contribution of rooftop solar to peak electricity demand, and installed rooftop solar capacity per capita (measured in kilowatts per resident). By applying these parameters, the chapter offers a multidimensional understanding of how different policy, economic, and climatic contexts shape rooftop solar outcomes globally.

Table 1 presents the simple indicators for rooftop solar penetration for selected countries: installed rooftop solar capacity in GW, share of rooftop solar energy on total annual energy demand in percentage and kW of installed rooftop solar capacity per resident in kW/person. The reported population data and total electricity demand figures for the year 2024 were utilised to compute these indicators.

Table 1 Country comparison - rooftop solar penetration

Country	Installed Rooftop Solar (GW)	Rooftop Solar % of Annual Demand	kW Rooftop Solar per Resident (kW/person)
China	225	2.55%	0.160
Germany	53	10.49%	0.635
Brazil	37	7.32%	0.175
Netherlands	28.60	19.95%	1.589
Australia	25.50	11.27%	0.937
India	18.80	1.20%	0.013

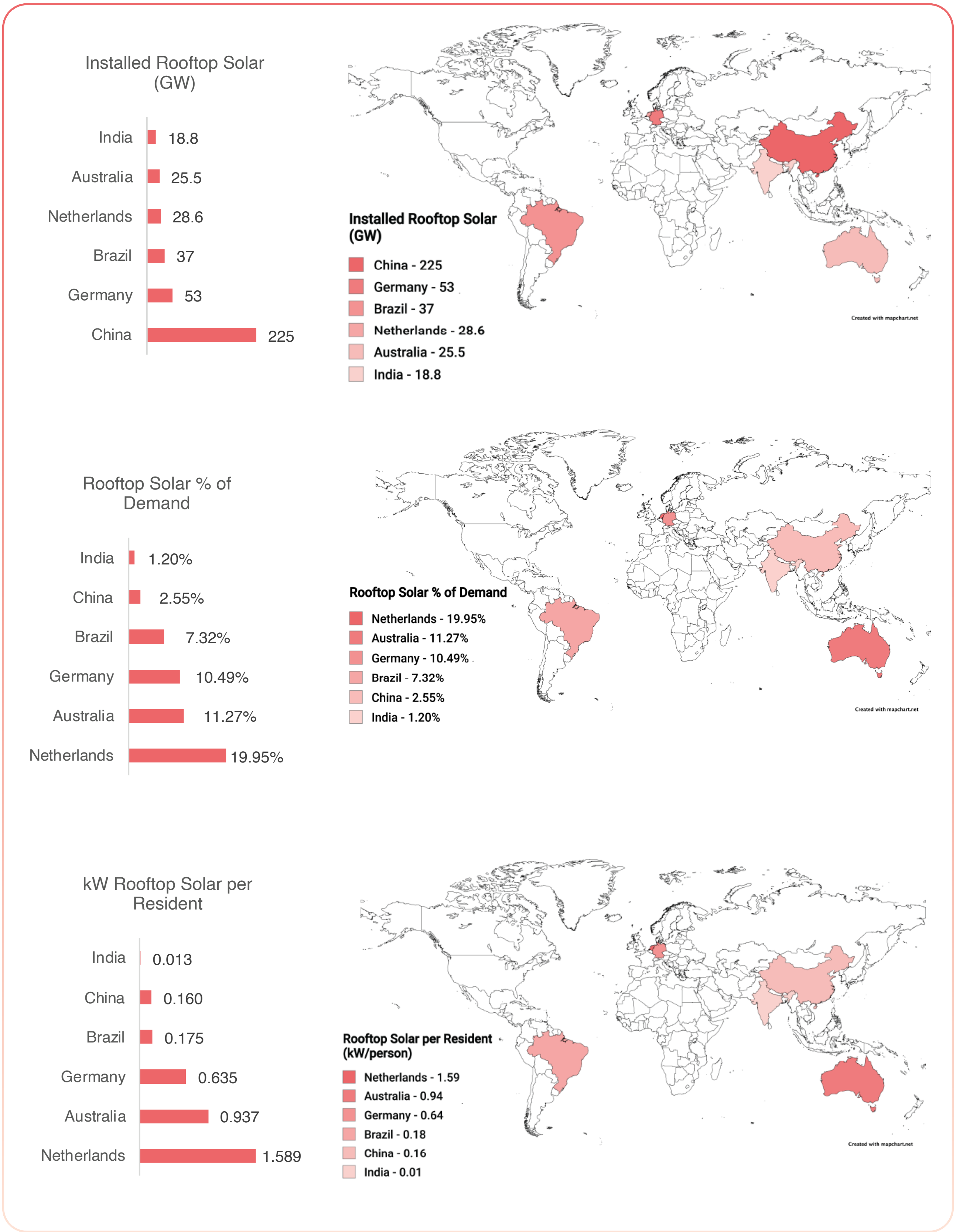
Source: ABSOLAR, n.d; CEEW, 2025; CBS 2025; Clean Energy Council, 2025a; MNRE, 2025

China has the highest installed rooftop solar capacity at 225 GW (2024 data) (CEEW, 2024), but this accounts for 2.55 percent of its annual electricity demand and 0.16 kilowatts per person. This suggests that while China leads in absolute capacity, its rooftop solar penetration relative to its population and total demand remains modest. Brazil and Australia follow with 37 GW (ABSOLAR, n.d) and 25.50 GW (Clean Energy Council, 2025a), respectively. However, their figures differ significantly in terms of impact. In Brazil, rooftop solar contributes around 7.32 percent of the country's annual electricity demand and accounts for 0.17 kW per person. In contrast, Australia stands out with 11.27 percent of its demand met by rooftop solar and 0.94 kW per person with widespread household-level adoption.

India, despite its large population and strong solar potential, has 18.8 GW of installed rooftop solar, translating (MNRE, 2025) to only 1.28 percent of national demand and just 0.013 kW per person. Germany, with 53 GW (as per 2024 data), sees around 10 percent of its electricity demand met by rooftop solar and maintains 0.63 kW per person, reflecting a steady adoption. The Netherlands emerges as another leader with 28.6 GW of installed capacity (residential- 11.60 GW and commercial -16.90 GW) (CBS, 2025), where rooftop solar contributes more than 19% in the electricity demand with 1.59 kW per person. In March 2025, the Netherlands achieved a 34.20% residential solar penetration rate, with approximately 2.88 million solar-powered homes out of a total of 8.40 million households. In comparison, Germany has a lower penetration rate of 9.80%, yet it leads in absolute numbers, with 4.03 million homes equipped with solar panels out of 41.30 million households (Sunsave, 2025).

Overall, the data highlight that countries like Germany, Australia and the Netherlands have achieved both high levels of installed capacity relative to population and a significant share of electricity demand met by rooftop solar. In contrast, countries such as China and India, despite high total installations, still have considerable potential for deeper household-level penetration and stronger contributions to overall electricity supply.

Figure 1 Country comparison - rooftop solar penetration



Source: ABSOLAR, n.d; CEEW, 2025; CBS 2025; Clean Energy Council, 2025a; MNRE, 2025

Global Insights on Rooftop Solar: Shaving Peaks and Storing Power

The contribution of rooftop solar to peak energy demand measures how much rooftop photovoltaic (PV) systems reduce the electricity required from the grid during the times of highest system demand ("peak"). This parameter is crucial because shaving or shifting the peak reduces strain on the grid, can offset the need for expensive peaking power plants, and improves overall grid efficiency.

Australia:

Rooftop solar has a major impact in Australia's peak daylight hours. In states like South Australia, rooftop PV has covered well over 100% of local (net) demand during some low-load sunny periods, even pushing demand negative at times (exports to other regions) (Watt-Logic 2021). In Australia, for every 1 MW added from rooftop solar, daytime electricity demand from the grid drops by about 0.5 to 0.6 MW. This means rooftop solar often provides half or more of its output to reduce midday demand, especially in major states (Frontiers in Energy Research, 2023) (AEMO, 2024). Rooftop PV has shifted grid peaks from midday (historically) to late afternoon or dusk, as solar covers midday peaks and load now ramps up quickly after sunset (Powerlink Queensland, 2024).

Australia is experiencing a rapid scale-up of both household and utility-scale BESS, strongly promoted by national and state governments to complement high rooftop solar uptake (Australian Energy Council, 2025) (Clean Energy Council, 2025b). As of 2024–2025, government rebates, direct subsidies, and dedicated programs like the Cheaper Home Batteries Program (CHBP) and the Capacity Investment Scheme are accelerating the adoption of residential and grid-scale batteries (CHBP, n.d) (DCCEEW, 2025). In 2024, a record 72,500 home batteries were installed—up 27% from the prior year—partly due to new federal incentives and market design reforms, making batteries a mainstream feature of new rooftop solar installations (SunWiz, 2025).

Key enablers in Australia include strong financial incentives, favorable market design, high consumer confidence, and excellent solar resources. However, challenges remain. The so-called "duck curve" effect causes steep ramps in demand after sunset, while high solar penetration can create grid congestion and reverse power flows. Additionally, battery storage remains expensive for many consumers, and regulatory frameworks must continuously adapt to the changing grid landscape.

Netherlands:

While rooftop PV penetration is high, the country's system-wide peak often occurs in the evening, after solar production has dropped. Still, rooftop solar significantly reduces overall daytime peak grid demand, although specific figures for peak shaving are limited and typically less impactful in the winter when peaks arrive after sunset (Bricknest. 2025) (IEA-PVPS, 2024). Dutch utilities are now experimenting with tariffs and demand-side management to better match rooftop solar output with daytime peaks, aiming to shift more demand to sunny hours and relieve evening peak loads (Eneco, 2025) (PV Magazine, 2025).

The Dutch government allocated €100 million in 2024 for battery energy storage deployment tied to solar PV, with a focus on smoothing grid peaks and supporting renewable integration. This subsidy, part of a larger €416 million climate package, is intended to bridge business case gaps and will directly incentivize both home and large-scale batteries co-located with rooftop PV (Energy Storage News, 2024). Financial incentives per kWh are available for discharging batteries during peak demand hours (Energy Storage News, 2024).

Enablers include targeted government subsidies, strong household solar uptake, grid modernization efforts, tariff reforms and innovative utility programs (ACM, 2024) (IEA-PVPS, 2024). On the other hand, the effectiveness of rooftop solar is hampered by seasonal variation, evening peaks, and increasing strain on grid infrastructure due to high volumes of distributed generation.

Germany:

Germany's high rooftop PV adoption helps lower midday peaks (Fraunhofer ISE, 2025) (GridX, 2025). However, as in the Netherlands, grid peaks in Germany are trending later in the day, after solar output declines, limiting the peak reduction capability to sunny midday intervals.

Germany is actively expanding battery energy storage systems (BESS), particularly home storage paired with rooftop solar. In 2024, nearly 580,000 new battery systems were installed, bringing the total to about 1.8 million—an annual growth of 50% (BSW-Solar, 2025). The German Solar Association has called battery integration with PV "the new standard," and ongoing policy reforms aim to remove market barriers, streamline permitting, and permit grid-feed from home batteries (BSW-Solar, 2023)

The country's progress is supported by a mature solar market, robust R&D ecosystem, and evolving regulatory landscape. Nonetheless, the misalignment between peak solar output and system demand continues to pose a barrier. Additional challenges include legacy permitting complexities, and market access limitations for storage systems.

Brazil:

Brazil has become Latin America's leader in distributed solar PV, with over 37 GW installed by early 2025—supplying approximately 5.6% of national electricity generation for the year 2024 (ABSOLAR, n.d) (EPE, 2025). Rooftop solar reduces daytime demand on local grids, especially in solar-rich states like São Paulo and Minas Gerais, where generation often aligns with commercial and industrial peak loads (PV magazine, 2024).

To manage the growing evening "load ramp," Brazil is expanding battery energy storage. In 2024, 269 MWh of new BESS capacity was installed (Greener, 2025) (Energy Storage News, 2025), and 2025 marks the rollout of the country's first formal regulatory framework for grid-connected and distributed batteries (PV magazine Brasil, 2025). Government-backed auctions are expected to unlock multi-gigawatt storage deployment by 2027–2029, complemented by tax incentives for local BESS manufacturing and proposals to reduce import duties (The Smarter E, 2025).

Enablers include generous net metering through 2045, abundant solar resources, and emerging fiscal and regulatory support for storage. However, the sector still faces high capital costs, evolving regulations, limited grid capacity, and gaps in technical skills (Energy Tracker Asia, 2025) (PVknowhow, 2025).

Insights: Across countries with high rooftop solar adoption, a common pattern is emerging: while solar PV can substantially reduce midday grid demand, its contribution to actual system peak shaving is increasingly limited by the shift in peak hours to the evening. This has made energy storage not just a complementary technology, but a necessary one. Countries like Australia are leading in integrating rooftop solar with storage, while others like the Netherlands and Germany are quickly catching up through targeted policies and infrastructure investments. The alignment of incentives, regulatory reforms, and grid modernisation will be critical to fully realising the potential of rooftop solar in reducing peak demand and enabling a resilient, low-carbon energy future.

Table 2 Country comparison - rooftop solar impact and challenges

Country	Impact on Peak Demand	Main Challenge	Storage Progress	Government Support for BESS
Australia	Strong (up to 100% offset, some negative demand)	Peak shifts to evening (“duck curve”)	High uptake (852 MWh added in 2024)	Battery rebates, investment schemes
Netherlands	Moderate (esp. C&I, less in winter)	Evening peaks dominate	Scaling up (subsidies, pilots)	€100M battery fund, smart tariffs
Germany	High (midday peaks) (some curtailment)	Evening peaks dominate	Rapid growth (5,80,000 battery systems in 2024)	Battery standards, policy reforms
Brazil	Medium (sunny daytime local peak)	Evening peak dominate	Early stage (269 MWh in 2024 auctions)	Regulatory reforms and tax incentive

Source: ABSOLAR, n.d.; ACM, 2024; AEMO, 2024; Bricknest, 2025; BSW-Solar, 2023; BSW-Solar, 2025; DCCEEW, 2025; Eneco, 2025; Energy Storage News, 2024; Energy Tracker Asia, 2025; Fraunhofer ISE, 2025; Frontiers in Energy Research, 2023; Greener, 2025; GridX, 2025; IEA-PVPS, 2024; Powerlink Queensland, 2024; PV Magazine, 2025; PVknowhow, 2025; The Smarter E, 2025.

Benchmarking States on Rooftop Solar Adoption

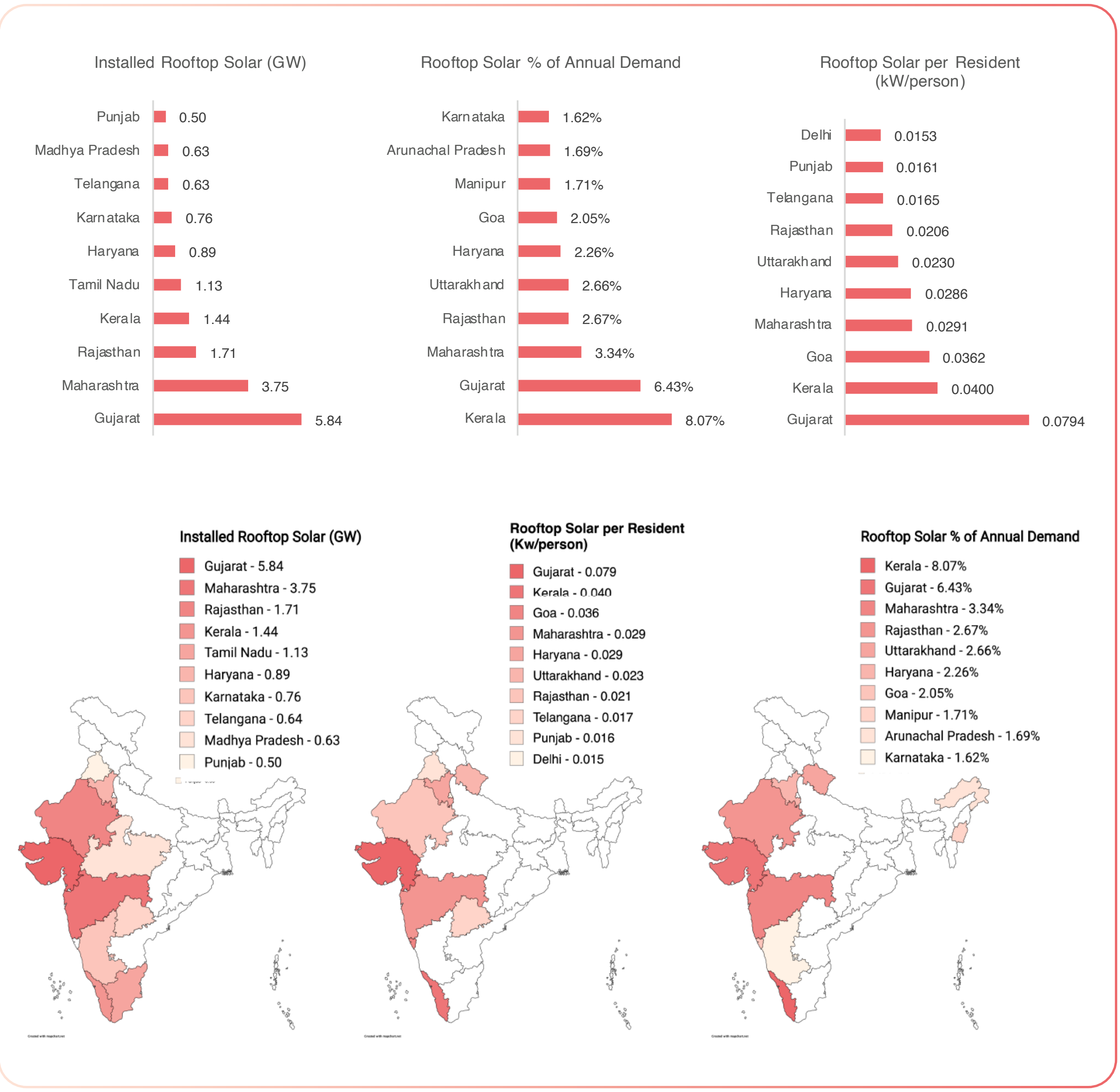
India's rooftop solar adoption exhibits a wide variation across states, influenced by differences in policy support, grid infrastructure, and consumer uptake. This section compares rooftop solar deployment across states using three key indicators: (i) installed capacity, (ii) share of annual electricity demand met, and (iii) kilowatts per resident, offering a clear lens to assess Tamil Nadu's position and opportunities for growth.

Table 3 State comparison - rooftop solar penetration

State/UT	Installed Rooftop Solar (GW)	Rooftop Solar % of Annual Demand	Rooftop Solar per Resident (kW/person)
Gujarat	5.84	6.43%	0.0794
Maharashtra	3.75	3.34%	0.0291
Rajasthan	1.71	2.67%	0.0206
Kerala	1.44	8.07%	0.0400
Tamil Nadu	1.13	1.55%	0.0146
Haryana	0.89	2.26%	0.0286
Karnataka	0.76	1.62%	0.0110
Telangana	0.63	1.31%	0.0165
Madhya Pradesh	0.63	1.09%	0.0071
Punjab	0.50	1.24%	0.0161
Andhra Pradesh	0.43	0.86%	0.0080
Uttar Pradesh	0.38	0.43%	0.0016
Delhi	0.34	1.46%	0.0153
Uttarakhand	0.27	2.66%	0.0230
Bihar	0.19	0.77%	0.0015
Chhattisgarh	0.15	0.64%	0.0047
Assam	0.11	1.48%	0.0030
Odisha	0.11	0.43%	0.0023
Dadra & Nagar Haveli and Daman & Diu	0.11	1.46%	0.0714
Jharkhand	0.09	0.78%	0.0023
Chandigarh	0.07	6.68%	0.0570
Puducherry	0.07	3.60%	0.0392
West Bengal	0.07	0.18%	0.0007
Himachal Pradesh	0.06	0.80%	0.0083
Goa	0.06	2.05%	0.0362
Jammu & Kashmir	0.04	0.44%	0.0031
Tripura	0.01	1.33%	0.0029
Manipur	0.01	1.71%	0.0031
Arunachal Pradesh	0.01	1.69%	0.0042
Andaman & Nicobar Islands	0.01	2.89%	0.0138
Sikkim	0.01	1.40%	0.0073
Ladakh	0.00	2.68%	0.0132
Mizoram	0.00	0.52%	0.0024
Lakshadweep	0.00	4.30%	0.0232
Nagaland	0.00	0.20%	0.0004
Meghalaya	0.00	0.02%	0.0001

Source: MNRE, 2025; CEA, 2022; MoHFW, 2020 (CUF assumed ≈ 17%)

Figure 2 State comparison - rooftop solar penetration, top ten states



Source MNRE, 2025; CEA, 2022; MoHFW, 2020

Case Studies from Gujarat, Haryana, Kerala, Uttarkand and Maharashtra

Rooftop solar has helped several Indian states lower their electricity demand during the daytime, easing pressure on the grid and cutting the need for expensive power plants. However, most are now challenged by evening peaks when solar is unavailable. These case studies from Gujarat, Kerala, Haryana, Uttarakhand, and Maharashtra highlight both the daytime benefits and the need for storage and new solutions to manage evening demand.

Case Study **Gujarat**

Rooftop solar has a pronounced impact on peak electricity demand, particularly during sunny daytime hours. With the highest installed rooftop capacity in India, rooftop PV in Gujarat has increasingly enabled residential, commercial, and agricultural consumers to offset grid imports, flattening local distribution feeders' midday peaks (Gujarat Information Department, 2025) (MNRE, 2025). Gujarat is the leading state if it comes to rooftop solar capacity per resident (kW/person) and is only second behind Kerala in terms of estimated rooftop solar energy share on total annual energy demand. However, like other high-solar regions, Gujarat faces the challenge of the "evening peak": as the sun sets, grid demand rapidly ramps up, requiring conventional generation or imports (ICED, n.d.). Gujarat is beginning to see pilot projects and policy discussions around battery storage for both urban and agricultural consumers, plus feed-in tariffs and aggregator-driven business models (TERI, 2025). But, distributed storage deployment is still at an early stage and regulatory frameworks for aggregating and remunerating storage participation are nascent.

Case Study

Kerala

Kerala, with the highest rooftop solar energy share on total annual electricity demand and the second-highest residential rooftop penetration relative to state population. Before PM Surya Ghar, Kerala promoted rooftop solar through Soura programme under the Urja Kerala Mission. It has aslo developed a rooftop solar portal "E-Kiran" for consumers to register, submit subsidy applications, and track their applications. The state's rooftop solar systems now generate sufficient power to meet 22% of daytime electricity demand (Mercom India, 2025). However, Kerala faces a supply-demand timing mismatch, as peak electricity demand occurs between 6 pm and 11 pm (ICED, n.d.) when solar generation is unavailable, while solar producers consume only 36% of their generated power during daylight hours and export 64% to the grid (Down to Earth, 2025). BESS adoption is limited but growing, with few projects (TPREL, 2025). The draft Kerala Power Policy 2025 promotes energy storage solutions (ESS). However, the accompanying draft net metering regulations place a restrictive eligibility cap-limiting installations to 1 kW (minimum) and 3 kW (maximum), extendable to 5 kW for systems equipped with hybrid inverters having at least 30 % storage capacity. This raises concerns about higher cost and potential slowdown in adoption.(ANERT, 2024; Mercom India, 2025).

Case Study

Haryana

As of 31 July 2025, Haryana had installed 889.60 MW of grid-connected rooftop solar, (MNRE, 2025). The Draft Haryana Solar Power Policy 2023 proposed a target of 1,600 MW of rooftop solar and 1,200 MW through solarised irrigation pumps by 2030 (HEREDA, 2023). In addition, the state has announced plans to solarise government buildings (approximately 122 MW potential) and to install 2.20 lakh rooftop systems by FY 2026–27 (PTI, 2025). Haryana's hourly demand profile shows demand peaking in the mid-afternoon and then declining toward evening. Haryana exhibits a daytime peak with a dip in the early evening, followed by a modest rebound at night (ICED, n.d). This indicates that rooftop PV aligns partly with the state's peak demand, but evening demand management and complementary storage solutions remain important for balancing fluctuations. Studies show that daytime rooftop PV reduces feeder loading, mitigates transformer stress, and can improve voltage profiles under high penetration levels (NREL, 2021) (TERI, 2020). This indicates that similar impacts may unfold in the state as adoption scales. The state has now entered procurement for a standalone BESS. However, the project is still at a very early stage, and no commissioned assets have been reported; storage uptake currently lags behind rooftop solar growth.

Case Study Uttarakhand

Rooftop solar in Uttarakhand is rapidly scaling, especially in hillside settlement clusters and remote villages where new solar projects can directly offset daytime grid demand and reduce diesel generator reliance. The state has set a target of 1,400 MW of distributed solar capacity by 2027 (GoUK, 2023). To support this, Uttarakhand provides an additional state subsidy on top of the central assistance, along with schemes (UREDA, n.d) and targeted incentives for residential and commercial-industrial consumers (GoUK, 2023). These measures, combined with sizeable central support, are driving new adoption across both urban and rural segments. The main challenges, however, remain unresolved. Grid integration in hilly terrain poses persistent technical difficulties (Singh et al., 2024), yes while delays in subsidy disbursement undermine consumer confidence and vendor liquidity. At the same time, the state has a limited pool of trained technicians and installers, which continues to slow down deployment in rural and peri-urban areas.

Case Study Maharashtra

Maharashtra's rapid climb to the second-highest rooftop solar capacity in India is driven by strong policy incentives, including net metering, the Central Financial Assistance (CFA), and the comparatively high household electricity rates (MNRE, 2025) (CEEW, 2025a). This growth is supported by a favourable policy framework, including the availability of all five metering regimes—net metering, gross metering, net billing, group net metering, and virtual net metering (CEEW, 2025a)—which gives households and commercial consumers flexibility to choose models best aligned with their load patterns. For residential users, the combination of central financial assistance (CFA) under the PM–Surya Ghar scheme and Maharashtra's relatively high household electricity tariffs makes rooftop solar particularly attractive.

Hourly demand data for Maharashtra show a clear afternoon peak, coinciding with rooftop PV output. This alignment allows solar to directly contribute to peak demand relief, particularly in urban centres with heavy loads (ICED, 2025). However, the curve also illustrates that evening demand remains substantial (ICED, 2025), underscoring the need for complementary storage and demand-side management solutions to sustain flexibility after sunset. Efforts to complement rooftop solar with distributed battery energy storage remain nascent. As a result, rooftop solar has expanded rapidly, but its potential to fully reshape Maharashtra's load curve remains constrained until storage or demand-side management solutions scale.

Table 4 Key enablers and challenges across the states: Gujarat, Kerara, Haryana, Uttrakhand; Maharashtra

States	Key enablers	Challenges
Gujarat	Ambitious state targets, and a proactive distribution utility	Peak load shift to evening, grid management at local substations, early-stage storage markets
Kerala	High household interest, effective utility engagement, progressive local government programs	Seasonal variability, evening peak ramping, and high up-front BESS costs
Haryana	Mandates for rooftop solar on new government and some private buildings	"Duck curve" effect, limited distributed storage, and evolving regulatory framework for grid services.
Uttarakhand	High rural energy demand, effective net metering (including export tariff), targeted state subsidies, and proactive state agency support.	Grid integration in mountainous regions, small installer base, delays in subsidy clearance, and modest impact on evening
Maharashtra	Attractive government subsidy, robust net metering, strong solar resource, and a progressive regulatory response to sector needs	Limited battery storage penetration, policy uncertainty over banking, a mismatch between solar output and evening peak, and slow administrative approvals for new systems

Cross-State Lessons: Across all leading Indian rooftop solar states, daytime grid peak demand is declining due to solar adoption, enhancing efficiency and reliability at the distribution level. However, without storage, the shift in system peak to evening hours is now common, echoing international "duck curve" challenges.The imperative is clear: Pairing rooftop solar with battery storage—and enabling advanced grid management—will be essential for maximising the grid benefits and sustainability of high rooftop solar adoption. Programs and pilots now taking off in these states should be scaled up, with regulatory reforms, granular incentives, and business model innovation at their core.

State-wise Policy Landscape for Rooftop Solar in India

Solar metering mechanisms: Net metering is now universally permitted across all Indian states and union territories, establishing it as the foundational model for consumer participation in rooftop solar. Several states provide additional flexibility through net feed-in/net billing (exporting surplus energy) and gross metering (exporting all energy). States like Andhra Pradesh, Assam, Kerala, and Maharashtra allow both, supporting diverse consumer needs and business models. A few progressive states and union territories—such as Delhi, Maharashtra, Goa, and Chandigarh—offer group or virtual net metering. This enables collective rooftop solar generation for apartments, institutions, or disaggregated buildings and is particularly relevant for urban areas and dense built environments.

Annual settlement of credits is the most common practice across states for net metering and net feed-in. A few states use monthly or half-yearly settlements, particularly for net feed-in arrangements. Most residential consumers are allowed to install systems up to 100% of their sanctioned load (SL). Commercial and Industrial (C&I) users often face stricter limits—for example, 50–75% of SL in Gujarat, Haryana, and Telangana. A few states permit significantly larger systems; Maharashtra allows installations up to 5,000 kW.

Solar capacity limitations: To manage grid stability, many states restrict solar system size or energy export based on sanctioned load or historical consumption, often capping exports at 50–80% of usage. Limits based on distribution transformer (DT) capacity are also common, with norms such as 75% to 100% of DT capacity in states like Assam, Punjab, and Odisha.

Peer-to-peer (P2P) trading is currently permitted only in Delhi, Karnataka, and Uttar Pradesh, representing a new frontier for decentralised energy exchange.

Time-of-Day (ToD) tariffs to incentivise exports during peak hours are offered in Goa, Tamil Nadu, Tripura, and some union territories.

Network charges: Tamil Nadu is among the few states to implement a network or grid support charge on gross solar generation—a unique and contested approach not commonly observed elsewhere in India.

Despite MNRE guidelines, policy fragmentation persists. Each state continues to design rooftop solar policies tailored to its grid, consumer base, and local priorities. While this supports local innovation, it also creates inconsistencies that can deter investment and slow nationwide scale-up.

Table 5 : Rooftop solar policy landscape of states and union territories

State	Net Metering	Net Feed-In	Gross Metering	Virtual/ Group	Settlement Period	Typical Size Limit (kW)	Max % of Sanctioned Load	Export/Consumption Limit	Notable Policy Feature(s)
Andaman & Nicobar I.	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering, wide mechanism
Andhra Pradesh	Yes	Yes	Yes	Yes	Yearly	1–1000	100%	80% of consumption	Group metering
Arunachal Pradesh	Yes	Yes	Yes	Yes	Yearly	1–1000	80%	80% of consumption	
Assam	Yes	Yes	No	No	Yearly (Net M)	1–1000	80%	80% of consumption	Export=consumption limit
Bihar	Yes	No	Yes	No	Yearly	1–SL	100%	80% of consumption	
Chandigarh	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Chhattisgarh	Yes	No	No	No	Yearly	1–500	100%	100%	
Dadra Nagar Haveli & DD	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Delhi	Yes	No	No	Yes	Yearly	1–SL	100%	100%	Peer-to-peer + virtual metering
Goa	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	ToD, group metering
Gujarat	Yes	No	Yes	No	Yearly	1–1000	50% (C&I), 100% (Res)	100% of DT	ToD pilot; strong utility support
Haryana	Yes	No	Yes	No	Yearly	1–500 (Res), 1–SL (C&I)	50% (C&I), 100% (Res)	50% (C&I), 100% (Res)	Consumption/export cap
Himachal Pradesh	Yes	Yes	No	Group	Yearly	1–1000	50%	70% of DT	Group metering
Jammu & Kashmir	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Jharkhand	Yes	No	Yes	Yes	Yearly	1–2000	100%	100%	Group metering
Karnataka	Yes	No	Yes	No	Yearly	1–1000	80%	80% of consumption	Peer-to-peer
Kerala	Yes	Yes	Yes	No	Yearly	1–1000	100%	75% of DT	Soura program
Ladakh	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Lakshadweep	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Madhya Pradesh	Yes	No	Yes	Yes	Yearly	1–500	80%	80% of DT	Group metering
Maharashtra	Yes	Yes	Yes	Yes	Yearly	1–5000	100%	70% of DT	Group metering, large size
Manipur	Yes	No	Yes	No	Yearly	1–10	100%	100%	
Meghalaya	Yes	No	No	No	Yearly	1–1000	100%	15% of DT	Export/consumption cap
Mizoram	Yes	No	Yes	No	Yearly	1–10	100%	100%	
Nagaland	Yes	No	Yes	No	Yearly	1–500	100%	100%	
Odisha	Yes	No	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Puducherry	Yes	Yes	Yes	Yes	Yearly	1–500	100%	75% of DT	Group metering
Punjab	Yes	Yes	Yes	No	Yearly	1–500 (Res), 50–SL (Grp)	100%	80% of SL	Group metering, agri focus
Rajasthan	Yes	Yes	Yes	No	Yearly	1–1000	100%	80% of SL	Type-dependent limits
Sikkim	Yes	No	No	No	Yearly	1–500	40%	30% of DT	
Tamil Nadu	Yes	Yes	Yes	No	Yearly	1–999 (most)	90–100%	90% of DT	ToD, network charge
Telangana	Yes	No	Yes	No	Half-yearly	1–1000	50%	50% of SL	
Tripura	Yes	No	Yes	Yes	Yearly	1–10	60%	60% of DT	Group metering
Uttar Pradesh	Yes	Yes	Yes	No	Yearly	1–2000	100%	75% of DT	Peer-to-peer
Uttarakhand	Yes	No	No	Yes	Yearly	1–1000	100%	100%	Group metering
West Bengal	Yes	Yes	Yes	No	Yearly	1–500	100%	100%	

Tamil Nadu Rooftop Solar: A Decade of Growth and the Road Ahead

The past 10 years of progress: Rooftop solar growth in Tamil Nadu has remained steady over the past decade, with annual growth rates not varying dramatically year to year. By mid-2025, rooftop solar capacity crossed 1,000 MW, but this is still less than 10% of Tamil Nadu's utility-scale solar capacity (Auroville Consulting, 2025)). The biggest increase in capacity came in 2024–2025, when more than 200 MW of rooftop solar was added. In terms of percentage, the highest annual growth was in 2018 at 84%. However, overall growth has been steady rather than accelerating.

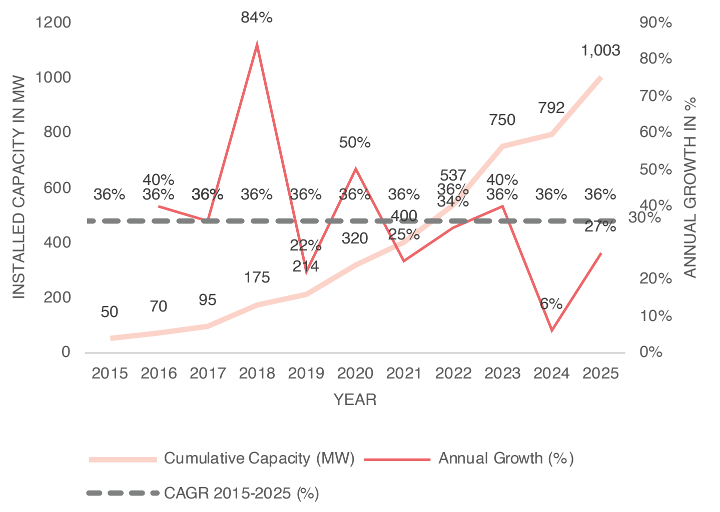
Below is the annual installed capacity (cumulative, MW) of rooftop solar in Tamil Nadu for the last ten years, collected from government and trade sources. Tamil Nadu's rooftop solar adoption has been steady but gradual relative to its significant potential and population.

Table 6 Tamil Nadu Rooftop Solar Progress 2015-202

Year	Cumulative Rooftop	Annual growth
2015	50	
2016	70	40%
2017	95	36%
2018	175	84%
2019	214	22%
2020	320	50%
2021	400	25%
2022	537	34%
2023	750	40%
2024	792	6%
2025	1,003*	27%

Sources: MNRE. 2025, Auroville Consulting 2025
*(*Data as of June 2025)*

Figure 3 Tamil Nadu Rooftop Solar Progress 2015-2025



Rooftop solar potential and its future:

Tamil Nadu's rooftop solar potential is estimated at 60,479 megawatts (MW), a figure that vastly exceeds current levels of deployment. If fully utilized, this potential could translate to approximately 95.40 terawatt-hours (TWh) of electricity annually—enough to cover 47% of Tamil Nadu's projected electricity demand in 2030–31, or 38% by 2034–35 (C-STEP 2025) (Auroville Consulting, 2025). This rooftop solar estimate forms a substantial part of a broader distributed solar energy resources (DER) potential of 129,166 MW, which encompasses other applications such as floating, canal-top, rail- and road-integrated, building-integrated, and urban photovoltaic systems (Auroville Consulting, 2025) (C-STEP, 2025).

Despite this remarkable potential, Tamil Nadu had installed only around 1,003 MW of grid-connected rooftop solar as of June 2025, achieving less than 2% of its total technical rooftop potential (Auroville Consulting, 2025). This level of deployment is less than 10% of the state's utility-scale solar capacity and amounts to under 30% of its policy target for distributed, consumer-scale solar of 3,600 MW by 2023.

Table 7 Estimated rooftop solar potential for Tamil Nadu

Metric	Value	Units
Estimated Total Rooftop Solar Potential	60,479	MW
Current Installed Rooftop Solar (as of June 2025)	1,003	MW
Share of Rooftop Potential Realized	1.67	%
Annual Gen. Potential (Full RTS)	95.40	TwH
% of 2030–31 Projected Demand	47	%

Sources: CSTEP 2025, Auroville Consulting 2025

KUSUM-C Challenges & Opportunities:

The implementation of KUSUM-C in Tamil Nadu was formally shaped by a series of Tamil Nadu Electricity Regulatory Commission (TNERC) orders and consultative processes from 2020 onward. In September 2020, TNERC initiated broad stakeholder engagement around a proposed levelized tariff of ₹2.28/kWh for 25 years, targeting the solarization of 20,000 grid-connected agricultural pumps. This process solicited extensive sector feedback before emerging as a formal tariff order (TNERC, 2020a). TNERC issued successive orders that approved the solarization scheme, officially designated the Tamil Nadu Energy Development Agency (TEDA) (now merged into TNGECL) as the nodal implementation agency, and detailed procurement and implementation guidelines for TANGEDCO (now renamed as TNPDCL), the state's distribution utility (TNERC, 2020a) (TNERC, 2021b).

A notable feature of these orders was the approval of both CAPEX and RESCO implementation models. The RESCO (Renewable Energy Service Company) model allowed TEDA to contract private developers who finance, build, and operate the solar systems at no upfront cost to farmers. Under this model, the developer recovers investment via long-term tariffs paid by TANGEDCO, while farmers continue to receive free or subsidized power for irrigation (TNERC 2020a). Additional farmer benefits included the potential for export incentives: should solar systems generate surplus power beyond on-farm needs, farmers could receive direct payments or credits for grid exports. The orders also addressed cost-sharing arrangements, time-bound commissioning and the assurance of streamlined regulatory and payment structures to speed deployment and reduce barriers for both farmers and developers (TNERC, 2021b). However, while the scheme had many promising features and potential to reduce TANGEDCOS cross-subsidy burden, it was never taken up for implementation. Adoption of behind-the-meter, grid-interactive solar energy in Tamil Nadu's agricultural sector has been limited, as electricity for farming is provided free of charge. The KUSUM-C scheme, announced in

Tamil Nadu in 2019, was designed as a third-party model in which a solar developer would install solar energy systems at the farm level and sell the generated power to the Discom. Under this arrangement, farmers would continue receiving free grid electricity and also benefit from a solar incentive. However, the scheme relied on the introduction of energy meters, while farm electricity consumption is currently unmetered. This metering requirement was seen as a step toward reintroducing electricity charges for farmers, leading to strong opposition.

Surya Ghar Challenges & Opportunities:

Tamil Nadu officially launched the PM Surya Ghar Muft Bijli Yojana in February 2024, appointing TANGEDCO (now renamed as TNPDCL) as the nodal agency and targeting millions of households across the state (TANGEDCO, 2024). Consumers are encouraged to apply online via the Surya Ghar portal or local TANGEDCO offices, with the process enabled by digital verification and automatic integration with state DISCOM billing systems. All domestic consumers, including tenants and housing society members, are eligible for central subsidies, but no additional state incentives are currently offered (TANGEDCO, 2024).TANGEDCO maintains that existing net metering policies apply (TNPDCL, n.d) and has set up district-level solar helpdesks and awareness campaigns to facilitate uptake.

As per July, 2025 data, Tamil Nadu has received 99,244 applications, installation realisation of less than 40%, covering 43,808 households, and 136.38 MW of commissioned capacity (PM Surya Ghar portal). However, TANGEDCO has acknowledged slow adoption rates, attributing this largely to Tamil Nadu's free electricity schemes and limited financial benefit for many households. No extra state support, concessional loans, or incentives beyond the central scheme have been introduced, although further communication drives are planned in areas with high rooftop potential (TANGEDCO, 2024).

Table 8 Policy enablers and barriers for rooftop solar in Tamil Nadu

Thematic Area	Policy Enablers	Policy Barriers
Application & Digital Process	- Integrated online applications and consumer detail verification via TANGEDCO/ TNPDCL and the national portal.	- Technical integration issues between TNPDCL and MNRE portals caused approval and billing delays.
Subsidies & Affordability	- Up to 60% central subsidy for ≤2 kW via PM Surya Ghar.	- No new Tamil Nadu top-up subsidy; only central support, making installations less financially attractive particularly for households with low electricity consumption and low tariffs.
Technical & Regulatory Process	- No technical feasibility needed for most domestic systems under 3 kW.	- Delays and inconsistencies in metering upgrades, vendor approvals, and post-installation grid/billing integration.
Net Metering & Net Feed-in	- Net metering is available for all domestic consumers, net feed in is available to all consumers	- Export cap: household net metering capped at 90% of consumption per year; this especially limits benefits for high-generation.
Loan/Vendor Support	- Loans/support for installation.	- Shortage of approved/empanelled vendors and limited bank tie-ups restrict consumer choice and delay deployment.
Consumer Awareness & Engagement	- Awareness campaigns, vendor helpdesks, outreach in urban/ semi-urban centres to drive knowledge and interest.	- Persistently low household awareness and motivation, especially where free/subsidised power means little/no bill savings from solar.
Network Charges	- For MSMES and domestic consumers, partial relief from network charges after 2025 High Court order.	- Network (grid support) charges on the rooftop solar generation for all users, reduce investment attractiveness for prosumers.

Lessons and Takeaways for Tamil Nadu

Despite steady national progress, behind-the-meter solar, such as rooftop solar or solar for agriculture in Tamil Nadu, remains at an early stage, with household-level adoption and share of electricity demand well below that achieved in leading countries or states. The real transformative impact, as global experience shows, comes from widespread, equitable household and institutional adoption. Thus, Tamil Nadu should go beyond aggregate MW targets and set clear goals for the number of homes and buildings equipped with rooftop solar. Global experience also highlights the importance of scaling up BESS alongside distributed solar to maximize grid benefits, an area where most Indian states are still in the early stages. However, BESS becomes a priority after distributed solar reaches a meaningful share of total system capacity.

03 Distributed Solar & Large Solar Development

Distributed energy resources like rooftop solar, alongside utility-scale solar, are vital for India's clean energy transition, offering faster deployment, land savings, grid resilience, job creation, and subsidy reduction to overcome the limits of centralized models.

In order to accelerate India's renewable energy transition and meet the surging electricity demand, it is critical to leverage the complementarity between Distributed Energy Resources (DER) like rooftop solar and ultra-megawatt ground-mounted (UMW) solar systems. However, continued reliance on centralized models alone is increasingly constrained by land acquisition challenges, grid congestion, and the financial stress faced by electricity distribution companies (DISCOMs).

In this context, the solar DER model, specifically behind-the-meter (BTM) systems such as rooftop solar, can complement solar capacity expansion. The deployment of solar DER is increasingly recognised as a strategic need to meet growing power demand and reduce technical losses in electricity distribution, with schemes like PM Surya Ghar Muft Bijili Yojana and PM KUSUM directly promoting distributed solar adoption. This is further reinforced by the revised Renewable Purchase Obligation (RPO) norms, which require distribution licensees to increase the share of distributed renewable energy in their supply mix from 1.50% in 2024–25 to 4.50% in 2029–30 (PIB, 2024a). This chapter undertakes a comparison of DER and UMW solar across a common set of indicators. The goal is to guide policymakers and planners in designing a more balanced and resilient deployment strategy.

Comparison Framework

DER and UMW solar projects, while both being solar technology, differ in design and interaction with the electricity system in terms of resources, technical specifications, business models, and implementation. An indicator-based approach helps bring these differences into view. It allows planners, utilities, and policymakers to view the trade-offs between the two deployment models across a range of outcomes- such as revenue, cost savings, grid operations, and societal co-benefits. This method was chosen to allow policy makers to take a more multi-faceted view that goes beyond procurement cost and kWh cost alone, and considers human health and environmental concerns, energy security considerations, land use implications and implementation capacities, to name a few.

This indicator-based framework approach is aligned with international best practices, which recommend evaluating DERs using multi-dimensional frameworks. For example, the Rocky Mountain Institute (RMI) notes that no single value can fully capture the benefits of DERs, and uses multiple monetised and non-monetised indicators to reflect stakeholder-specific impacts such as avoided system costs, grid impacts, and community-level benefits (RMI, 2013). Similarly, another study argues that when exact numbers are not available, informed judgments based on real-world experience are still important (IREC, 2013).

The process of identifying indicators was carried out in two stages. The first stage review of national and international studies was done to assess the costs and benefits of distributed and utility-scale solar. This helped in identifying how solar models have been evaluated across various dimensions of cost, resources, grid interaction, planning and societal impacts. In the second stage, the list of indicators was refined to focus on those that matter for the Indian context, affecting cost, resources, grid operations and co-benefits. Each indicator had to meet three conditions:

1. **Planning relevance:** The indicator had to relate to the kinds of trade-offs planners, policy makers and regulators face, such as cost - installation costs and LCOE, impact on state- subsidy, impact on DISCOMS revenue- impact on billing, impact on grid - avoided costs, and co benefits- employment, which model can provide.
2. **Comparability:** Given the differences between DER and UMW solar, indicators were selected to enable comparison by a uniform standard, such as land use per MW, and impact on the grid.
3. **Evidence:** Each indicator should be assessable using available data and documented implementation experience. Where quantitative data were limited, qualitative assessment was grounded in field experience and various studies conducted to understand their impact.

Table 9 Framework for a Multi-dimensional Assessment of DER and UMW

#	Indicator	Unit	Description
1	Installation Cost	₹/kW	Capital cost required to install the system per kW
2	Levelised Cost of Energy (LCOE)	₹/kWh	Cost of generating each unit of electricity
3	Employment	FTE per MW	Full-time equivalent jobs generated per MW of installed capacity.
4	Land Requirement	MW/acre	Land area required per MW of installed capacity
5	Avoided Cost	₹/kWh	- Avoided Energy Cost (₹/kWh) - Avoided Generation Capacity Cost (₹/kWh) - Avoided Transmission Capacity Cost (₹/kWh) - Avoided Distribution Capacity Cost (₹/kWh)
6	Avoided Subsidy Amount	₹/kWh	The amount that can be avoided per unit of electricity consumed.
7	Supply Resilience	High or Low	Risk of generation loss due to external disruptions such as weather or natural disasters.
8	Energy Self-Reliance	High or Low	The extent to which the system can supply demand locally, especially when combined with storage.
9	Siting Flexibility	High or Low	Deployment can be targeted depending on locations and demand requiring less regulatory and process and approval
10	Voltage Control	High or Low	Aid in the under voltage problem in feeders
11	Impact on Billing	Yes or No	Effect on the quantity of electricity units that can be billed by the DISCOM.

Installation Cost: Installation cost refers to the capital expenditure required to set up one kilowatt (kW) of solar capacity. For rooftop solar, market insight data from April 2025 indicate total installed costs from ₹ 1.75 to 2.05 lakh for a 2 kW system (₹ 87,500/kW - ₹ 1,02,500/kW) to ₹ 5.70– ₹ 6.40 lakh for a 10 kW system (₹ 57,000/kW- ₹ 64,000/kW) (SolarSquare, 2025), with per kW costs declining as system size increases. These depend on factors such as panel type, inverter technology, mounting structure height, cable length, roof type, location, and after-sales service packages (SolarSquare, 2025). For UMW solar, industry benchmarks range from ₹ 3 to ₹ 5 crore/MW (₹ 30,000/kW - ₹ 50,000/kW) depending on location, construction and system configuration like panels, distance from substation etc. DRE systems cost more in per-kW terms than ground-mounted systems due to smaller system size and site-specific installation configurations. In contrast, ground-mounted solar is lower per kW but incurs additional costs in land acquisition, transmission infrastructure, and centralized grid integration.

Levelized cost of electricity (LCOE): The LCOE measures the average cost of producing one kilowatt-hour (kWh) of electricity over the lifetime of a project, accounting for capital expenditure, operations and maintenance, and financing. It enables a direct comparison between technologies and scales by standardising costs on a per-unit generation basis. Using ranges of capital cost, the LCOE were calculated based on standard lifetime and performance assumptions.

For ground-mounted ultra-megawatt (UMW) solar, we used a capital cost range of ₹ 3–₹ 5 crore/MW (₹ 30,000 to ₹ 50,000/kW) based on market analysis. An LCOE between 2.32 ₹/kWh and 3.87 ₹/kWh was determined.

Table 10 LCOE for UMW solar

Capital cost - ₹/kW	LCOE (₹/kWh)
50,000	3.87
45,000	3.48
40,000	3.09
35,000	2.71
30,000	2.32

Source: SECI tender website; Mercom India, 2025b and Market analysis

For rooftop solar, we adopted a capital cost range of ₹ 50,000 to ₹ 70,000 per kW. The lowest value reflects the MNRE benchmark cost (TNERC, 2021a), while the highest is based on installers' feedback, where quotes ranged from ₹ 45,000 to ₹ 70,000 per kW depending on location, system configuration, and component choices. The same range was taken for KUSUM-C (IPS).

At these capital costs, the unsubsidised LCOE for rooftop solar ranges from ₹ 3.88 to ₹ 5.25 per kWh. With capital subsidies, the LCOE falls to between ₹1.84 and ₹ 3.20 per kWh, and under the KUSUM-C programme with subsidy support it can reach as low as ₹1.77 to ₹ 2.29 per kWh. If network charges are levied, however, the LCOE increases again, to between ₹ 4.20 and ₹ 5.57 per kWh without subsidies, and ₹ 2.16 to ₹ 3.52 per kWh when subsidies are included. However, LCOE alone does not capture the additional system benefits of rooftop solar, such as avoided land use, reduced T&D losses, and improved supply resilience.

Table 11 LCOE for rooftop solar and KUSUM-C (IPS)

Capital cost - ₹/kW	RTS -LCOE (₹/kWh)	RTS with subsidy -LCOE (₹/kWh)	KUSUM-C with subsidy - LCOE (₹/kWh)	RTS with NC -LCOE (₹/kWh)	RTS with subsidy & NC -LCOE (₹/kWh)
70,000	5.25	3.20	2.29	5.57	3.52
65,000	4.90	2.86	2.16	5.22	3.18
60,00	4.56	2.52	2.03	4.88	2.84
55,000	4.22	2.18	1.90	4.54	2.50

Market analysis and Installers' feedback (NC- Network Charge)

Employment Generation: Employment measures full-time equivalent (FTE) jobs generated per MW of installed capacity across installation and O&M phases. Numerous studies have highlighted employment as a social benefit of solar energy deployment (IREC, 2013) (RMI, 2013) (CEEW, 2017, 2023) (IRENA, 2024) (CLEAN, 2024) (Auroville Consulting, 2019a). Among the various solar technologies, DRE systems such as rooftop solar are found to generate higher employment per megawatt installed compared to utility-scale ground-mounted systems. According to a study, rooftop solar projects create approximately 24.72 FTE job-years per megawatt, while utility-scale solar projects result in 3.45 FTE job-years per megawatt (CEEW, 2017, 2023).

This becomes important as India needs to create 90 million job opportunities by 2030 to absorb 60 million new entrants to the workforce and 30 million people transitioning out of agriculture (Sankhe et al, 2020). In parallel, recognizing the potential of solar DER in supporting livelihood applications, the Ministry of New and Renewable Energy (MNRE) issued a framework for promoting livelihood through decentralized solar systems (MNRE, 2022). Solar DER generates localised employment not just with high FTE, but also by contributing to different applications, enabling entrepreneurship, sustainable livelihoods and reducing rural to urban migration.

Land Requirement: UMW solar projects require large land areas, posing planning and social challenges, whereas rooftop solar systems are a land-neutral option. In Tamil Nadu, meeting 100% of electricity demand with ground-mounted solar would need around 5,383 km², about 4.14% of the state's land, equivalent to the area of Erode district. Even at 50% solar penetration, roughly 3,000 km² would be required, comparable to Chengalpattu district. With each megawatt of utility-scale PV needing 3 to 5 acres, land demand is increasing (Auroville Consulting, 2023c).

Land acquisition, usually expected to take 6–9 months and can extend to 18–24 months in some states (Ember, 2025a). Despite the availability of high-irradiance wastelands, developers often avoid these due to poor accessibility and lack of grid connectivity, pushing projects onto agricultural or peri-urban land. This trend has triggered concerns about land-use conflicts, ecological disruption, and livelihood displacement (Thomas et al., 2022). According to Land Conflict Watch (2025), at least 29 land conflicts are tied to renewable energy projects impacting over 47,000 people and 28,000 hectares of land, affecting investment of ₹ 62,838 crores,

largely due to inadequate consultation and disruption to farming and pastoral practices.
The risks, ranging from legal delays to community opposition, can dilute the perceived cost-effectiveness and scalability of utility solar. In contrast, solar DER systems offer a lower-conflict pathway for expanding clean energy. Systems, such as rooftop solar, building-integrated photovoltaics (BIPV), and canal-top PV installations or rail-top PV installations, use existing infrastructure and avoid new land acquisition.

Avoided cost: Several studies have mentioned the benefits to the utilities which they can incur from solar DER in monetary terms (RMI 2013, IREC 2013, IEA, 2021a, 2021b, 2022, Auroville consulting, 2023b). These studies have mainly referred to the cost which can be avoided by utilities. While exact monetary value depends on location, design and operational conditions, these studies have highlighted broad benefit areas, for example, solar DER can reduce energy purchases that would otherwise be purchased from power plants by signing PPAs. They can lower transmission and distribution losses as production and consumption of electricity is at the installed site. Further, solar DER can reduce the need for future investment in large-scale power plants and grid infrastructure and, in some cases, delay or avoid costly upgrades to substations, transformers, or transmission lines.
In this framework, we recognised these avoided costs[1] -

1. Avoided energy cost (ACE)
2. Avoided generation capacity cost (AGCC)
3. Avoided distribution capacity cost (ADCC)
4. Avoided transmission capacity cost (ATCC)

[1]See Annexure Tables 29-34 for the assumptions used in the avoided-cost calculations for PM Surya Ghar and PM KUSUM-C (IPS). We use Auroville Consulting's Value of Distributed Energy Resources (VODER) method implemented in the Solva tool. Total Network benefits are reported in ₹/kWh as the sum of: ACE, ADCC, ATCC, and AGCC.

Case Studies

Avoided Cost Calculation for PM Surya Ghar

Analysis for PM-Surya Ghar was conducted on a sample domestic HT feeder to evaluate the avoided cost benefits of rooftop solar integration. Assuming each household installs a 2 kW rooftop solar system connected at the tail end. For multiple adoption levels selected, the avoided cost of energy (ACE) was found to be **₹5.05/kWh**, which is higher than the marginal cost considered in the analysis.

Solar energy adoption levels	30%	20%	10%
System size (MW)	9.04	6.02	3.01
ACE (₹/kWh)	5.05	5.05	5.05
ADCC (₹/kWh)	0.02	0.02	0.03
ATCC (₹/kWh)	0.02	0.02	0.02
AGCC (₹/kWh)	0.15	0.15	0.15
Total network benefits	**5.24**	**5.24**	**5.25**

Case Studies

Avoided Cost Calculation for PM KUSUM-C (IPS)

Analysis for PM-KUSUM-C (IPS) was conducted on a sample HT feeder, with high agricultural consumers, to evaluate the avoided cost benefits of solar PV integration. Assuming each farm installs an 11 kW system connected at tail end. For multiple adoption levels selected, the avoided cost of energy (ACE) was found to be **₹4.79/kWh**, which is higher than the marginal cost considered in the analysis.

Solar energy adoption levels	100%	50%	25%
System size (MW)	0.77	0.39%	0.19
ACE (₹/kWh)	4.79	4.79	4.79
ADCC (₹/kWh)	0.00	0.00	0.00
ATCC (₹/kWh)	0.02	0.02	0.02
AGCC (₹/kWh)	0.15	0.15	0.15
Total network benefits	**4.96**	**4.96**	**4.96**

Avoided Subsidy Amount (₹ / kWh Avoided): Avoided Subsidy is the amount of subsidy which can be avoided per unit of electricity consumption. Tariff subsidies form a vital component of India's power distribution sector. These subsidies are provided by the state government to compensate DISCOMs for providing electricity to selected consumer categories such as agricultural, rural, and low-income domestic consumers at prices below the actual cost of supply. Over one-fifth of discom revenue in FY 2023-24 came from state subsidies, a rise from 17.81% the year before (PFC, 2025).

Table 12 Tariff subsidy as a share of total revenue for DISCOMs in India

FY	Tariff Subsidy Billed (₹ crore)	Total Revenue (₹ crore)	Subsidy as % of Revenue
2021-22	1,44,741	8,25,473	17.53%
2022–23	1,69,016	9,48,934	17.81%
2023–24	2,10,784	10,36,543	20.34%

Source: PFC, 2025

From FY 2021-22 to FY 2023-24, the subsidy burden as a proportion of revenue increased by approximately 16%. This highlights a fiscal risk for states and increases the cross-subsidy burden for commercial and industrial users.

From FY 2021-22 to FY 2023-24, total energy sold across India rose by 13%, but subsidy outlays increased by 45.6%. In the same period, the average subsidy per unit sold by Indian DISCOMs grew by nearly one-third, rising from 1.30 ₹/kWh to 1.68 ₹/kWh.

Table 13 Tariff subsidy billed per unit sold (₹/kWh) for discoms, average all India and average Tamil Nadu

Year	India – Tariff Subsidy (₹ crore)	India – Gross Energy Sold (MU)	India – Subsidy per Unit (₹/kWh)	TANGEDCO – Tariff Subsidy (₹ crore)	TANGEDCO – Gross Energy Sold (MU)	TANGEDCO – Subsidy per Unit (₹/kWh)
2021–22	1,44,741	11,09,306	1.30	8,932	82,076	1.09
2022–23	1,69,016	12,07,442	1.40	13,784	87,917	1.57
2023–24	2,10,784	12,52,633	1.68	14,976	92,735	1.61
2024-25	No data	No data	No data	15,852	1,09,939	1.44
2025-26	No data	No data	No data	17,052	1,16,621	1.46

Source: PFC, 2025; CEA 2022; TNERC, 2025c; TNERC, 2025d

In Tamil Nadu, for the FY 2025–26, the estimated subsidy payable by the Government of Tamil Nadu to its distribution utility amounts to ₹ 17,052.14 crore (TNERC, 2025c) (TNERC, 2025d). This corresponds to an average of ₹ 1.46 per unit of electricity (kWh), based on the state's estimated energy consumption of 1,16,621 million units (MU) for the year 2025-26 (CEA, 2022).

DRE systems reduce demand in all sectors, which, in the case of subsidised electricity consumers, translates. into an electricity subsidy reduction to the state government and a cross-subsidy reduction to the DISCOM

Supply Resilience: Risk of generation loss due to external disruptions such as weather or natural disasters. Improving supply resilience is central to energy policy. The conventional grid architecture, which is centralized, linear, and dependent on the seamless operation of all interconnected components, is not well suited to withstand large-scale, long-duration outages caused by extreme weather or other threats (RMI, 2020). Whereas DERs offer a different and resilient model. Diversifying the energy generation with smaller, geographically dispersed units reduces vulnerabilities and isolates risks, enabling portions of the grid to remain functional even when central systems fail (RMI, 2013, 2020).

Having DERs in the utility's energy mix improves grid resilience. Other than providing localised benefit from generation and consumption, it also facilitates faster recovery time. Though the resilience benefits of DERs are difficult to quantify in economic terms, they hold immense value for households, industries, businesses, and essential services that depend on a continuous electricity supply (IEEFA, 2024a). Moreover, a decline in technology costs has made distributed clean energy systems a viable and scalable instrument to safeguard power systems against both chronic stress and acute shocks (IEA, 2022). While UMW solar plants are indispensable for bulk power generation, this dependency limits their resilience contribution at the local level, in situations where grid disruptions occur downstream of generation (RMI, 2020). In contrast, DERs offer a strategic benefit, allowing a higher contribution in improving supply resilience.

Energy Self-Reliance: The extent to which the system can supply demand locally, especially when combined with storage technologies. Access to reliable and affordable energy is foundational to economic development (CEEW, 2025b) (Ringler et al., 2022). Solar DERs have emerged as helpful tools for enhancing energy reliability, particularly at the distribution and end-user levels. As we have seen, their distributed nature enables localised power generation and self-consumption. This reduces dependence on centralised grid infrastructure and provides backup power during outages through combinations of inverters and energy storage technologies (RMI, 2013). Having solar DERs in utilities' energy mix can support their obligation to deliver reliable power to consumers, especially who are vulnerable and underserved, without incurring additional expenditures on grid reinforcement (IREC, 2013). For example, in rural contexts, rooftop solar installations deliver consistent daytime electricity to agricultural users (TERI, 2019).

In contrast, UMW scale solar plants, while important for achieving renewable energy targets and supplying bulk power, are dependent on transmission and centralized grid infrastructure. UMW plants cannot provide localised support during emergencies for example, it is to plan for periods when the sun is blocked by clouds (IEA, 2021a), nor do they directly serve underserved populations unless paired with substantial infrastructure investments. Thus, in the context of enabling energy self-reliance, DERs present a more adaptive alternative which ultimately enhances energy access in the population.

Siting Flexibility: Siting flexibility determines how deployment can be targeted depending on locations and demand, requiring less regulatory and process and approval. All these affect the speed, cost, and scale at which solar capacity can be added.

Solar DER systems, other than being land neutral, connect to the local distribution grid at voltages up to 33 kV and do not need new long-distance transmission lines. Environmental clearances are not required, and regulatory approvals are fewer. As a result, a project can move from planning to operation in three to six months. On the other hand, UMW solar plants must be connected to high-voltage transmission lines and require large sites. This requires the construction of transmission infrastructures and evacuation lines. Projects have to secure multiple approvals, including land acquisition, environmental and social impact assessments, along with public consultations, and interconnection studies, regulatory approval, and clearances are high. These steps, along with the need for ready transmission capacity, mean that even after a project is awarded, commissioning can take three to five years. According to a market insight, multiple large-scale solar projects scheduled for early 2025 faced delays due to limited substation and transmission infrastructure, land acquisition issues, and PPA signing delays (Mercom India, 2025b).
This means DER can be targeted in areas with high demand or network constraints and offers high siting flexibility compared to UMW-scale plants.

Voltage Control: Aid in the under-voltage problem in feeders. Voltage impacts from solar generation differ depending on whether the source is a DER or a UMW solar plant. UMW solar plants, typically connected at 33 kV, 132 kV, or higher transmission levels, contribute to bulk energy supply but have minimal influence on local voltage profiles where voltage deviations such as under voltage or overvoltage occur (GIZ, 2017). Solar DER systems like rooftop solar connected at low (0.4 kV) or medium voltage (11 kV) levels, have a direct and localised impact on voltage. A study showed that rooftop PV can cause voltage rise in rural feeders (GIZ, 2017). However, in weak urban grids like those in Delhi, where under-voltage problems were observed, rooftop PV improved voltage levels (GIZ, 2017). Few studies from Indian feeder modelling show that when solar output matches local demand and systems are placed toward the ends of feeders, they can lift low voltages and help stabilise supply. But where generation exceeds demand, especially close to distribution transformers, the same systems can cause voltage rise and create local imbalances (NREL, 2021; TERI, 2020). The lesson is that the impact of rooftop solar depends as much on where it is located and how it lines up with demand as on how much capacity is added. The GISS tariff order further supports this by highlighting how behind-the-meter systems like rooftop solar coupled with BESS can provide voltage improvement (TNERC, 2021a).

Unlike UMW solar, DERs, which are close to locations where voltage issues occur, have a faster response to stabilize voltage and defer costly upgrades (IEA, 2022). Now, inverters equipped with smart technology, compliant with safety and regulations, are available and being used for installing rooftop solar (TERI, 2019). While both models of solar generation are essential, solar DERs models coupled with smart inverters can help to mitigate localised voltage issues, especially under voltage problems at the distribution level.

Impact on DISCOM Billing: Effect on the quantity of electricity units that can be billed by the DISCOM. In 2023-24, TANGEDCO realised an average revenue of ₹ 10.66 per unit of electricity sold, out of which revenue from the sale of power is 6.37 ₹/kWh (PFC, 2025). The addition of solar DER, such as rooftop systems operating under net metering or net feed-in, directly reduces the volume of electricity billed to participating consumers. Each self-consumed unit displaces a unit of billed sales, creating a revenue reduction of approximately 6.37 ₹/kWh. But the actual net impact is lower when marginal power purchase costs during solar generation hours, reductions in technical losses are accounted for, and fixed charges or applicable network charges are collected. Where rooftop adoption occurs in subsidised consumer categories, the subsidy burden per unit can decline, partially offsetting revenue loss.

Table 14 Tamil Nadu (TANGEDCO) – Revenue Structure on Energy Sold Basis

FY	Gross Energy Sold (MU)	Revenue from Sale of Power (₹/kWh)	Other Operating Income (incl. Wheeling) (₹/kWh)	Tariff Subsidy (₹/kWh)	Other Income & Revenue Grants (₹/kWh)	ARR on Energy Sold Basis (₹/kWh)
2021–22	82,076	4.75	0.29	1.09	1.53	7.65
2022–23	87,917	5.81	0.38	1.57	1.62	9.37
2023–24	92,735	6.37	0.49	1.61	2.18	10.66

Source: PFC 2025 (Note: Other Income & Revenue Grants include revenue grants from GoTN (loss-funding): ₹17,129.76 crore and other income: ₹3,102.39 crore. Total: approx 20,232 crore = 2.18 ₹/kWh)

Utility-scale ground-mounted solar procured under long-term power purchase agreements does not affect the volume of electricity that the DISCOM bills to its consumers. The generation is injected into the grid and sold through existing tariffs, so the financial impact lies on the procurement side. Whether it is favourable or not depends on how the PPA tariff compares with the marginal cost of supply. However, when commercial and industrial consumers meet their demand from utility-scale projects via open access or captive arrangements, their purchases from the DISCOM decline. Because these are high-tariff consumers who contribute to cross-subsidising other customer categories, the revenue loss per unit in such a case can be greater than from rooftop solar installations.

Results of the Multi-dimensional DER and UMW Assessment of: The results below summarise how each model performs across 11 key indicators, providing evidence to inform context-specific solar deployment.

This assessment highlights that while both DER like rooftop solar and UMW utility-scale solar are essential for India's renewable energy transition, they serve complementary roles: UMW solar delivers low-cost bulk generation but faces land, grid, and approval bottlenecks, whereas DER offers faster deployment, land neutrality, higher employment, avoided subsidies, grid resilience, and local energy self-reliance. The indicator-based comparison shows rooftop and other DER systems outperform UMW solar on co-benefits such as job creation, land savings, subsidy reduction, siting flexibility, and voltage support, while UMW remains more cost-efficient per kWh. Together, a balanced strategy leveraging both models can address rising demand, reduce DISCOM stress, and create a more resilient, inclusive, and sustainable power system for India.

Table 15 Results of the Multi-dimensional DER and UMW Assessment

#	Indicator	Unit	DER	UMW Solar
1	**Installation Cost**	₹/kW	50,000 – 70,000	30,000 – 50,000
2	**Levelised Cost of Energy (LCOE)**	₹/kWh	3.88 – 5.25	2.32 – 3.87
3	**Employment**	FTE per MW	~24.72	~3.45
4	**Land Requirement**	MW/acre	None	3 – 5
5	**Avoided Cost**	₹/kWh	4.96 – 5.25	None
6	**Avoided Subsidy Amount**	₹/kWh	1.46	None
7	**Supply Resilience**	High or Low	High	Low
8	**Energy Self-Reliance**	High or Low	High	Low
9	**Siting Flexibility**	High or Low	High	Low
10	**Voltage Control**	High or Low	High	Low
11	**Impact on DISCOM Billing**	Yes or No	Yes	No

Notes:

1. *RTS: Cost varies by system size, inverter, structure height, cabling, roof type, and location. UWM: Costs vary with location, land acquisition, panel type, system design, and distance from substation. Lower per-kW cost than DER but incurs additional costs for land, transmission lines, and centralized integration.*
2. *LCOE: Per unit cost of RTS with capital subsidy is estimated to be in the range of 1.84 – 3.20 ₹/kWh (with capital subsidy). The cost of systems with KUSUM-C subsidy is estimated to be in the range of: 1.77 – 2.29 ₹/kWh. Per unit cost of RTS without subsidy but including network charges as applicable in Tamil Nadu is estimated to be in the range of 4.20 – 5.57 ₹/kWh.*

04 Government Trust Areas: Agriculture & Households

India is gradually advancing its efforts in the renewable energy sector with flagship initiatives such as the PM Surya Ghar for households and KUSUM for agriculture. Both schemes seek to advance energy accessibility and sustainability.

PM-Surya Ghar: Ambitious Targets and Current Status:

Launched in February 2024, PM-Surya Ghar seeks to install rooftop solar panels on 1 crore (10 million) residential homes by 2027 (PIB, 2024b). The scheme targets India's vast base of residential electricity consumers. Households are incentivised with up to 60% subsidy for systems up to 2 kW and 40% for additional capacity up to 3 kW. This translates to a direct subsidy ranging from ₹30,000 (1 kW) up to ₹78,000 (3 kW and above) (PIB, 2024b), making solar considerably more economical. The PM-Surya Ghar scheme is designed to provide free or low-cost electricity, significantly reducing power bills for millions. The scheme promotes local employment for installation and maintenance, and boosts India's manufacturing sector through mandates on indigenous production of solar equipment.

In March 2025, the scheme achieved a milestone of 1 million installations countrywide (GOI, 2025b). It is estimated that around 45% of the residential households that have adopted the scheme are receiving zero electricity bill (GOI, 2025b). Further, as of August 2025, there have been more than 17 lakhs installations under the scheme; however, the conversion rates from applications to installations are approximately 23% (MNRE, n.d), highlighting persistent gaps in awareness, financing, and procedural efficiency.

Table 16 - PM Surya Ghar Yojana achievements by State

State/UT	Households Benefited	Installed Capacity (MW)	Average (KW)/ per household)
Gujarat	4,21,502	1,580.24	3.75
Maharashtra	2,71,350	1,023.57	3.77
Uttar Pradesh	2,10,847	738.7	3.50
Kerala	1,35,747	541.25	3.99
Rajasthan	74,817	313.87	4.20
Madhya Pradesh	57,300	221.59	3.87
Andhra Pradesh	48,019	167.87	3.50
Uttarakhand	43,564	159.79	3.67
Tamil Nadu	38,207	136.8	3.58
Assam	36,025	118.77	3.30
Haryana	33,294	118.24	3.55
Telangana	17,551	70.26	4.00
Odisha	12,991	42.77	3.29
Karnataka	11,980	47.89	4.00
Bihar	10,719	38.77	3.62
Jammu & Kashmir	10,140	36.96	3.64
Punjab	8,701	40.26	4.63
Chhattisgarh	5,395	22.74	4.22
Himachal Pradesh	4,039	14.05	3.48
Delhi	3,220	16.2	5.03
Puducherry	1,479	5.3	3.58
Goa	946	8.2	8.67
Jharkhand	856	3.39	3.96
West Bengal	846	2.57	3.04
Tripura	832	2.85	3.43
Ladakh	765	2.54	3.32
Chandigarh	642	2.57	4.00
Lakshadweep	559	1.87	3.35
Manipur	495	2.05	4.14
Mizoram	487	1.86	3.82
DNH & DD	413	1.7	4.12
Andaman & Nicobar Islands	75	0.24	3.20
Nagaland	54	0.18	3.33
Meghalaya	22	0.05	2.27
Sikkim	10	0.04	4.00
Arunachal Pradesh	0	0	0.00

Source: MNRE PM Surya Ghar: Muft Bijli Yojana. National Portal for Rooftop Solar

KUSUM-C: Solarizing India's Agriculture

The KUSUM scheme consists of Component A for decentralized solar power plants on unused land, Component B for installing standalone solar pumps, and Component C which includes both feeder-level solarization and Individual Pump Solarisation (IPS) to solarize existing grid-connected agricultural pumps, allowing farmers to use solar energy for irrigation and sell excess power to the grid.

The sub-scheme KUSUM-C (IPS) targets the solarization of 3.5 million grid-connected pumps by 2026, with the goal of reducing the burden on both public utilities and farmers while boosting on-farm energy independence. Individual farmers/ group of farmers/ Water User Associations (WUA)/Farmer Producer Organizations (FPO)/ Primary Agriculture Credit Societies (PACS) or cluster based irrigation systems are eligible. The scheme also prioritizes small and marginal farmers for inclusion. Solar capacity allowed is up to twice the pump capacity, with 60% of the pump cost subsidized (30% each from central and state governments) (MNRE, 2024).

As of July 2025, progress under KUSUM-C (IPS) has been low nationwide—only about 14.7% of the target has been achieved, with states like Tamil Nadu yet to see any adoption (GOI, 2025c). Only nine states have approved installations totalling 60,828 pumps; only 8,966 pumps have been installed across Kerala, Rajasthan, Tripura, Uttar Pradesh, and West Bengal (GOI, 2025c). The table below provides a state-wise summary of the total number of Individual Pump Solarisation (IPS) units sanctioned and solarised under the KUSUM-C program as of July 2025.

Table 17 – PM KUSUM-C (IPS) status

State Name	Sanctioned - IPS (Nos.)	Solarised - IPS (Nos.)	Realisation (%)
Uttar Pradesh	12,000	4,264	36%
Kerala	9,448	2,259	24%
Rajasthan	2,138	2,138	100%
Tripura	3,600	285	8%
West Bengal	20	20	100%
Andaman And Nicobar	436	0	0%
Punjab	186	0	0%
Tamil Nadu	5,000	0	0%
Telangana	28,000	0	0%
Total	**60,828**	**8,966**	**15%**

Source: GOI, 2025c (National portal for PM KUSUM)

In conclusion, the attractiveness of the PM-Surya Ghar and KUSUM-C schemes is evident in their ability to reduce financial barriers through subsidies, create rural employment via training and expanded vendor networks, and drive application rates with targeted awareness campaigns. However, persistent challenges remain, with limited outreach resulting in low conversion rates from the installation application. Procedural complexities, such as cumbersome paperwork and coordination issues across multiple agencies, further impede the adoption process. Notably, pre-existing state policies offering free or highly subsidized electricity, as seen in Tamil Nadu, diminish the economic appeal of solar solutions for farmers, restricting scheme uptake. Addressing these multi-faceted barriers is critical for realizing the full potential of India's rooftop and agricultural solar initiatives.

Table 18 – Comparison of PM-Surya Ghar Yojana & PM KUSUM-C (IPS)

Criteria	PM-Surya Ghar Yojana	PM KUSUM-C (IPS)
Target	Install rooftop solar for 1 crore (10 million) households by 2027	Solarize 35 lakh grid-connected agriculture pumps by 2026 and reduce diesel use in farming.
Implementation Modus	Consumers register online, select an approved vendor, get installation and inspection, connect to the grid, and receive subsidy directly after successful commissioning.	Delivered through state DISCOMs and nodal agencies with a focus on small/marginal farmers.
Subsidy	Up to 60% subsidy for systems up to 2kW and 40% for 2–3kW systems, capped at ₹78,000 for 3kW or higher. State governments may add further subsidies.	Up to 60% subsidy for pumps with of up to 7.5 HP capacity - 30% central subsidy (50% in special regions), up to 30% from states or UTs, and the remainder paid by the farmer.
Achievements	Over 10 lakh (1 million) installations by March 2025,	8,966 pumps installed as of July 2025
Main Challenges	Low uptake in states with free or subsidized electricity, financial barriers for low and middle-income households, low consumer awareness, complex regulatory requirements and vendor availability in the area.	Limited farmer motivation in states providing free/subsidized electricity, financial constraints, region-specific technical issues (e.g., appropriate pump sizing), and slower progress in certain components.

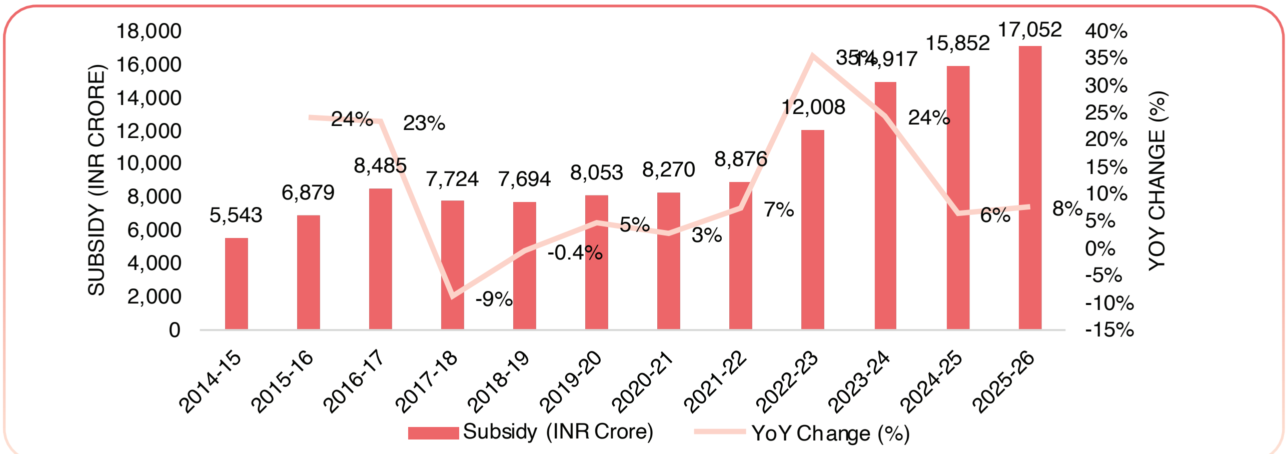
05 Tamil Nadu's Electricity Subsidy and Cross-Subsidy Landscape

Electricity subsidies have increased from ₹5,600 crore in 2014-15 to over ₹16,000 crore in 2025-26—a nearly threefold increase. The long-term trend is escalating public expenditure.

Energy subsidies exist in nearly all countries, often justified for social welfare, job creation, renewable energy support, economic development, and energy security. Yet, it is important to assess whether these subsidies advance a just energy transition and align with UN-recommended interventions (Auroville Consulting, 2023a). In Tamil Nadu, electricity—primarily generated from coal and lignite—receives significant subsidies. The state government subsidises domestic users and several other categories (agriculture, huts, power looms, hand looms, places of worship) by lowering the per kWh cost and compensating the state utility, TANGEDCO, for some of this reduction. TANGEDCO also cross-subsidises by charging industries and commercial users' higher tariffs, but these cross-subsidies have not covered overall supply costs. This has resulted in a cumulative revenue gap and necessitated government bailouts (Auroville Consulting, 2023a). Since most electricity comes from emission-intensive thermal plants, these subsidies often end up supporting polluting energy sources. There is also a need to evaluate whether subsidies are effectively reaching low-income households and addressing energy poverty (Auroville Consulting, 2023a).

Electricity subsidies have grown in absolute terms, rising from ₹5,600 crore in 2014-15 to over ₹16,000 crore in 2025-26—a nearly threefold increase. The long-term trend is escalating public expenditure on energy subsidies, both in size and as a proportion of state expenditure, reflecting increasing electricity consumption, subsidy coverage (100 units free for all domestic, free/low tariffs for several sectors), and rising costs of power supply.

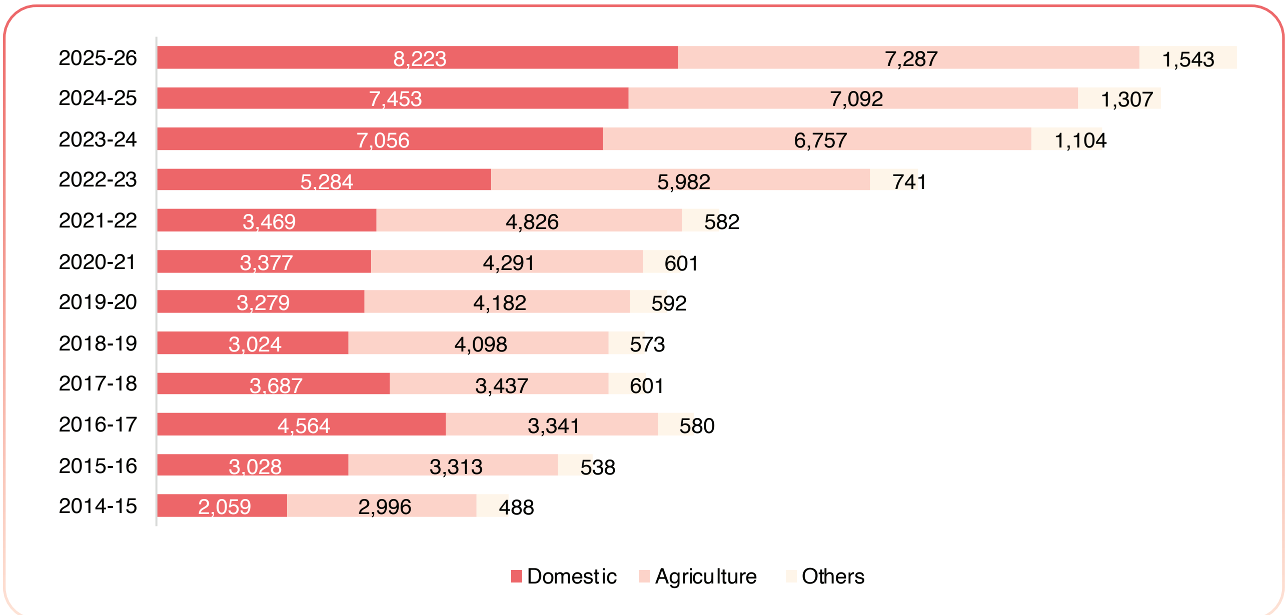
Figure 4 Electricity subsidy disbursement by the Tamil Nadu Government



Sources: TNERC 2015a, 2015b, 2016, 2017, 2018, 2019, 2020b, 2021c, 2022, 2023, 2024a, 2024b, 2025a, 2025c, 2025d

Detailed breakup by sector reveals that domestic consumers consistently receive the largest share of subsidy, followed by agriculture (fully subsidised), then huts, power looms, and places of worship. For 2025-26, domestic and agricultural users together account for roughly 85% of all subsidy outlays, reflecting a policy emphasis on protecting the household economy and food production. For example, out of a total ~₹16,000 crore in subsidies allocated for FY 2025-26, domestic supply receives over ₹7,700 crore; agriculture (including normal category, Self-Financing Scheme (SFS) category and Lift Irrigation Co-operative Societies secures over ₹7,000 crore (TNERC, 2025b) (TNERC, 2025c). This structure shows a classic "social tariff" model, prioritizing welfare for the residential base and agrarian sector. However, a recurring issue is that not all low-income households are adequately targeted—the largest absolute subsidy amounts often benefit higher-consuming (and likely wealthier) households due to the slab structure.

Figure 5 Electricity subsidy disbursement by sector



Sources: TNERC 2015a, 2015b, 2016, 2017, 2018, 2019, 2020b, 2021c, 2022, 2023, 2024a, 2024b, 2025a, 2025c, 2025d

The trajectory of "Subsidy as a percentage of State Budget" is a useful barometer for fiscal pressure. While total subsidy outlay grows almost every year, the proportional share has fluctuated, dipping slightly in years of rapid budget expansion or tariff normalization, but rebounding with fresh rounds of tariff hikes absorbed as subsidy (notably in 2023-24). Despite efforts to rationalize tariffs and target subsidies better, the state's political choice has been to keep tariff impacts shielded from most residential and agricultural users.

Table 19 Comparison of TN State Budget with Electricity Subsidy

Years	Total State Budget (₹ Crore)	Subsidy (₹/ Crore)	Subsidy as a percentage of State Budget %
2014-15	1,53,308	5,543	3.62%
2015-16	1,74,811	6,879	3.94%
2016-17	1,88,709	8,485	4.50%
2017-18	2,03,082	7,724	3.80%
2018-19	2,41,653	7,694	3.18%
2019-20	2,64,556	8,053	3.04%
2020-21	3,00,390	8,270	2.75%
2021-22	3,29,035	8,876	2.70%
2022-23	3,33,251	12,008	3.60%
2023-24	3,65,321	14,917	4.08%
2024-25	4,12,504	15,852	3.84%
2025-26	4,39,293	17,052	3.88%

Sources: TNERC 2015a, 2015b, 2016, 2017, 2018, 2019, 2020b, 2021c, 2022, 2023, 2024a, 2024b, 2025a, 2025c, 2025d: PRS Legislative Research, "Tamil Nadu Budget Analysis" (annual reports for each year: 2014-15, 2015-16, 2016-17, 2017-18, 2018-19, 2019-20, 2020-21, 2021-22, 2022-23, 2023-24, 2024-25, and 2025-26

Note: This excludes the Bailout, Loss Funding and/or Equity Infusion

Apart from the direct electricity subsidy, the Tamil Nadu government also regularly provides additional bailout, loss funding and/or equity infusion. The Tamil Nadu government provided ₹17,117 crore as loss funding to TANGEDCO in FY2023-24, ₹14,442 crore in 2024-25 and ₹7,700 crore budgeted for 2025-26. This "loss Funding" is in addition to the regular electricity subsidies and constitutes extraordinary financial assistance mandated to cover TANGEDCO's accumulated operating deficits and ensure the utility's solvency. This potentially limits budgetary room for investments in other key priority areas.

Table 20 below provides a detailed breakdown of how electricity subsidies are distributed across different domestic consumption slabs in Tamil Nadu. This shows the distribution of subsidies by domestic slab, highlighting the number of connections, units, and costs per category. While the largest group (up to 100 units) includes the most connections, the bulk of the total subsidy cost is actually incurred for higher slabs (201–500 units), largely because these households consume more. Tamil Nadu applies a telescopic tariff structure for electricity. The first 100 units are provided free of charge, while subsidised tariffs continue for higher levels of usage. As a result, households that consume more electricity receive a disproportionately large share of the total subsidy, ultimately benefiting from a greater subsidy per household. Although subsidies are meant to protect small consumers, the system's structure means that higher-consuming (often higher-income) households receive the lion's share of the total rupee benefit. This exposes a classic problem: broad-based slab subsidies have weak targeting and tend to leak benefits upstream. A significant efficiency and equity opportunity exists if subsidies were capped, limited to one connection per household, or better integrated with social welfare targeting.

Table 20 Subsidy outlay by slabs for domestic consumption for FY 2025-26

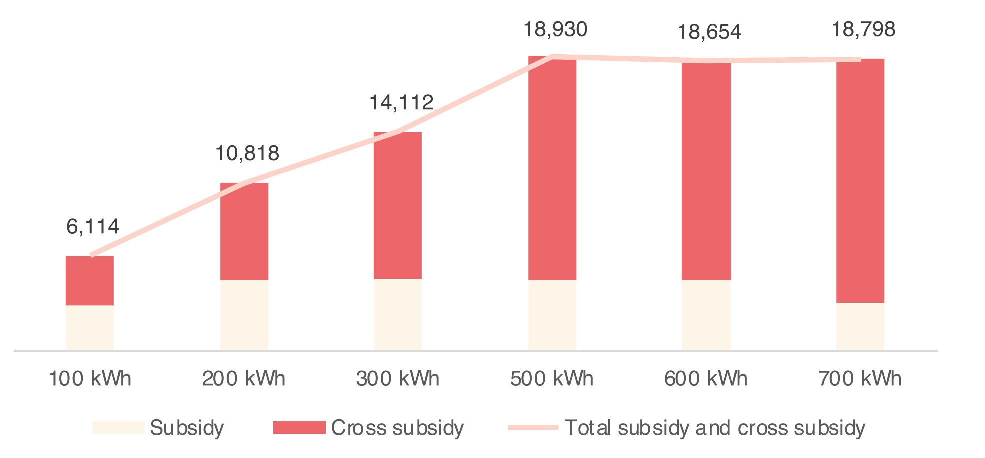
Slab	No. of Services (lakhs)	Slab Share of Total (%)	Estimated Tariff Subsidy (INR Crore)
Bi-monthly consumption up to 100 units	82.90	33.00%	962.25
Bi-monthly consumption 101-200 units	62.60	24.90%	2,308.94
Bi-monthly consumption 201-500 units	86.80	34.50%	3,722.17
Bi-monthly consumption above 500 units	19.40	7.70%	665.62
Total	251.70	100%	7,659.00

Source: TNERC, 2025a

Note: The total subsidy outlay for FY 2025-26 presented in Table 18 differs slightly from the value shown in Figure 5. This variation is due to an increase in subsidy mandated by TNERC (2025c), for which slab-wise details were not available.

In Tamil Nadu's electricity sector, cross-subsidy refers to the practice of charging higher tariffs to commercial and industrial users to keep tariffs artificially low for domestic and certain priority consumer groups. Figure 6 illustrates that Tamil Nadu's current electricity tariff and subsidy structure delivers the largest rupee benefit not to the smallest consumers but to households in the upper middle of the consumption distribution. The combination of direct subsidies and cross-subsidies results in weak targeting, leading to the inefficient allocation of public resources—calling for reform towards better targeting and gradual rationalisation as part of a fair energy transition.

Figure 6 : Estimated subsidy and cross subsidy disbursement by average monthly



Tamil Nadu's power sector is an example of the "subsidy trap," where a blend of tariff suppression, cross-subsidies, and fiscal bailouts sustains artificially low tariffs for priority groups. While this protects the poor and agricultural sector in the short term, the long-term impact is persistent losses for the power utility. These policies also undermine the business case for household rooftop solar, which cannot compete with highly subsidized grid tariffs.

Reforms—such as explicit targeting, direct benefit transfers, and dedicated rooftop solar programs for low-income households and marginal farmers—present a unique opportunity for the state of Tamil Nadu to achieve multiple goals simultaneously, including social welfare, economic development, and environmental sustainability.

06 Optimising Welfare Delivery for Energy Equity

As Tamil Nadu accelerates its energy transition, more precise targeting of electricity subsidies and related welfare schemes can strengthen social equity and ensure that public benefits reach the most vulnerable.

Tamil Nadu has long stood apart in India for its unique approach to inclusive socio-economic development, guided by the principles of social justice and rooted in Dravidian ideology. Over decades, the state has consciously fostered a governance model that blends egalitarian principles with progressive welfare measures—a philosophy commonly known as the Dravidian development model. This distinctive framework has profoundly influenced the state's political and social landscape. The beauty of this approach lies in its commitment to universal access, making basic services available to every citizen, regardless of their socio-economic status. Take electricity, for example: every household in Tamil Nadu enjoys 50 free units of power each month, a benefit made possible through government subsidies and cross-subsidies from TANGEDCO that extend not just to homes but also to farmers, weavers, artisans, and even places of worship (Auroville consulting, 2023a). The agricultural sector in Tamil Nadu accounts for about 20% of the state's electricity consumption (Auroville Consulting, 2019b). The TN government provides free electricity to farmers as a subsidy.

While the Dravidian model's commitment to universal access has delivered remarkable social gains, it also raises important questions about the optimal use of limited state resources. As the needs of Tamil Nadu's population evolve, there is growing recognition of the necessity to target subsidies and welfare benefits better, ensuring that support reaches those who require it most. For instance, the policy of providing 50 units of free electricity to all households—irrespective of income—though egalitarian in intent, is essentially indiscriminate. Evidence suggests that high-income households tend to benefit disproportionately from such blanket subsidies compared to their lower-income counterparts. This approach not only strains the state's finances but may also inadvertently encourage wastage and reduced incentives for energy conservation. Moreover, universal subsidies do little to promote the adoption of sustainable alternatives, such as rooftop solar installations as a welfare scheme, which could contribute both to energy security and environmental sustainability. Moving forward, exploring more precise ways of identifying and supporting the genuinely needy, while encouraging responsible consumption and the adoption of clean energy solutions, will be critical for the continued success and sustainability of Tamil Nadu's welfare model.

Building on this context, this chapter will evaluate both global and domestic best practices for targeting beneficiaries in welfare programs, drawing lessons on how these approaches can be leveraged for the renewable energy transition in Tamil Nadu. The state is well-positioned to integrate and adapt central government schemes such as the PM Surya Ghar: Muft Bijli Yojana, which subsidises rooftop solar for domestic consumers, and the PM KUSUM-C (IPS) program, which supports solarisation of grid-connected agriculture pumps for farmers. By tailoring these flagship initiatives to local realities and embedding them within the “Dravidian development model”, Tamil Nadu can uniquely design implementation frameworks that prioritise those most in need, enhance the reach of clean energy subsidies, and reinforce the state’s commitment to social justice.

As Tamil Nadu accelerates its energy transition, more precise targeting of electricity subsidies and related welfare schemes can strengthen social equity and ensure that public benefits reach the most vulnerable. By integrating targeted beneficiary approaches into rooftop solar programs, the state can ensure that disadvantaged groups not only transition to clean energy but also benefit from additional income opportunities, such as the sale of surplus electricity to the grid. This creates a powerful opportunity to support sustainable livelihoods for small and marginal farmers as well as low-income households, and catalyse a just, equitable green transition. National initiatives like the PM Surya Ghar scheme and the KUSUM-C (IPS) scheme offer replicable models that Tamil Nadu can adapt and tailor to meet its unique socioeconomic objectives.

Comparative Case Study Analysis

Case Studies 1

Pradhan Mantri Ujjwala Yojana (PMUY), India

The Pradhan Mantri Ujjwala Yojana (PMUY) scheme, launched in 2016, provided clean cooking fuel access to poor households by offering free Liquefied petroleum gas (LPG) connections (CAGI, 2019).). The central government covers the LPG cylinder deposit and first refill subsidy through direct transfers, collaborating with Oil Marketing Companies (OMCs) and state agencies for procurement, distribution, and customer onboarding (CAGI, 2019)).

Beneficiary Target Approach: Identification under PMUY initially leveraged the BPL census and SECC-2011 databases to allocate LPG connections to women heads of households (CAGI, 2019), and was later broadened under PMUY 2.0 to include SC/ST communities, PMAY beneficiaries, and other marginalised sections to ensure comprehensive coverage (MoPNG, n.d).

Program Outcome: PMUY has provided over 10.33 crore LPG connections to poor households, making up nearly one-third of India's active domestic LPG consumers by 2025. Beyond access, PMUY has reduced indoor air pollution, improved women's health, cut drudgery, and supported environmental conservation, earning global recognition from the IEA and WHO as the world's largest clean cooking access program (PIB, 2025).

Case Studies 2

Chief Minister's Solar Powered Green House Scheme (CMSPGHS), Tamil Nadu

The Government of Tamil Nadu launched the Chief Minister's Solar Powered Green House Scheme (CMSPGHS) in 2011 to provide permanent houses with basic amenities to rural poor households, along with a solar home lighting system (CAGI, 2024). Extended in 2016–21, the scheme was revised in 2020–21 by withdrawing the solar component and merging its cost with construction, retaining the unit cost at ₹2.10 lakh (CAGI, 2024). For tribal households, the unit cost was set at ₹3 lakh. Houses were to be built by beneficiaries following approved designs under the supervision of the Department of Rural Development and Panchayat Raj (CAGI, 2024).

Beneficiary Target Approach: To qualify under the CMSPGHS, a beneficiary had to reside within the Village Panchayat, be listed in the permanent BPL wait list, own a site of not less than 300 sq. ft. with clear patta, and not possess another pucca house or have availed benefits under any other housing scheme. From this list, priority was given to certain vulnerable groups. Eligible poor persons outside the BPL list could apply to the Block Development Officer and, upon verification and approval by the District Collector and Grama Sabha, were added to the wait list. Final selection was made by a Committee comprising the Block Development Officer (Village Panchayats), Deputy Block Development Officer, and the Village Panchayat President, with the approved list ratified by the Grama Sabha (RDPRD, n.d).

Program Outcome: Only a small percentage of the intended rural poor benefited due to strict land ownership requirements and misallocation during beneficiary selection. Systemic mismanagement in beneficiary selection, underrepresentation of the most vulnerable, and non-uniform allocation across regions. Delays in construction, fund release, and supply of materials; contractor and tendering irregularities leading to compromised quality (CAGI, 2024).

Case Studies 3

Off-Grid Solar Access Project (KOSAP), Kenya

The Kenya Off-Grid Solar Access Project (KOSAP), launched in 2018 with a total outlay of USD 150 million, the project with multiple components, targets the delivery of 250,000 stand-alone solar home systems, 120 mini-grids, and 150,000 clean cooking solutions, alongside USD 25 million dedicated to community facilities such as health and education institutions. It further seeks to establish sustainable supply chains, create local employment, and build capacity to support long-term energy access in Kenya (IEA, 2023) (World Bank, 2017).

Beneficiary Target Approach: Beneficiary targeting utilised geographic, demographic, and socio-economic criteria focusing on the 14 marginalised counties (IEA, 2023a). Results-based targeting mechanisms incentivised service providers to reach genuinely underserved populations through payment structures linked to verified installations in target areas, aligning commercial incentives with development objectives (Ministry of Energy, Government of Kenya, n.d).

Program Outcome: KOSAP successfully deployed 1,78,598 solar home systems, providing electricity access to approximately 900,000 people while demonstrating effective results-based financing mechanisms in achieving rapid deployment through private sector capacity (World Bank, 2024). Despite significant economic and social impacts, including reduced household energy expenditures and improved service delivery, challenges emerged in ensuring long-term sustainability and after-sales service in remote areas due to geographic dispersion and limited infrastructure.

Case Studies 4

Solar Home System Program, Bangladesh

Bangladesh's Solar Home Systems (SHS) programme was launched in 2003 by the Infrastructure Development Company Limited (IDCOL) with support from the World Bank and other international development partners. It has since become the world's largest off-grid solar electrification programme, providing electricity access to over 20 million people through the installation of more than 4.1 million SHS units by 2018 (World Bank, 2021).

Beneficiary Target Approach: The programme focused on rural households and communities beyond the reach of the national grid, where conventional electrification was economically unfeasible (World Bank, 2021). Delivery relied on partner organisations (POs), largely NGOs and microfinance institutions—that marketed systems, extended consumer credit, installed units, and provided after-sales services (World Bank, 2021). The financing model combined declining donor-funded grants ("buy-down subsidies") with microcredit. Customers typically paid a 10–15% down payment and repaid the balance over about three years, with instalments structured to be comparable to previous kerosene expenditures (World Bank, 2021). IDCOL refinanced POs using concessional loans from international partners at interest rates of around 6–9% with tenors of 5–10 years ((World Bank, 2021).

Program Outcome: By reducing upfront costs and aligning repayments with existing energy spending, the SHS programme enabled mass adoption in low-income rural contexts. The result was improved household welfare, better educational outcomes through lighting access, reduced kerosene use, and expanded opportunities for rural enterprises (World Bank, 2021). Beyond households, the programme demonstrated a scalable public–private partnership model for clean energy delivery that has been studied and adapted globally.

Case Studies 5

China's Solar Energy for Poverty Alleviation Program (SEPAP), China

The solar energy for poverty alleviation program (SEPAP) is a comprehensive renewable energy-based poverty reduction initiative implemented across China from FY2014-FY2020, aimed at promoting rural economic empowerment, energy access, and social inclusion through solar energy technology (Zhang et al., 2020). The Chinese government funds SEPAP through a multi-tiered financing mechanism combining direct government subsidies, policy bank lending, and corporate social responsibility contributions (Zhang et al., 2020). Revenue generation follows a feed-in-tariff model where village collectives sell electricity to state grid companies and distribute earnings to eligible poverty-stricken families through public welfare posts, small public welfare undertakings, and direct income transfers (Zhang et al., 2020).

Beneficiary Target Approach: The beneficiary targeting focuses on poverty-stricken rural households across multiple categories, including those without work capacity, disabled individuals, and elderly populations in designated poor counties (Zhang et al., 2020).

Program Outcome: The program's effects are cumulative, showing stronger impacts 2-3 years post-implementation, with eastern China regions being poorer counties experiencing greater poverty reduction benefits (Zhang et al., 2020). By 2020, SEPAP achieved substantial scale, installing 26.49 million kW of solar capacity and benefiting 4.18 million poor households across 1,472 counties and 1,38,091 villages.

Learning outcomes from the case study

The comparative analysis of six development programs across India, Kenya, Bangladesh, and China reveals critical insights about the determinants of success and failure in large-scale social interventions. The most successful programs - PMUY delivering over 100 million LPG connections, Bangladesh's SHS program becoming the world's largest off-grid solar initiative, and China's SEPAP benefiting 4.18 million households - demonstrate that transformative outcomes at scale are achievable when programs combine well-designed targeting mechanisms, sustainable financing models, and robust implementation frameworks. These successes validate that systematic approaches utilising existing databases, focused targeting, and multi-stakeholder coordination can overcome traditional barriers to reaching marginalised populations effectively. The limited success of Tamil Nadu's CMSPGHS scheme shows that even well-funded, well-designed programs can fail without strong implementation, clear accountability, and effective institutional coordination.

This shows that development programs to become sustainable, must balance immediate access with long-term behavioural change and financial viability. Successful examples like Bangladesh's SHS and China's SEPAP aligned user incentives with program sustainability, while subsidy-dependent or overly complex initiatives faced persistent challenges in maintenance and impact.

Targeted beneficiary

As highlighted earlier in this report, Tamil Nadu's current electricity subsidy framework is broadly disbursed and disproportionately benefits higher-income households in absolute terms—undermining the core objective of a welfare program aimed at supporting the most vulnerable. Similarly, virtually unlimited free electricity is provided to farmers regardless of their landholdings, resulting in significant benefits accruing to larger and more resource-rich farmers. Alternatively, the state could adapt and tailor central schemes - KUSUM-C (IPS) and PM Surya Ghar- to provide targeted support to low-income households (HH)—defined as those holding Below Poverty Line (BPL) ration cards and consuming less than 100 kWh of electricity per bi-monthly billing cycle—and to marginal farmers[2] who are marginal agriculture households.

As of August 2025, Tamil Nadu has a total of 1.15 crore (11.5 million) ration cards issued, with 96.68 lakh (9.66 million) cards classified as Priority Household (PHH) and 18.64 lakh (1.86 million) as Antyodaya Anna Yojana (AAY). Tamil Nadu has approximately 1.90 million agricultural households possessing marginal land holdings[3]. AAY targets families below the poverty line who are most vulnerable, such as landless laborers, marginal farmers, destitute, elderly, widows, persons with disabilities, and others lacking stable income or social support. These figures represent the main pool of vulnerable and economically weaker sections eligible for publicly subsidised food and welfare (GoTN. 2025a).

By targeting this specific income range, the scheme ensures maximum impact on the most economically vulnerable population while maintaining fiscal efficiency and promoting inclusive development across Tamil Nadu's rural and semi-urban communities.

[2]A marginal farmer in this report be understood as a landholder farmer family (husband, wife, and minor children) whose collective operational holding falls within the lowest farm size category, i.e. less than 1 hectare (as per Agricultural Census definitions). For purposes of livelihood classification, such families also qualify as agricultural households when at least one member is self-employed in agriculture and the household earns at least ₹4,000 annually from agricultural activities (as per NSSO definition).

[3]Holding of less than 1 hectare of agricultural land

Table 21 Proposed beneficiary targeting approach for Surya Ghar and Kusum-C (IPS)

Target Group	Eligibility Criteria	Scheme to be Adopted	Targeting Tool	Total Eligible Beneficiaries
Low-income households	AAY Ration Card & < average 100 kWh/bi-monthly	PM Surya Ghar: Muft Bijli Yojana	Surya Ghar Online Application & Discom database	18.64 lakh AAY households
Marginal farmers	Household engaged in agriculture with collective operational holding in the marginal category, as per state land records	KUSUM-C (IPS)	KUSUM-C- only application, landholdings registry/scheme enrolment	19 lakh agricultural households with marginal holdings

The current application process is applied through the PM-Surya Ghar and PM-KUSUM single-window portal. For the PM-Surya Ghar scheme, Aadhaar is collected for the application process, an electricity bill for both schemes and a copy of the passbook for the bank details and a Land record for the PM-KUSUM-C (IPS) and the capacity of the grid-connected pumps.

Table 22 presents the estimated investment requirement if all eligible beneficiaries under both schemes were to be targeted. For 18.64 lakh low-income households, with a 2 kW rooftop solar system under PM Surya Ghar, the total capacity addition would be about 3,728 MW, requiring an investment of approximately ₹22,368 crore. Similarly, solarising 19 lakh marginal farmers with 11 kW pump systems under KUSUM-C would create a capacity of 20,900 MW, requiring around ₹1,25,400 crore in total investment. Together, this represents a very large potential of over 24 GW and an estimated investment requirement of nearly ₹1.48 lakh crore.

Table 22 Estimated Investment under complete beneficiary target

Target Group	No. of Beneficiaries (Lakhs)	Solar Capacity Per Beneficiary (kW)	Total Solar Capacity (MW)	Investment Per Beneficiary (₹)	Total
Low Income HH	18.64	2	3,728	1,20,000	22,368
Marginal Farmers	19	11	20,900	6,60,000	1,25,400

Table 23 Documents required under the existing application process

S. NO	Document type	PM-Surya Ghar	PM-KUSUM-C
1	Identify proof	Aadhaar	Aadhaar
		PAN Card	PAN Card
2	Electricity connection	Electricity bill	recent electricity bill with receipt
3	Bank details	Copy of Passbook or	Copy of Passbook
		Cancelled cheque	
4	Land Record	-	Land Record / Lease document

Source: GOI, n.d (PM Surya Ghar portal); PM KUSUM Portal

The state nodal agency, TNGECL, is authorised to implement the PM Surya Ghar scheme in Tamil Nadu, with access to all applications from the state, including beneficiary details, technical specifications, inspection reports, and subsidy status. In Tamil Nadu, 100% of households have linked their ration or smart cards to Aadhaar (PIB, 2021), allowing easy identification of AAY households through Aadhaar submission. Electricity bills collected via the Surya Ghar portal provide average bi-monthly consumption data. We recommend using a one-year bill or the connection number to confirm if a household consumes less than 100 units bi-monthly.

For marginal farmers, eligibility can be verified through land holding papers and pump capacity. Land records and service documents uploaded to the KUSUM-C (IPS) portal serve as proof.

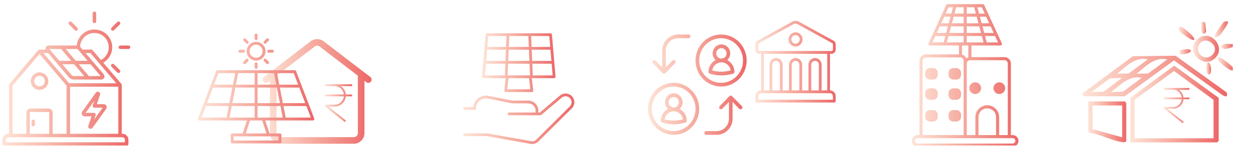
07 Delivery pathways for decentralized solar:PM Surya Ghar and PM KUSUM

The choice of business model is critical as well-designed models can mitigate upfront, unlock alternative financing channels, and ensure alignment of incentives for stakeholders.

While targeted beneficiary identification is a necessary step, it is not sufficient to ensure meaningful participation of low-income households, including small and marginal farmers, in solar programmes such as PM Surya Ghar (grid-connected rooftop solar for households) and PM KUSUM Component C - Individual Pump Solarisation (IPS). Even when eligibility is established, significant barriers continue to constrain uptake. These include the inability to meet residual upfront contributions despite subsidies, limited access to concessional loans despite their collateral-free design, delays in subsidy disbursal, and the limited financial incentive for consumers whose electricity is already heavily subsidised or free. For low-income domestic households, the provision of free electricity units per month means that their electricity bills are already very low, leaving little scope for solar to deliver meaningful savings. For farmers, the availability of free power for agricultural pumps removes any direct cost incentive to adopt solarisation unless clear and reliable avenues exist to monetise surplus generation. In this context, business and implementation models must be designed to address the following three interrelated challenges:

- **Reducing upfront cost exposure** for low-income households and farmers.
- **Improving financial intermediation** by enabling RESCOs, cooperatives, or community-based mechanisms to overcome the practical barriers to accessing collateral-free, low-interest finance.
- **Aligning incentives** across consumers, utilities, and the state government, particularly in Tamil Nadu.

The choice of business model is therefore critical. Well-designed models can mitigate upfront, unlock alternative financing channels, and ensure alignment of stakeholder incentives. This chapter examines business and implementation models for PM Surya Ghar (grid-connected rooftop solar for households) and PM KUSUM-C - Individual Pump Solarisation (IPS) in Tamil Nadu, focusing on vulnerable consumers, marginal farmers, and low-income households. By comparing key models—Build-Operate-Transfer (BOT), market-driven, TN government full subsidy, Peer-to-Government (P2G) solar trading and Zero Interest Financing—the analysis explores their benefits for end-users, DISCOMs, and the state government. The aim is to identify inclusive, financially sustainable approaches that accelerate equitable solar adoption while ensuring payment security, operational reliability, and mutually reinforcing gains for all stakeholders.



Market-Driven	BOT (Build-Operate-Transfer)	Full Subsidy	P2G (Peer-to-Government)	Super RESCO	Zero Interest Finance
Consumers finance rooftop solar (with MNRE subsidy), use net metering/ feed-in to offset bills and sell surplus.	EPC/RESCO installs, owns, and operates the system for a time period (Eg 5 years), recovering costs through a dedicated feed-in tariff, before transferring ownership to the consumer.	Government covers entire installation cost; consumer owns system from day one; savings and surplus accrue to consumer.	Consumers install and sell surplus solar directly to government entities via PPA at fixed tariff, offsetting govt electricity costs.	fully finances, installs, and operates; sells solar to the utility, while the government pays consumers generation-linked	Consumer gets a interest free loan to finance rooftop solar (with MNRE subsidy), use net metering/net feed-in to offset bills and sell surplus.

Market-Driven (Consumer-Driven) Model

In the market-driven model, beneficiaries purchase and own the solar system directly, availing the subsidy under PM Surya Ghar or PM KUSUM-C (IPS). The responsibility for financing the residual cost, securing a loan, rests with the household or farmer. In Tamil Nadu, consumers receive a 60% MNRE subsidy, with the balance repaid through bill savings and by exporting surplus solar to the grid at the net feed-in tariff. There are no special payment security mechanisms beyond conventional loan agreements, so consumers assume standard market credit risk.

Full Subsidy Model

The full subsidy model eliminates all upfront cost exposure by covering 100 per cent of the system cost through public funds. Under this model, the Government of Tamil Nadu would cover the entire rooftop solar installation cost through both MNRE (central) and state subsidies, targeting vulnerable and priority groups. Household/farms pay nothing upfront and assume no loan obligations. Installations may be managed by the government or appointed agencies, with possible transfer of ownership to the consumer post-commissioning. Households/farms benefit from solar self-consumption and receive the standard net feed-in tariff for surplus exported to the grid. Operation and maintenance may be provided by the government or delegated to qualified vendors. Payment security is assured, with the government planning to eventually recoup costs by reducing future subsidy outlays. This highly inclusive model eliminates barriers for low-income or marginalised groups, advancing both social equity and accelerated adoption of clean energy.

Build–Operate–Transfer (BOT) Model

Under the Build–Operate–Transfer (BOT) model, the developer finances, installs, and operates the system for a defined period, recovering costs through service fees, subsidies, or energy savings, before transferring ownership to the beneficiary. For Tamil Nadu, Tamil Nadu Green Energy Corporation Ltd (TNGECL) or an EPC would lead the installation, ownership, operation, and maintenance of rooftop solar systems for the loan period. Consumers pay nothing upfront; TNGECL covers the post-subsidy capital via a loan, with loan recovery ensured through revenues earned from surplus solar sold to the grid at a dedicated feed-in tariff on the solar gross generation. Once the loan has been repaid, the rooftop solar system ownership will be transferred to the consumer (in this case, after 5 years), who benefits from ongoing self-consumption and additional surplus solar credits at the state's net feed-in tariff. By removing upfront costs for consumers and centralizing finance, quality, and risk management, the BOT model supports rapid, risk-mitigated residential and institutional solar deployment, targeting scale and inclusiveness in Tamil Nadu's renewable energy transition.

Peer-to-Government (P2G) Model

The Peer-to-Government (P2G) model introduces a model in which the surplus solar energy is sold to a Government entity or facility. Households/farms self-consume the power they generate and sell any surplus directly to public sector institutions at a premium "P2P" tariff via an escrow mechanism. This escrow ensures that all sales revenue first goes to repaying the government loan, with excess credited to the household, assuring payment security for all parties. A min 5-year O&M service contract will be part of the overall upfront solar system purchase cost. This innovative structure fast-tracks solar adoption by removing both upfront cost and repayment risk, while supporting the government's commitment to green public infrastructure. It empowers residential prosumers, offers higher and more stable compensation than standard feed-in schemes, and reduces the state's dependence on external grid power, providing a double dividend for both citizens and government energy goals.

Super RESCO Model

Under the Super RESCO model, a third-party developer owns and operates the solar assets and sells the gross solar energy generated to the DISCOM. The household/farm continues to receive the incumbent grid energy subsidy and benefits additionally from a rooftop/land lease for the solar plant and a solar incentive. The solar incentive is proposed to be calculated on a 'virtual' net solar export calculation to motivate the farmer or the household to reduce grid energy consumption and thereby indirectly reduce the subsidy and the cross-subsidy burden on the Government and on TNPDCL. The solar will be paid for by TNPDCL.

Zero Interest Finance

In the Zero-Interest Finance model, beneficiaries get the MNRE capital subsidy to buy solar systems. The remaining cost is covered by a zero-interest loan from the Tamil Nadu government, taken by the household or farmer. The government pays the interest. There are no special payment security measures beyond normal loan terms, so consumers face standard credit risk. The consumer repays the principal payment of the loan from bill savings and from the sale of surplus solar energy to TNPDCL.

Table 24 Business model outline

Attribute	Market-Driven	BOT Model	Full Subsidy Model	P2G Solar Model (Households to Govt)	Super RESCO Model	Zero Interest Finance Model
Ownership/ Install	Consumer owns and installs	Utility (TNGECL) installs, owns, operates until loan repaid	TN Government initiates, consumer owns the system	Household owns and installs; may use approved O&M provider	RESCO/EPC	Consumer owns and installs
Consumer upfront Payment	10% Consumer capex	None from consumer	None from consumer	10% Consumer capex	None from consumer	10% Consumer capex
Subsidy	60% MNRE capital subsidy only	60% MNRE capital subsidy only	100% Full subsidy: MNRE &	60% MNRE capital subsidy only	60% MNRE capital subsidy only	60% MNRE capital subsidy only
Remaining Capital & Loan	30% by Consumer, repaid from bill savings and surplus solar sale	40% loan share by TNGECL, repaid via surplus solar sales	No loan to consumer; full cost covered by subsidies. Government to recover expense from subsidy reduction.	30% by Consumer, repaid from bill savings and surplus solar sale	40% loan share by RESCO/EPC, repaid via solar sales	90% by Consumer from interest free loan, repaid from bill savings and surplus solar sale
Surplus Solar	Net feed-in tariff paid directly to consumer.	Dedicated feed-in tariff on solar gross generation is used to repay loan; afterward, net feed-in tariff to consumer.	Net feed-in tariff to consumer. Net feed-in tariff at: 3.61 ₹/kWh	Sold at agreed tariff to government institutions; escrow ensures secured, priority payment.	N/A	Net feed-in tariff paid directly to consumer.
Solar metering mechanism	Net metering / Net feed-in	Net metering	Net metering	Net metering	Gross metering (for RESCO/EPC) at a solar feed-in tariff.	Net metering / Net feed-in
Solar self-consumption	Yes	Yes	Yes	Yes	No	Yes

Operation & Maintenance	Consumer responsible for O&M (hires vendor or self-maintains)	TNGECL provides O&M throughout loan period; may transfer to consumer post-transfer;	Min 5 year O&M service contract under approved g providers	Min 5 year O&M service contract under approved g providers;	RESCO/ EPC over the entire project lifetime	Consumer responsible for O&M (hires vendor or self-maintains)
Operation & Maintenance	Consumer responsible for O&M (hires vendor or self-maintains)	TNGECL provides O&M throughout loan period; may transfer to consumer post-transfer;	Min 5 year O&M service contract under approved g providers	Min 5 year O&M service contract under approved g providers;	RESCO/ EPC over the entire project lifetime	Consumer responsible for O&M (hires vendor or self-maintains)
Payment Security	None (standard loan risk)	Utility-managed (billing/ escrow)	N/A	Escrow account receives all P2G revenue, pays the loan principal first and remaining goes to the consumers	N/A	Interest paid by the government
Key Features	- Market freedom	- Zero upfront for consumer	- Zero-cost, full support for inclusion	Escrow mitigates risk	- Zero cost to the consumers	- Zero interest loan for consumers
	- Maximum user control	- Utility handles finance/risk	- No loans for consumer	- Stable institutional (public sector) buyer	-RESCO handles financial risk	- Maximum user control
	- Standard credit risk	- Automated recovery mechanism		- Accelerates public sector decarbonisation, empowers prosumer households	Consumer benefits from lease and solar incentive	- Standard credit risk

PM Surya Ghar – Business Model Results

When examining the business models for introducing rooftop solar to low-income households in Tamil Nadu, the 25-year financial benefits reveal critical differences among the three main stakeholders: the consumer (or prosumer), the Government of Tamil Nadu (in terms of electricity subsidy impact), and the power distribution company (TNPDCL). Among the business models considered for low-income rooftop solar in Tamil Nadu, Super RESCO and 100% Subsidy deliver the greatest direct benefits to consumers, while Peer-to-Government provides the largest fiscal savings for the government, BAU yields moderate advantages for all, and BOT's high cost to the government raises concerns about its financial sustainability..

Table 25 Surya Ghar for low-income households, 25-year cost-benefit analysis

Models	Metering Type	Consumer (₹)	Gov. (₹)	TNPDCL (₹)
Model 1 - Market Driven	Net feed-in	14,491	14,281	22,187
Model 2- Full Subsidy	Net metering	53,010	8,604	7,137
Model 3- BOT	Net metering	48,492	(434)	36,555
Model 4- P2G	Net metering	29,943	1,75,167	35,969
Model 5- Super Resco	Gross metering	65,209	-	-
Model 6- Zero Interest Finance	Net feed-in	26,529	1,669	22,187

The first model, BAU (Business As Usual) or consumer-driven deployment, produces relatively modest benefits for all parties. Over 25 years, the consumer saves ₹14,491, the government reduces its subsidy burden by ₹14,281, and TNPDCL realizes a benefit of ₹22,187. This points to a model where everyone gains moderately, but there is no transformative shift for any one group.

In the Full Subsidy model, the consumer's financial benefit rises significantly to ₹53,010, making this approach highly advantageous from a household perspective. The government still saves on the subsidy, but to a lesser extent, with benefits dropping to ₹8,604. TNPDCL's gain dips to ₹7,137, its lowest across all models. This indicates a policy leaning strongly pro-consumer, but one that offers less value to both the state and the utility.

The BOT (Build-Operate-Transfer) model offers a benefit of ₹48,492 to the. Over 25 years, it has provides the Government a net loss of ₹434 and TNPDCL savings of ₹36,555. This model delivers consumer benefits without significantly affecting the Government or TNPDCL's gains.

Under the Peer-to-Government (P2G) arrangement, the government secures its largest financial benefit, with a projected saving of ₹1,75,167, arguably because it is not required to subsidize capital expenditures or ongoing maintenance. TNPDCL also does well, at ₹35,969, while the consumer's benefit, although positive at ₹29,943, is not as pronounced as in the full subsidy or BOT scenarios. This model thus skews the advantages toward public finances, still helping the utility and providing a smaller, but real, impact on household economics.

The Super RESCO model stands out for the consumer. It delivers the benefit of ₹65,209 to the consumer over 25, this is exclusively on account of the rooftop lease income to the RESCO or EPC. The government and TNPDCL see no explicit financial impact. This business model transfers most of the benefits to households and the distribution company and may rely heavily on third-party capital and management.

The Zero-Interest Finance model offers consumers a benefit of ₹26,529 and TNPDCL a benefit of ₹22,187. Over 25 years, the government gains a net benefit of ₹1,669. This model provides greater value to consumers than the market-driven approach, making rooftop solar affordable for beneficiaries while keeping the government's fiscal impact minimal.

In summary, the Super RESCO and full subsidy models appear most transformative for low-income households. BOT is attractive for consumers, the government and the distribution company.. P2G has the greatest fiscal sustainability, dramatically relieving the state's subsidy burden while still benefiting households and TNPDCL. Zero Interest Finance also has positive benefits for consumers, government and the utilities. The BAU model, by contrast, represents incremental improvement across the board, serving as a baseline rather than a catalyst for change. Selection among these models should weigh the targeted policy outcome—whether it is maximising household benefit, fiscal prudence, or utility viability—and the willingness of the government or private sector to absorb the necessary risks and investments.

KUSUM-C (IPS) Business Model Results

The KUSUM-C (IPS) program in Tamil Nadu introduces behind-the-meter solar solutions for farms, and the following analysis compares the 25-year financial impacts of six different business models on farmers, the state government, and the electricity distribution company. For the KUSUM-C IPS program introducing behind-the-meter solar for farms, an evaluation of six business models over a 25-year horizon reveals distinct impacts on farmers (the consumers), Tamil Nadu's distribution company (TNPDCL), and the state government in terms of electricity subsidy dynamics.

Table 26 Kusum-C IPL for marginal farmers, 25-year cost-benefit analysis

Models	Metering Type	Consumer (₹ lakh)	Gov. (₹ lakh)	TNPDCL (₹ lakh)
Model 1- Market Driven	Net metering	(4.99)	8.54	5.87
Model 2- Full Subsidy	Net metering	(0.32)	7.71	4.73
Model 3- BOT	Net metering	(0.81)	3.43	7.27
Model 4- P2G	Net metering	(3.60)	10.79	7.27
Model 5- Super RESCO	Gross metering	1.17	(1.24)	4.35
Model 6- Zero Interest Finance	Net metering	(3.28)	7.71	9.46

In the business-as-usual (BAU) consumer-driven scenario, the farmer actually incurs a small financial loss of ₹4.99 lakh over 25 years, despite the primary intention of such programs being to alleviate farmer energy costs. However, the state government realizes a benefit of ₹8.54 lakh, and TNPDCL sees a positive impact of ₹5.87 lakh, suggesting the system, as currently structured, transfers value away from the farmer but provides modest fiscal and operational gains to both the government and the utility.

Switching to a model where the government provides a 100% subsidy, the loss to the farmer shrinks considerably to just ₹0.32 lakh. The government and TNPDCL still benefit—although the government's gain falls slightly to ₹7.71 lakh and TNPDCL's to ₹4.73 lakh. This approach moves closer to breaking even for farmers without eliminating benefits for other stakeholders, but the consumer's position remains negative.

A Build-Operate-Transfer (BOT) model provides a marginally larger loss for the farmer at ₹0.81 lakh, though both government and TNPDCL stand to gain ₹3.12 lakh and ₹7.27 lakh, respectively. While less favourable for the government, this scenario allows the utility to benefit more, and the financial burden on the farmer is still relatively contained.

The Peer-to-Government (P2G) model results in a more notable consumer loss of ₹3.60 lakh. Meanwhile, the government achieves the largest fiscal benefit of any model at ₹10.32 lakh, and TNPDCL matches its previous peak gain at ₹7.27 lakh. This option maximises subsidy reduction for the state and utility gain, but at the expense of farmer economics.

The Super RESCO model is unique, delivering one positive outcome for the farmer, at ₹1.17 lakh. However, this is offset by a loss to the government, which faces a small fiscal impact of minus ₹1.24 lakh, and a more moderate gain for TNPDCL at ₹4.35 lakh. Only under this structure does the farmer obtain a clear financial benefit, but this comes at a direct cost to the state.

Similar to the Consumer-Driven Model, the Net Zero Interest Model, though slightly more attractive, is not financially viable for farmers. However, the 25-year cost savings for the Government and TNPDCL remain substantial.

Taken together, these results indicate that, when rolling out KUSUM-C (IPS) solar for farms, most current business models—barring Super RESCO—do not provide direct, long-term savings to the farmer. If the objective is farmer-centric impact without creating large fiscal pressure, careful attention must be given to model structure and risk allocation, since shifting the balance between public investment, private participation, and operational efficiency significantly alters who wins, who loses, and by how much over time.

08 Conclusion & Recommendation

Tamil Nadu's electricity sector has long followed a welfare-driven approach that has expanded access and enabled inclusive growth. However, this model now faces structural challenges, including mounting subsidy burdens, distribution losses, and the underutilisation of clean energy potential.

Tamil Nadu has long championed social equity through inclusive welfare measures, with electricity subsidies historically serving as a tool for protecting vulnerable households and farmers. However, this tradition now comes with rising costs—subsidy outlays have exceeded ₹16,000 crore in 2025–26, nearly 4% of the state budget, and have grown by almost 80% in just four years. These subsidies, while socially popular, now risk benefitting higher-income households more than the poor, highlighting the need for sharper targeting so that support reaches those who need it most.

At the same time, Tamil Nadu holds enormous untapped potential for rooftop solar. Despite technical estimates far above 60 GW, actual rooftop solar deployment remains below 2% of this potential, accounting for less than 10% of the state's installed solar capacity as of mid-2025. Rooftop solar, as part of a broader suite of distributed energy resources (DERs), offers the ability to generate local jobs, reduce T&D losses, strengthen grid resilience, and cut greenhouse gas emissions—all while directly empowering households and small farmers.

National schemes such as PM Surya Ghar and KUSUM-C (IPS) present timely opportunities. These programs offer up to 60% subsidies and concessional loans for households and farmers, aligning well with Tamil Nadu's welfare values. By focusing on low-income groups and small landholders, the state can use these schemes not only to accelerate clean energy adoption but also to reduce subsidy burdens, stimulate local employment, and contribute to decarbonization goals.
For these benefits to materialize, Tamil Nadu must advance supportive, predictable, and simple policy mechanisms. Key priorities include:

- Clear, stable solar metering and grid regulations,
- Efficient, user-friendly application processes,
- Widespread consumer awareness campaigns,
- Consistent and adequate fiscal incentives.

Experience from global rooftop solar leaders shows that when these components are in place—alongside innovative business models (such as Super-RESCO, Peer-to-Government, BOT, or full subsidy for the poor)—adoption can scale rapidly, especially among underserved populations. To realize this vision, Tamil Nadu should:

- Move beyond aggregate solar MW targets to adoption targets, especially prioritising low-income households and marginal farmers.
- Many beneficiaries may not have access to a suitable rooftop for installation. To ensure equitable access, Tamil Nadu could explore alternative models such as virtual net metering and community solar projects.
- Combine central schemes with tailored state-level incentives and business models.
- Reform subsidy delivery by integrating beneficiary identification mechanisms, learning from schemes like Ujjwala Yojana and China's SEPAP, to maximise both equity and fiscal sustainability.
- Ensure affordable finance, high-quality vendor ecosystems, and local outreach through trusted institutions like panchayats and SHGs.
- Promote battery storage and advanced grid management to prepare for higher solar penetration and shifting demand peaks.

Finally, effective delivery will require unified and coordinated implementation—among TNERC, TNGECL, TANGEDCO/TNPDCL, local bodies, and civil society—supported by transparent data and clear mandates. With this comprehensive and targeted approach, Tamil Nadu can stay true to its ethos of social justice while building a secure, sustainable, and inclusive energy future for all.

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Annexure

Assumptions for Global & National Benchmarking Exercise

Table 27 Key assumption for computation on country-specific rooftop solar penetration indicators

Country	Rooftop Solar Capacity Factor (%)	Population (2024)	Electricity Demand 2024 (GWh)
Australia	14.0–14.5	2,72,04,810	2,81,640
Netherlands	9.5	1,79,94,240	1,19,140
Germany	11.4–11.5	8,35,10,950	5,05,920
China	13	1,40,89,75,000	1,00,72,950
India	14.8	1,45,09,35,790	20,27,130
Brazil	17.2	21,19,98,570	7,60,830

Source: World Bank, 2025; Ember, 2025b

Table 28 Key assumption for computation on State-specific rooftop solar penetration indicators

State/UT	Projected Total Population	Estimated State/UT Wise Energy Consumption (in GWh) 2024-25
Andaman & Nicobar Islands	405000	292
Andhra Pradesh	5,35,86,000	74,583
Arunachal Pradesh	15,94,000	595
Assam	3,64,93,000	10,994
Bihar	13,10,41,000	37,982
Chandigarh	12,59,000	1,616
Chhattisgarh	3,09,82,000	34,383
Dadra & Nagar Haveli and Daman & Diu	14,79,000	10,908
Delhi	2,22,77,000	35,277
Goa	15,93,000	4,244
Gujarat	7,35,13,000	1,36,487
Haryana	3,10,57,000	59,223
Himachal Pradesh	75,55,000	11,876
Jammu & Kashmir	1,38,31,000	14,505
Jharkhand	4,06,26,000	17,842
Karnataka	6,86,79,000	70,017
Kerala	3,61,11,000	26,940

Ladakh	3,04,000	225
Lakshadweep	69,000	56
Madhya Pradesh	8,89,85,000	86,686
Maharashtra	12,86,59,000	1,68,594
Manipur	32,89,000	897
Meghalaya	34,17,000	1,897
Mizoram	12,64,000	875
Nagaland	22,79,000	761
Odisha	4,69,53,000	37,668
Puducherry	17,32,000	2,832
Punjab	3,11,88,000	61,323
Rajasthan	8,30,60,000	96,437
Sikkim	7,03,000	552
Tamil Nadu	7,73,94,000	1,09,939
Telangana	3,84,99,000	72,966
Tripura	42,32,000	1,377
Uttar Pradesh	24,12,65,000	1,35,299
Uttarakhand	1,19,13,000	15,495
West Bengal	10,02,02,000	54,844

Source: CEA, 2022; MoHFW, 2020

Avoided Costs Calculation

The avoided cost calculations in Solva focus on measuring the technical and economic benefits of distributed energy resources (DERs) like solar and storage, compared to a traditional (business-as-usual) system. These calculations are carried out to determine how much money a utility can save by integrating local renewable resources instead of relying on central power plants and long-distance transmission.

Avoided Cost of Energy (ACE)

This is the money saved when local solar or storage meets electricity demand, reducing the need to buy energy from the grid or operate expensive, polluting power plants. It's usually calculated using the marginal cost of the most expensive generator that would have run if the DER wasn't present. More simply, it can use hourly energy price data or user-provided avoided costs.

Avoided Distribution Capacity Cost (ADCC)

Adding DERs can delay or avoid upgrades like installing new feeders or transformers. The avoided cost here is the difference in upgrade timing and costs between a system with DERs and one without. If DERs keep feeder loads under their maximum capacities for longer, utilities can avoid or postpone infrastructure investments.

Avoided Transmission Capacity Cost (ATCC)

Since DERs provide energy locally, less electricity needs to be sent over long transmission lines, reducing the requirement for expanding or contracting new transmission capacity. This cost is avoided by meeting peak demand locally, calculated using the value of transmission capacity and how much the DER contributes during high-demand hours.

Avoided Generation Capacity Cost (AGCC)

DERs may also reduce how quickly utilities need to sign contracts or build new centralized generating plants. This is a future cost that can sometimes be avoided entirely if DERs keep up with demand growth. The saving is based on how much new generator capacity is not needed because of DERs, considering future performance and costs.

Analysis for Avoided Costs- PM Surya Ghar:

Table 29 Feeder characteristics and assumptions for avoided cost analysis (Karungalpalayam HTF)

HTF - Karungalpalayam		
Marginal cost (Rs/kWh)	4.95	This is the average of thermal generators as given in ARR FY 23-24
Capacity addition (MW)	1,672.15	Taken from policy note FY23
Transmission loss	3.70%	Taken from ARR FY 23-24

Table 30 Connected load distribution across tariff categories –Karungalpalayam HTF

Tariff Category	Domestic (IA)	Commercial (V)	Industrial (IIIA & IIIB)	Others (-)	Total
No. of Consumers	15,060	3,074	303	435	18,872
Connected Load (kW)	27,448	8,754	6,636	1,903	44,742
% of Consumers	79.8%	16.3%	1.6%	2.3%	100%
% of Connected Load	61.3%	19.6%	14.8%	4.3%	100%

Considering a 2kW system for domestic consumers and limiting to the load-carrying capacity of the HT Feeder, adoption levels have been determined.

Table 31 : Estimated rooftop solar capacity addition at different adoption levels (Karungalpalayam feeder).

Adoption level	30%	20%	10%
Capacity (MW)	9.036	6.024	3.012

Analysis for Avoided Costs- PM KUSUM-C (IPS):

Table 32 Feeder characteristics and assumptions for avoided cost analysis (Solar HTF).

HTF - Solar		
Marginal cost (Rs/kWh)	4.95	This is the average of thermal generators as given in ARR FY 23-24
Capacity addition (MW)	1,672.15	Taken from policy note FY23
Transmission loss	3.70%	Taken from ARR FY 23-24

Table 33 Connected load distribution across tariff categories- Solar HTF

Tariff Category	Domestic (IA)	Commercial (V)	Industrial (IIIA & IIIB)	Others (-)	Total
No. of Consumers	2,766	817	53	70	3,706
Connected Load (kW)	5,615	3,177	582	340	9,714
% of Consumers	74.6%	22.0%	1.4%	1.9%	100%
% of Connected Load	57.8%	32.7%	6.0%	3.5%	100%

Considering an 11kW system for agricultural consumers, assuming others are agricultural consumers under the HT Feeder, adoption levels have been determined

Table 34 Estimated solar capacity addition at different adoption levels (Solar feeder, agricultural consumers).

Adoption level	100%	50%	25%
Capacity (MW)	0.77	0.39	0.19

Business Model Assumptions

Table 35 Business model assumptions for PM Surya Ghar

Assumptions	Units	Model 1 - BAU Consumer driven	Model 2 - 100% Subsidy	Model 3 - BOT Model	Model 4 - P2G	Model 5 - SUPER RESCO	Model 6 - Zero Interest Finance
Solar metering mechanism		Net feed-in	Net metering	Net metering	Net metering	Gross metering	Net feed-in
Annual electricity consumption	kWh/ year	600	600	600	600	600	600
Average annual tariff increase BAU	%	3%	3%	3%	3%	3%	3%
Annual increase in energy consumption	%	3%	3%	3%	3%	3%	3%
Solar PV capacity 50kWh/month	kW	2	2	2	2	2	2
Cost of rooftop solar	kW	60,000	60,000	60,000	60,000	60,000	60,000
Capacity Utilization factor	%	19%	19%	19%	19%	19%	19%
Grid availability factor	%	99%	99%	99%	99%	99%	99%
Average Solar self-consumption (25 year average)	%	40%	100%	100%	100%	100%	40%
Annual degradation solar	%	1%	1%	1%	1%	1%	1%
TANGEDCO cost of supply	₹/kWh	10.19	10.19	10.19	10.19	10.19	10.19
TANGEDCO average billing rate	₹/kWh	7.77	7.77	7.77	7.77	7.77	7.77
TANGEDCO overhead cost per kWh	₹/kWh	1.75	1.75	1.75	1.75	1.75	1.75
TANGEDO APP	₹/kWh	7.40	7.40	7.40	7.40	7.40	7.40
Net feed-in tariff/ Gross feed-in tariff (settlement on monthly basis at specified tariff)	₹/kWh	3.61	3.61	6.25	5.00	3.25	3.61
Network charges	₹/kWh	0.25	0.25	0.25	0.25	0.00	0.25

Local distribution losses	%	8%	8%	8%	8%	8%	8%
Operation and Maintenance Expenses in year 1	%	1.40%	1.40%	1.40%	1.40%	1.40%	1.40%
Annual increase in Operation and Maintenance Expenses	%	5.72%	5.72%	5.72%	5.72%	5.72%	5.72%
Insurance (% of depreciated asset value)		0.35%	0.35%	0.35%	0.35%	0.35%	0.35%
Depreciation Rate	%	3.60%	3.60%	3.60%	3.60%	3.60%	3.60%
Equity	%	30%	0%	30%	30%	30%	10%
Debt	%	70%	100%	70%	70%	70%	90%
Loan Tenure	years	7	7	5.00	7.00	9.00	7.00
Moratorium	years	0	0	0	1	1	0
Interest on loan	%	7%	7%	7%	7%	7%	0%
Interest on working capital	%	11%	11%	11%	11%	11%	11%
Inflation rate/annual increase in CoS	%	3%	3%	3%	3%	3%	3%
Discount rate	%	8.65%	8.65%	8.65%	8.65%	8.65%	8.65%
TN Government subsidy	%	0%	40%	0%	0%	0%	0%
MNRE subsidy	%	60%	60%	60%	60%	60%	60%
Consumer share on capex	%	100%	0%	0%	0%	0%	60%
Consumer share on loan	%	-	0%	-	-	-	-
TNPDCL share on loan	%	-	50%	-	-	-	-
Normal hours feed-in incentive	₹/kWh	-	-	-	-	0	-
Prime hours feed-in incentive	₹/kWh	-	-	-	-	0	-
Rooftop lease	₹/kWh	-	-	-	-	2,500	-
Normal hours export	%	-	-	-		75%	-
Current electricity tariff of Gov. Inst. *		-	-	-	8.80	-	-
Government Share of fiscal burden	%	-	-	85%	-	-	-
TNPDCL Share of fiscal burden	%	-	-	15%	-	-	-

**8.80 Rs/kWh for Low Tension Tariff II-B (1): (Government Educational Institutions and Hostel, Govt. Hospital, Other hospitals rendering totally free service) and Low Tension Tariff II-A: (Public Lighting, Water supply provided by Govt. /Local bodies)*

Table 36 Business Model assumptions for PM KUSUM-C (IPS)

Assumptions	Units	Model 1 - BAU Consumer driven	Model 2 - 100% Subsidy	Model 3- BOT Model	Model 4 - P2G	Model 5 - SUPER RESCO	Model 6 – Zero Interest Finance
Solar metering mechanism		Net metering	Net metering	Net metering	Net metering	Gross metering	Net metering
Annual electricity consumption	kWh/ year	9,802	9,802	9,802	9,802	9,802	9,802
Average annual tariff increase BAU	%	3%	3%	3%	3%	3%	3%
Annual increase in energy consumption	%	3%	3%	3%	3%	3%	3%
Solar PV capacity	kW	11.00	11.00	11.00	11.00	11.00	11.00
Cost of rooftop solar	kW	60,000	60,000	60,000	60,000	60,000	60,000
Capacity Utilization factor	%	19%	19%	19%	19%	19%	19%
Grid availability factor	%	99%	99%	99%	99%	99%	99%
Average Solar self-consumption (25 year average)	%	100%	100%	100%	100%	100%	100%
Annual degradation solar	%	1%	1%	1%	1%	1%	1%
TANGEDCO cost of supply	₹/kWh	10.19	10.19	10.19	10.19	10.19	10.19
TANGEDCO average billing rate	₹/kWh	7.77	7.77	7.77	7.77	7.77	7.77
TANGEDCO overhead cost per kWh	₹/kWh	1.75	1.75	1.75	1.75	1.75	1.75
TANGEDO APPC	₹/kWh	7.40	7.40	7.40	7.40	7.40	7.40
Net feed-in tariff/ Gross feed-in tariff (settlement on monthly basis at specified tariff)	₹/kWh	3.37	3.37	3.37	5.00	3.37	3.37
Network charges	₹/kWh	0.00	0.00	0.00	0.00	0.00	0.00
Local distribution losses	%	8%	8%	8%	8%	8%	8%
Operation and Maintenance Expenses in year 1	%	1.40%	1.40%	1.40%	1.40%	1.40%	1.40%

Annual increase in Operation and Maintenance Expenses	%	5.72%	5.72%	5.72%	5.72%	5.72%	5.72%
Insurance (% of depreciated asset value)		0.35%	0.35%	0.35%	0.35%	0.35%	0.35%
Depreciation Rate	%	3.68%	3.68%	3.68%	3.68%	3.68%	3.68%
Equity	%	30%	0%	30%	30%	30%	30%
Debt	%	70%	100%	70%	70%	70%	70%
Loan Tenure	years	7	5	5	10	10	7
Moratorium	years	0	0	0	1	1	0
Interest on loan	%	7%	7%	7%	7%	7%	0%
Interest on working capital	%	11%	11%	11%	11%	11%	11%
Inflation rate/annual increase in CoS	%	5%	5%	5%	5%	5%	5%
Discount rate	%	8.65%	8.65%	8.65%	8.65%	8.65%	8.65%
Weighted average emission factor	t/kWh	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
TN Government subsidy	%	30%	70%	30%	30%	30%	30%
MNRE subsidy	%	30%	30%	30%	30%	30%	30%
Consumer share on capex	%	70%	0%	0%	0%	0%	70%
Consumer share on loan	%	-	0%	-	-	-	-
TNPDCL share on loan	%	-	50%	-	-	-	-
Normal hours feed-in incentive	₹/kWh	-	-	-	-	1.5	-
Prime hours feed-in incentive	₹/kWh	-	-	-	-	1.5	-
Min annual incentive	₹/kWh	-	-	-	-	3,000	-
Normal hours export	%	-	-	-	-	75%	-
Current electricity tariff of Gov. Inst. *		-	-	-	8.80	-	-
MNRE Benchmark cost per kW	₹/kW	40,679	40,679	40,679	40,679	40,679	40,679
Land lease per acre in ₹	₹	-	-	-	-	80,000	-

8.80 Rs/kWh for Low Tension Tariff II-B (1): (Government Educational Institutions, Hostel, Govt. Hospital, Other hospitals rendering totally free service) and Low Tension Tariff II-A: (Public Lighting, Water supply provided by Govt. /Local bodies)

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