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Indian Residential Rooftops: A Vast Trove of Solar Energy Potential

Resurgent Demand and Strong Supply-Side Enablers Support a Highly Favourable Market Outlook

Executive Summary

India's residential rooftop solar capacity as of 31 March 2022 may only be a mere 2,010 megawatt (MW). But because of a rising need for cost savings and increasing awareness among consumers, we expect residential solar rooftop installations to rapidly accelerate in the coming years. By the end of fiscal year 2023, we expect cumulative residential rooftop solar capacity to reach 3,214MW, nearly a 60% year-on-year increase. We note that the central government's recent steps to create a single national digital portal to simplify the process of rooftop solar installations for residential consumers and formalising a direct benefit transfer mechanism for subsidies will aid the demand in the segment. Our assessment of state-wise attractiveness for rooftop solar installations finds that Gujarat, Haryana and Maharashtra are the three most favourable states. Going forward, we recommend state governments take concerted efforts in expediting and streamlining net-metering and subsidy-related procedures. They also must reduce the intervention of state electricity distribution companies in the entire process of residential rooftop solar installation.

India had announced an ambitious goal of achieving net-zero emissions by 2070 at the 2021 UN Climate Change Conference (COP26) in Glasgow. As a step towards this goal, the Indian government updated the country's nationally determined contribution (NDC) – a climate action plan - in August 2022. As per the NDC, India targets to achieve 50% of the cumulative power capacity from non-fossil fuel-based energy resources by 2030.

Solar is a crucial segment that will contribute significantly to this national target. The solar segment in India can be primarily categorised based on the scale and location of the system implemented. There are two types of systems: large-scale (or utility-scale systems) and small-scale (or rooftop solar). Utility-scale systems are offsite systems, whereas rooftop solar systems are installed on-site.

With the Jawaharlal Nehru National Solar Mission's launch in 2010, India targeted generating 100 gigawatts (GW) of solar power by 2022. Of this total capacity, 60GW was to come from the utility-scale segment and the remaining 40GW from the rooftop solar segment.

Of this 40GW rooftop solar target, JMK Research estimates that only 11.8 GW is in place as of 31 March 2022. Of this, the residential sub-segment accounts for merely a 17% (2,010 MW) share, which is minuscule given India has more than 300 million households.

This is mainly because of a lack of consumer awareness, implementation and administrative issues in net metering approval, lack of timely disbursement of central and state subsidies, lack of availability of attractive financing options, etc. There is also a need to enhance the quality of residential solar installations and provide robust after-sales service to build consumer confidence in the Indian context.

We expect the growth of residential rooftop solar installations to accelerate in the near term across India because of the strong policy push and resurgent market demand. By FY2023, JMK Research estimates that the residential rooftop solar market will most likely achieve 3,214MW of cumulative installed capacity.

To accelerate the pace of rooftop solar installations in the residential segment, the central government has introduced many incentive schemes in the last decade. These mainly comprise financial assistance or subsidies, which various state electricity distribution companies (DISCOMs) have transferred to rooftop system installers. In addition, some states, beyond facilitating the provision of central subsidies, also provide subsidies from their own budgets.

The three most favourable states for residential rooftop solar installations are Gujarat, Haryana and Maharashtra.

Further, the World Bank's latest approval of a US$165 million credit line for the Indian residential solar segment is likely to help this segment become more affordable for end consumers.

In another significant development, in July 2022, the central government launched a single national digital portal to simplify the process of rooftop solar installation for residential consumers. The centre has also formalised a direct benefit transfer (DBT) mechanism for rooftop solar subsidies. Thus, residential consumers (those registered on the solar rooftop installation portal) can now 'directly' avail of the central subsidy.

Considering the availability and disbursal of subsidies in different states along with other factors, such as net metering approvals, the three most favourable states for residential rooftop solar installations are Gujarat, Haryana and Maharashtra. Gujarat's SURYA scheme, which saw 1.1GW installed in the state in the last 18 months, is one of the shining examples for other regional markets to emulate. Gujarat showcased how proactive support from state agencies, streamlining relevant procedures and effective implementation of incentives to end consumers can lead to the successful adoption of rooftop solar.

For other states as well, the prospect of rooftop solar adoption grows more attractive due to the growing need for cost savings and rising awareness among residential consumers.

Concerted efforts in streamlining/expediting net metering and subsidy-related procedures for consumers are imperative. This would include reducing DISCOMs' intervention in the entire process of residential rooftop solar installation.

Gujarat's SURYA scheme demonstrates that digitalisation (i.e., communication of relevant and simplified information through digital media) of the entire value chain infrastructure is critical. In addition to overall consumer awareness, digitalisation warrants reliable digital tools for financial institutions (FIs) for market assessment and pre- and post-installation monitoring of solar plants, etc.

Also, lately, several residential consumers are shifting towards high-end rooftop solar offerings. These include utilising high-wattage modules and integrating battery energy storage with rooftop solar. We expect these trends to become mainstream in the near term. And going forward, establishing a robust value chain infrastructure will be vital to develop an adequate number and variety of high-quality rooftop solar offerings.

Glossary of Terms

Abbreviation	Definition
BESS	Battery energy storage system
BRPL	BSES Rajdhani Power Limited
C&I	Commercial and Industrial
CAGR	Compound Annual Growth Rate
CAPEX	Capital expenditure
CEC	California Energy Commission
CEI	Chief Electrical Inspectorate
CFA	Central Financial Assistance
CGHS	Cooperative Group Housing Society
CMC	Comprehensive Maintenance Contract
DBT	Direct Benefit Transfer
DCR	Domestic Content Requirement
DISCOM	Distribution companies
EMI	Equated Monthly Instalment
EPC	Engineering, procurement and construction
FI	Financial Institution
GHS	Group Housing Society
GST	Goods and Services Tax
GUVNL	Gujarat Urja Vikas Nigam Limited
GW	Gigawatt
ITC	Investment tax credit
KSEB	Kerala State Electricity Board
kWh	Kilowatt-hour
LCOE	Levelised cost of electricity
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MW	Megawatt
NDC	Nationally Determined Contribution
NSM	National Solar Mission
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OPEX	Operational expenditure
PV	Photovoltaic
RE	Renewable energy
RESCO	Renewable Energy Services Company
RoI	Return on Investment
RWA	Residential Welfare Associations
SASH	Single-family Affordable Solar Housing
SGIP	Self-generation incentive program
T&D	Transmission and Distribution
UT	Union Territory

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1. Introduction

India has more than 300 million households and is endowed with abundant sunshine almost throughout the year, with an annual average of 300 sunny days. This shows that the potential for rooftop solar installations in residential spaces is huge in India. However, currently, India's cumulative residential rooftop solar market is nowhere near its full potential.

The share of the residential rooftop solar segment in the overall electricity generation capacity of the country is minuscule. This is because the penetration of solar photovoltaic (PV) technology in the residential segment has been shallow, unlike many developed economies, such as Australia, where about 25% of all Australian households have rooftop PV systems. The key drivers for the greater penetration of rooftop solar in the residential segment of advanced countries include high retail electricity costs, low solar power costs, attractive and effective government incentives, etc.

India began making dedicated efforts toward adopting solar power with the National Solar Mission (NSM) launch in January 2010, initially known as the Jawaharlal Nehru National Solar Mission. The NSM is the umbrella initiative to promote solar power in India. Under this mission, the central government provided financial assistance (subsidies) to set up solar PV plants on residential rooftops. Along with this initiative, some states also introduced their own rooftop solar subsidies for the residential segment, over and above the central subsidies.

In February 2019, the centre set an official target to install 4 gigawatts (GW) of cumulative residential rooftop solar capacity by 2022. However, even the availability of government subsidies could not provide the desired impetus for the growth of this segment. Thus, the pace of rooftop solar adoption in the residential segment has been abysmal across different states (except Gujarat, which happens to be the best example of widespread residential rooftop solar adoption). The lack of consumer awareness had been one of the major impediments to adoption, especially in the pre-COVID-19 era. Post-COVID-19, there has been a strong surge in demand, backed by enhanced consciousness about cost savings, the environment, etc.

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Interestingly, while the pace of the solarisation of India's residential segment has been underwhelming, India has been the world's least expensive residential solar power market for about a decade. In 2020, the average cost of a residential rooftop solar system in India was US$658 per kilowatt (kW), declining by 73% from the

2013 level.[1] In comparison, in 2020, the residential rooftop solar cost in leading residential markets, such as Japan, the United Kingdom, Switzerland and the United States of America (the US), was 3.3x to 6.4x that of India.

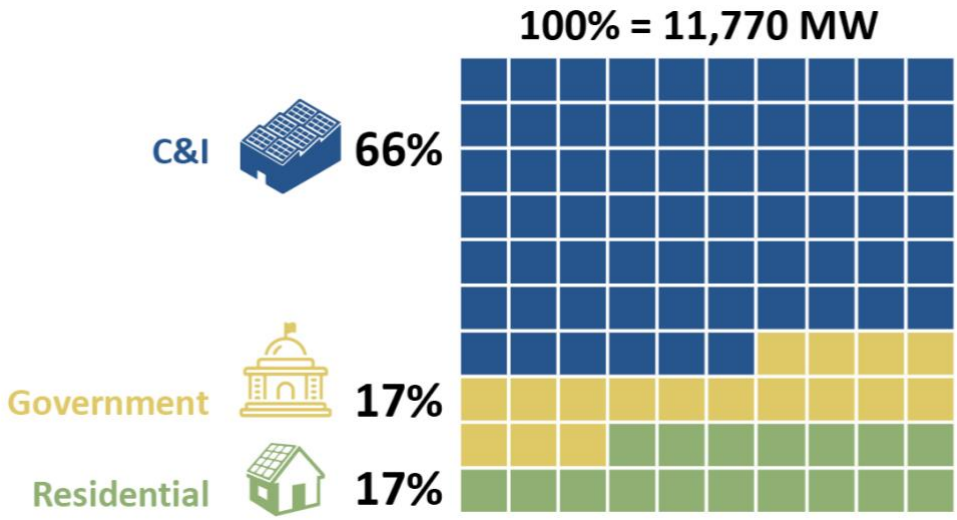
2. Residential Rooftop Solar Market Overview

Despite the high cost-effectiveness of residential rooftop solar systems in India, the market remains vastly underdeveloped. This section establishes this reality by elaborating on the installation trends and the business models relevant to the residential market.

2.A. Installation Trends

As of fiscal year (FY) 2022, India's overall rooftop solar market reached a cumulative installed capacity of 11,770MW. Of this, the residential segment has a share of just 17% (2,010MW), while the commercial and industrial (C&I) segment has the majority share of 66% (7,715MW).

Figure 1. Segment-wise Distribution of India Rooftop Solar Market (as of 31 March 2022)



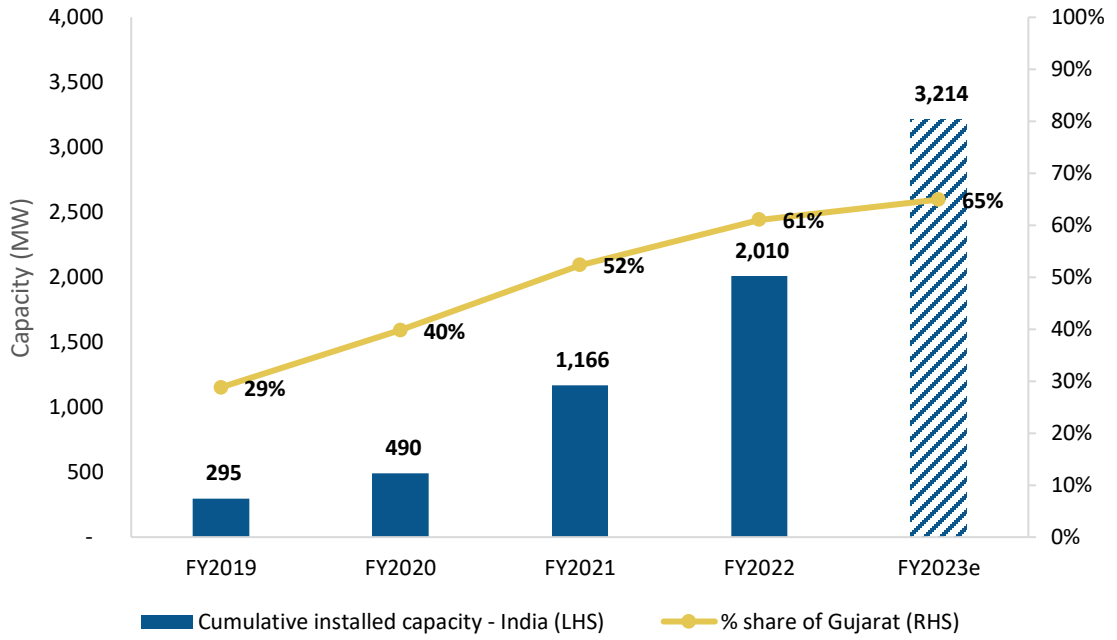
Source: JMK Research

From FY2019 to FY2022, the residential segment grew at a compound annual growth rate (CAGR) of 90%. This trend of cumulative installations is mainly due to the rooftop solar boom in Gujarat, especially over the past three fiscal years. As of FY2022, Gujarat holds the lion's share, 61% (1,227MW), of India's cumulative residential segment capacity. We provide more details on the state's residential rooftop solar progress in the "Success stories" section.

[1] IRENA. Renewable Power Generation Costs in 2020. June 2021.

While the growth of the pan-India market has been dismal so far, we expect it to accelerate in the near term because of the strong policy push and resurgent market demand. By FY2023, JMK Research estimates that the residential rooftop solar market will most likely achieve 3,214MW of cumulative installed capacity.

Figure 2. Cumulative Installed Capacity Trends: Residential Rooftop Solar



Source: JMK Research
Note: The above figure indicates the trend for overall (subsidised and non-subsidised) residential installation. The cumulative subsidised capacity, as of FY2022, was ~1.3GW.

2.B. Business Models

For a high-growth trajectory, it is necessary to nurture and augment the market demand, which requires stable and effective business models. Typically, business models are classified based on ownership. Capital expenditure (CAPEX) and operational expenditure (OPEX) models are the two traditional modes of business in the overall rooftop solar market.

Between these two models, CAPEX has been the most prevalent choice in the Indian residential segment. In the CAPEX model, the customer pays upfront for the system cost and thus wholly owns the solar plant. The responsibility of undertaking O&M of the system also lies with the customer.

In the OPEX model (also known as the renewable energy services company (RESCO)), a third party, i.e., a RESCO, provides 100% capital for setting up the solar system. The RESCO sets up, operates and maintains the system and sells the generated electricity to the customer at a pre-determined tariff.

However, the RESCO model barely exists in the residential market, with only a few instances involving group housing societies/residential welfare associations (GHS/RWA). This is due to the high contractual and payment risks that project developers face because of the lack of creditworthy consumers.

The equated monthly instalment (EMI) model is a variation of the CAPEX, requiring partial to zero upfront investment and EMIs or monthly pay-outs from the customer at a later stage. This model is slowly gaining relevance in the residential market.

We compare the commercial aspects of the three business models in Table 1.

Table 1. Key Commercial Aspects of the Three Business Models for Residential Rooftop Solar

Aspect	CAPEX	EMI	RESCO
Upfront Payment	100% of the system cost	Part or zero upfront payment	Zero upfront payment
Tax benefits to customer	Available	Available	Not available
Levelised cost of electricity (LCOE)	Lowest	Higher than CAPEX	Higher than CAPEX and EMI

Source: JMK Research

These three business models have been predominantly implemented, keeping consumers at the core of the models. This consumer-centric approach is standard, and DISCOMs do not directly facilitate them. However, there do exist a few cases of a DISCOM-centric approach. For more details about this approach, see the 'Way forward' section.

The traditional, CAPEX-based rooftop systems have seen sluggish adoption in the residential segment despite strong government initiatives from the central as well as various state governments.

2.C. Key Players

Healthy growth prospects supported by surging consumer demand are inducing the strong development of the supply side of the residential market. However, the Indian supply side, as it stands, is hugely underserving the market. There is a significant dearth of high-quality solar equipment, operation and maintenance (O&M) services, performance guarantees, etc.

In addition, the supply base for the Indian residential rooftop solar market is highly fragmented. In the whole set of supply-side players, there are many low- to mid-sized vendors and just a handful of top-tier developers. The latter group includes companies such as Tata Power, Amplus Solar, Solar Square and Zunroof. These players provide high-performance solar systems with performance guarantees and comprehensive maintenance packages, and well-trained, qualified technicians deliver their services.

Among the top-tier players, the most reputed brand is Tata Power, which has commissioned 100-150MW of residential solar systems across India.[2] There are two key reasons for Tata Power's commendable achievement in the residential segment:

- **One-stop shop**: Tata Power offers a one-stop solution for residential rooftop solar installation. It caters to consumer needs by bundling and providing all the relevant services, ranging from financing to engineering, procurement and construction (EPC) to O&M.

- **Strong Distributor network**: Being one of India's oldest solar power players, Tata Power has a strong pan-India presence and is present in more than 100 cities in India. The company also has a strong distributorship base with over 250 channel partners across the country.

The residential market is also strongly referral-driven. Therefore, prompt after-sales support services for end consumers are also imperative. Furthermore, it is necessary for the players to offer scalable business solutions for them to accelerate their growth in the residential market.

3. Key Market Drivers

The two fundamental drivers for the residential market are the availability of government subsidies and the prospect of savings on electricity bills through rooftop solar power. Other indirect catalysts, such as low reliability of retail power from the grid and rising consumer awareness, are also helping push the residential rooftop solar market forward.

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3.A. Prospect of Savings in Electricity Bill

Rooftop solar customers in the residential segment can achieve considerable annual cost savings (about 25% or more) on their electricity bills. Also, for some states, the cost of consuming power (in per kilowatt-hour (kWh) terms) generated from residential rooftop solar systems is substantially lower than procuring grid-based power from the local DISCOM. In fact, the gap between the two costs of power has only widened over recent years because of the general deflationary nature of the cost of solar power and the rising average cost of supply for DISCOMs.

Grid tariffs for residential consumers are likely to become more expensive going forward. This would enhance the economic case for adopting rooftop solar plants.

[2] Insight from primary research.

3.B. Lack of Reliability of the Retail Electricity Supply

The reliability of retail power supply continues to be a severe challenge in India. Though it has a surplus power generation capacity, India lacks the necessary infrastructure to maintain a brown fuel supply chain and power transmission and distribution (T&D). Many of the population living in semi-urban and rural areas of the country still face frequent power outages and/or voltage fluctuations. The lack of stability of the power distribution network in these areas has been a compelling factor behind the adoption of rooftop solar in the residential segment.

In the second quarter of 2022, the health of the entire Indian electricity network deteriorated in light of various atypical occurrences. The daily electricity deficit in India rose from an average of 0.3% to 1%.[3] The key factors leading to this unwarranted situation are higher than usual temperatures across India, the resurgence of industrial activities (leading to increased demand), and an acute shortage of coal (leading to a reduced power supply).

This power crisis has inadvertently underscored the significance of renewable electricity supply in India, especially on-site ones. As a result, we expect the residential rooftop solar market to grow faster in the foreseeable future.

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3.C. Imposition of Regulatory Mandates

Some administrative authorities in India have implemented regulations that mandate the installation of solar PV systems on the rooftops of residential buildings. These authorities sought to take this encouraging step to provide a fillip to the growth of solar installations in their respective jurisdictions.

Municipality

At the municipality level, the Municipal Corporation of Karimnagar was one of the first corporations to pass a resolution requiring all houses, apartments, community halls and commercial establishments with a built-up area of more than 2,700 square feet to install rooftop solar plants. From 1 March 2019, new buildings falling in this category needed to make provisions for solar rooftop panels before availing construction permits. Buildings constructed before this date also had to install solar panels.

[3] Fitch Ratings. India to Face Supply Challenges, Rising Electricity Demand. April 2022.

Union Territories

Among the Union Territories (UTs), Chandigarh, in a notification issued on 18 May 2016, made the installation of rooftop solar power plants mandatory in residential units measuring 500 square yards and more and in group housing societies. However, the regulation was not very effective as the response from households was low due to several bureaucratic bottlenecks.

State

At the state level, the West Bengal government made it mandatory for all large housing societies (having a total contract demand of more than 500kW) to install solar rooftop systems to meet at least 1.5% of their total electrical load.

Another state that formalised mandatory rooftop solar plant installations for residential buildings is Haryana. It is now mandatory for all residential buildings with a plot size of 500 square yards or more to install a solar power plant.

3.D. Extension of World Bank Credit Line

In the post-COVID-19 era, the most notable update in the Indian residential rooftop solar financing sphere has been the sanctioning of the World Bank's first concessional rooftop solar financing programme for the residential market in India. The World Bank has been one of the primary lending supports for this market, specifically the C&I segment.

In June 2022, the World Bank extended a fresh credit line of US$165 million to the Indian rooftop solar market to be channelled exclusively to the residential market. Reportedly, the concessional financing programme will directly finance 450MW of residential rooftop solar systems. It intends to incentivise DISCOMs to engage directly with residential consumers to bolster capacity building in the respective segment.

In June 2022, the World Bank extended a fresh credit line of US$165 million to the Indian rooftop solar market to be channelled exclusively to the residential market.

Broadly, the fund would aid in financing certain DISCOM-side measures, including the identification of:

- Groups of residential customers
- Optimal locations for solar rooftop systems and battery energy storage systems (BESS)
- Appropriate business practices that would help the DISCOMs in expediting rooftop solar installation

4. Government Initiatives

4.A. At the Central Level

Under the NSM, in December 2015, the Ministry of New and Renewable Energy (MNRE) launched "Phase 1" of the Grid-Connected Rooftop and Small Solar Power Plants Programme. The aim was to install 4.2GW of rooftop solar plants in the country by 2020. In March 2016, as part of this programme, the MNRE introduced the first-ever incentive for the residential segment.[4]

As formally named, the incentive, or central financial assistance (CFA), was also extended to the social and institutional segments. The amount of CFA was determined based on benchmark costs and the category of states (see Table 2).

As set by the MNRE, the benchmark costs covered all the system costs (including costs of solar modules, inverters, balance of system, etc.) except the costs of net metering and battery back-up.

Table 2. CFA Structure for the Grid-Connected Rooftop Solar and Small Solar Power Plants Programme, Phase 1

State Category	CFA
General category	30% of the benchmark cost
North-east and special category	70% of the benchmark cost

Source: MNRE

In February 2019, the centre approved "Phase 2" of the Grid-Connected Rooftop and Small Solar Power Plants Programme to achieve a cumulative rooftop solar capacity of 40GW by 2022. Of this target, 4GW was to come from the residential segment, including households in rural areas. The MNRE offered CFA for residential consumers once again to fast-track capacity addition in the segment.

Table 3. CFA Structure for the Grid-Connected Rooftop Solar and Small Solar Power Plants Programme, Phase 2

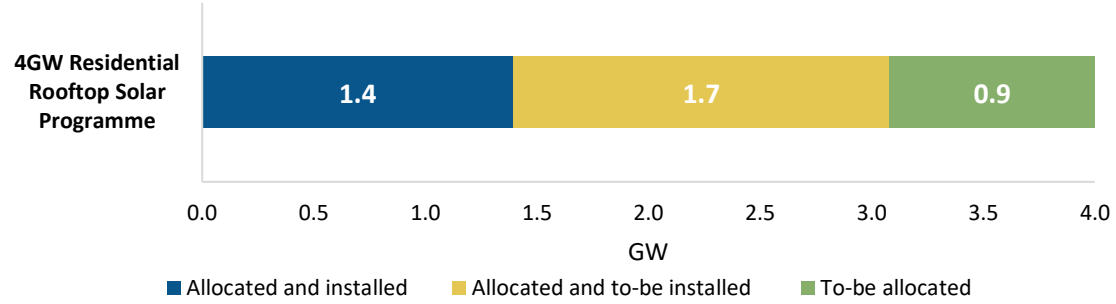
Housing Category	System Capacity	CFA
Individual households	**Up to 3kW capacity**	40% of the benchmark cost
	Above 3kW and up to 10kW capacity	40% of the benchmark cost for first 3kW + 20% of the benchmark cost for the rest of the capacity
GHS/RWA	**Up to 500kW capacity**	20% of the benchmark cost

*Note: *CFA is limited to rooftop solar systems supplying power only to common facilities.*
Source: MNRE

[4] MNRE. Grid Connected Rooftop and Small Solar Power Plants Programme – Amendment. March 2016.

As of 30 July 2022, the MNRE has allocated 3.1GW of residential rooftop solar capacity of the 4GW target capacity. Of the allotted capacity, a total of 1.4GW has been installed.[5]

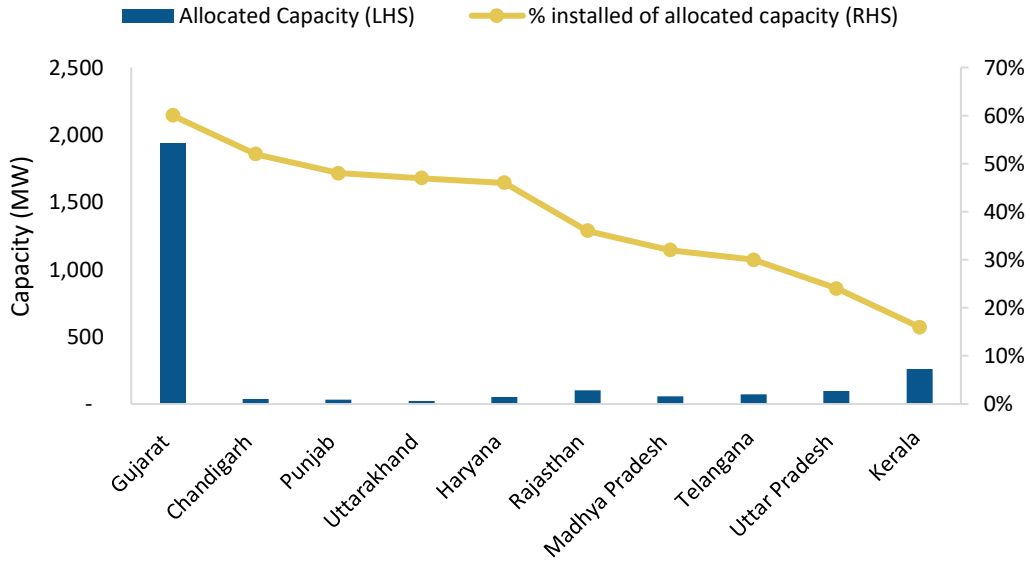
Figure 3. Status of the MNRE's Grid-Connected Rooftop Solar and Small Solar Power Plants Programme (Phase 2) for the residential segment



Note: For subsidized capacity only. Progress as of 30 July 2022.
Source: MNRE, JMK Research

About 63% of the allocated capacity across India has been earmarked for Gujarat. Of these, 60% have been installed by the state under the MNRE's rooftop solar Phase 2 programme.

Figure 4. State-Wise Break-Up of Capacity Under the Grid-Connected Rooftop Solar and Small Solar Power Plants Programme (Phase 2)



Source: MNRE, JMK Research

In a more recent development, on 30 July 2022, the central government launched a national portal to simplify the procedure for rooftop solar installations. Any

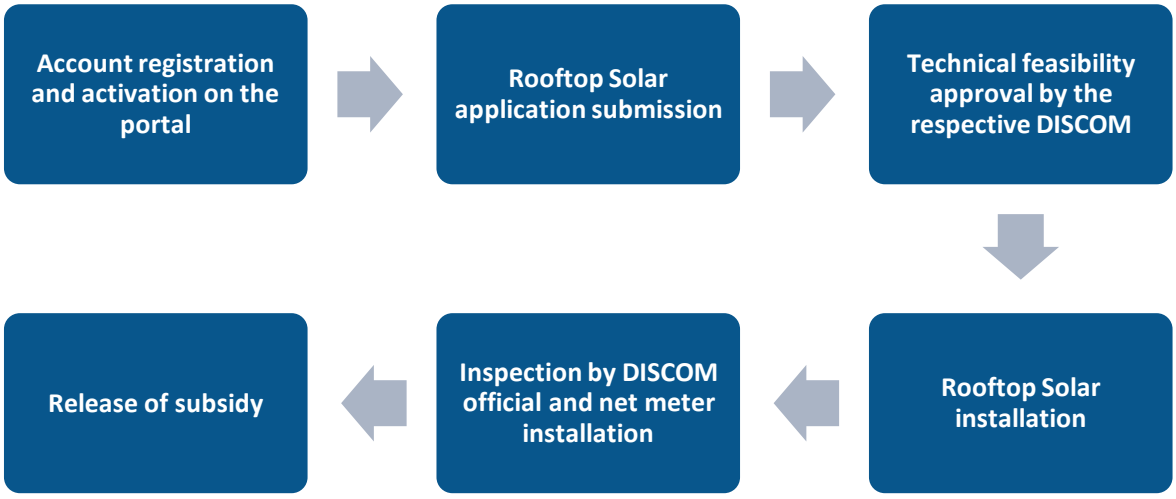
[5] MNRE

consumer from the residential segment is eligible to apply for a rooftop solar system installation via this portal.

Selecting a vendor registered with local DISCOMs, solar modules, solar inverters and other balance of plant and equipment is left to the consumers' discretion. Further, the central government will credit the subsidy to the consumer using the direct benefit transfer (DBT) mechanism. In addition, it will be available only to those consumers who register on the portal by 31 December 2022.

The portal will also enable an applicant to track the installation process for a rooftop solar plant online, starting from the registration of the application to the credit of the subsidy in the consumer's bank account (after the installation and inspection of the plant).

Figure 5. Process to Follow on the "National Portal for Rooftop Solar"



Source: MNRE

Along with the announcement on the rooftop solar portal, the central government also notified a new CFA structure under the simplified national scheme. According to this structure, the subsidy amounts for different slabs of system capacity are fixed and standardised across all states and UTs. The government will release the subsidy only after the relevant DISCOM gives clearance on the successful commissioning and installation of the metering system.

For the first time, the central government will be offering a subsidy for residential rooftop solar systems of 10kW and greater capacity. For any qualifying system with a capacity of 10kW and above, the government will provide a fixed subsidy amount of Rs94,822 (~US$1,170).

Table 4. CFA Structure for Residential Rooftop Solar Segment as per the New Simplified Procedure (w.e.f. 30 July 2022)

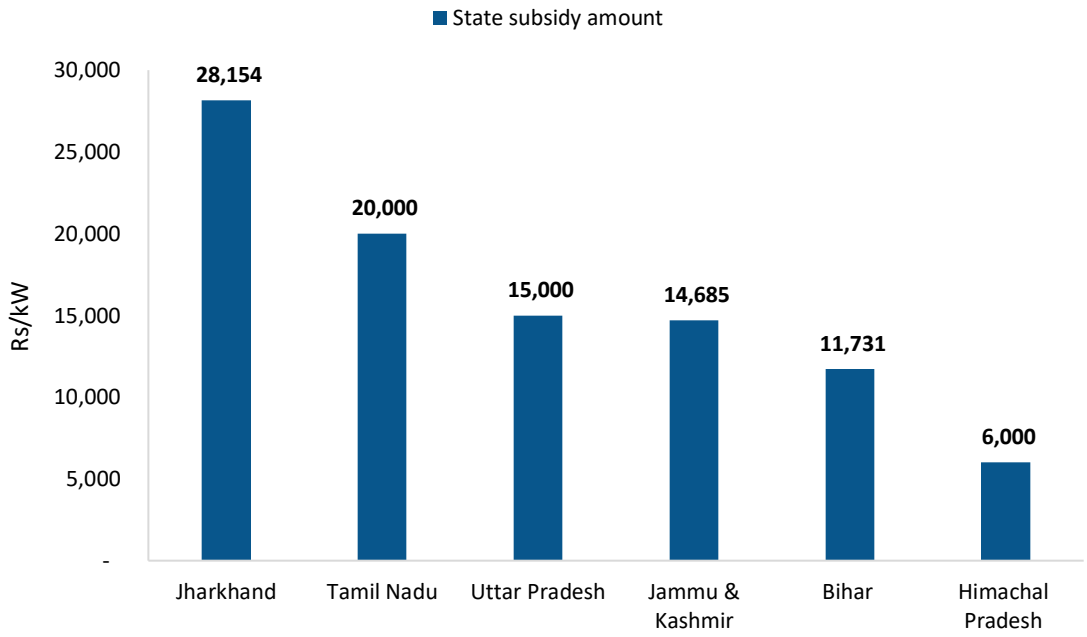
Rooftop solar system capacity	Applicable subsidy
Up to 3kW	Rs14,588 (~US$180) per kW
Above 3 kW and less than 10 kW	Rs14,588 (~US$180) per kW for first 3kW + Rs7,294 (~US$90) per kW for the rest of the capacity
10 kW and above	Rs94,822 (~US$1170)

Note: The CFA would be calculated based on the total solar module capacity or solar inverter capacity or capacity as approved by the relevant DISCOM, whichever is lower.
Source: MNRE, JMK Research

4.B. At the State Level

The MNRE's rooftop solar programme has facilitated many states implementing subsidy schemes for the residential segment. Some even offer their own subsidy schemes (i.e., a subsidy funded from the state's budgets), which are applicable over and above the central subsidy scheme.

Figure 6. State-level Rooftop Solar Subsidies (Applicable Over and Above the MNRE Subsidy)



Note*: The subsidy amounts depicted in the figure are with respect to 1kW systems and the latest state benchmark costs and do not include state-level subsidies for Goa. For more details on the state-level subsidies, refer annexure.*
Source: Respective state energy development authority websites, JMK Research

Irrespective of the promoter (centre or state), DISCOMs have traditionally acted as the implementing agencies for these subsidy schemes. They have to issue relevant tenders (to set up residential rooftop solar plants in their respective power distribution areas) and subsequently empanel vendors, pay CFA to the vendors, etc.

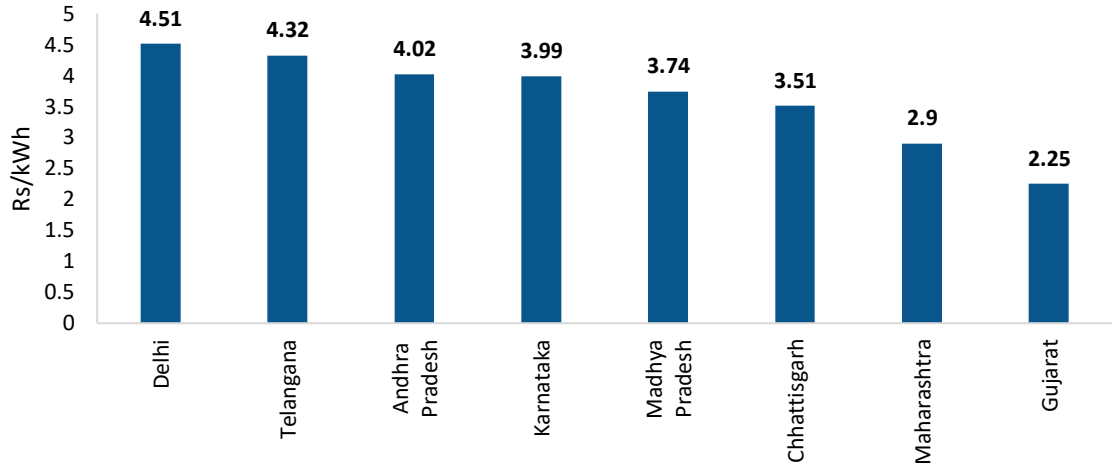
5. Net Metering Regulations for Residential Segment

In addition to government initiatives, such as financial assistance, the launch of the single-window portal, etc., a strong regulatory environment is critical to the growth of the residential rooftop solar market.

As opposed to the C&I segment, the outlook of state electricity regulators and DISCOMs toward the residential rooftop solar segment has been relatively favourable. Almost all the states provide residential consumers with net metering provisions.

Under net metering, the compensation for surplus energy injection at the end of the settlement period makes the rooftop solar system an attractive proposition for the end consumer. This is especially true for residential consumers, considering their highly variable and unpredictable demand patterns. Due to the mismatch between peak solar hours and peak load demand hours for the residential segment, residential consumers may inject a substantial volume of surplus energy into the grid.

Figure 7. State-wise surplus energy injection rates in net metering (residential segment)



Source: Respective state electricity regulatory commissions, JMK Research

For most states, the surplus energy injection rate lies between Rs2/kWh (US$0.024/kWh) and Rs4.5/kWh (US$0.055/kWh). This is significantly lower than the prevailing residential OPEX tariff rates of Rs5.5/kWh (US$0.067/kWh) to Rs6/kWh (US$0.073/kWh). Notably, several major states, such as Tamil Nadu,

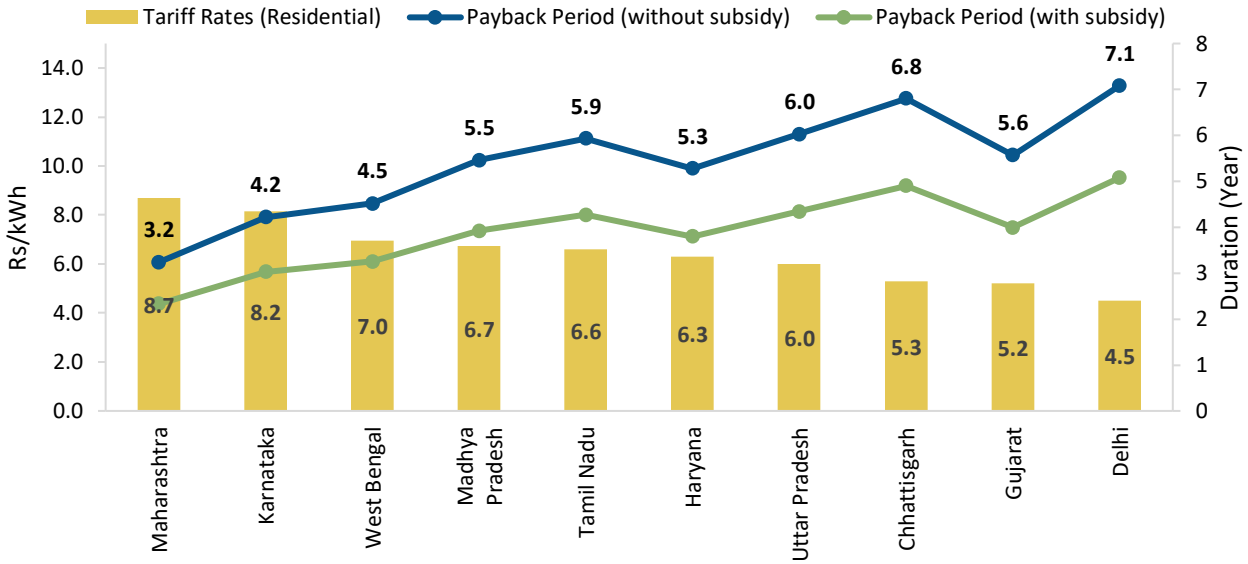
Punjab, West Bengal and Haryana, do not provide any compensation for surplus energy injection.

6. Payback on Rooftop Solar Systems Versus Residential Grid Tariffs

Payback on the investment for residential rooftop solar systems varies across states with respect to the respective grid tariff rates. To analyse the variation in the payback, we have calculated the payback periods for a 1kW rooftop solar system for 10 states (see Figure 8). Considering the states chosen for analysis, the grid tariffs (excluding fixed charges) for residential consumers vary between Rs4.5/kWh (US$0.055/kWh) (Delhi) and Rs8.7/kWh (US$0.11/kWh) (Maharashtra).

The higher the grid tariff, the higher the savings per unit (kWh) for residential solar consumers. Thus, the payback period for a rooftop solar plant in states with higher grid tariffs is typically less than those with lower grid tariffs. The payback period also depends on other factors, such as solar irradiance and generation. Thus, in some states, such as Gujarat (with higher solar generation), the payback period is lower compared to states like Chhattisgarh, which have higher grid tariff rates.

Figure 8. State-Wise Residential Grid Tariffs Versus Payback Period for Rooftop Solar Systems



Note: The tariff rates in the table represent only the energy charge component of the grid tariff. The final tariff rate is typically 20-30% higher than the energy charge.
Assumptions:
(1) Monthly electricity consumption of residential consumers: 300 units (across the 10 states)
(2) Capacity of the rooftop solar system: 1kW
(3) Cost of the system: INR 52,000/kW
Source: Tariff orders of respective state electricity regulatory commissions, JMK Research

For a 1kW non-subsidised, residential rooftop solar plant, the payback period varies from 3.2 years (Maharashtra) to 7.1 years (Delhi). In addition, the payback periods decrease substantially if the central and state-level subsidies are considered. For example, for a 1kW residential rooftop solar plant linked with the new CFA, the payback period would vary from 2.3 years (Maharashtra) to 5.1 years (Delhi).

7. State-Wise Attractiveness Index for Residential Rooftop Solar Sector

In order to analyse the state-wise conduciveness for residential rooftop solar installations, we designed a state attractiveness index. We assigned each state 'marks' out of five, with one meaning the 'least favourable', across four different parameters: electricity cost savings, net metering favourability, subsidy outlook and DISCOM rating. Further, we allocated these four parameters individual weightages, as shown in Table 5. We assigned these weightages based on insights from JMK Research's interviews with residential rooftop solar developers and consumers.

Table 5. State Attractiveness Index: Parameters, Description and their Weightages

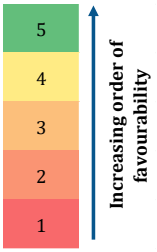
Parameter	Description	Weightage
Electricity cost savings	Cost savings realised on account of the consumption of power from a rooftop solar system vis-à-vis power consumption from DISCOM at retail tariffs	35%
Net metering favourability	Favourability in terms of respective state regulations for net metering provisions. The fewer the net metering restrictions, the higher the favourability.	30%
Subsidy availability and disbursal	Availability of (central and/or state) subsidy scheme(s) and the status of subsidy disbursal	20%
DISCOM rating	Relative rating of states based on the performance of DISCOMs. An important factor in determining DISCOMs' 'inclination' toward adopting rooftop solar.	15%

Source: JMK Research

We show the final scores based on these parameters (and their respective weightages) for 10 different Indian states in Figure 9. As per the total scores, Gujarat ranked first, while the second and third most attractive states are Haryana and Maharashtra, respectively.

Figure 9. State (Residential Rooftop Solar) Attractiveness Index

State	Parameter: Electricity cost savings	Net metering favourability	Subsidy availability and disbursal	DISCOM rating	Total score
Gujarat	3	5	5	5	4.3
Haryana	4	4	4	5	4.2
Maharashtra	5	4	2	4	4.0
Karnataka	5	4	3	1	3.7
Madhya Pradesh	4	4	4	1	3.6
Uttar Pradesh	4	3	3	2	3.2
Delhi	2	4	4	3	3.2
Tamil Nadu	4	4	2	1	3.2
West Bengal	4	3	1	4	3.1
Punjab	3	3	3	3	3.0



Source: JMK Research

8. Challenges

Some challenges that act as restraints in terms of policy and regulation are delayed subsidy disbursal and rising solar equipment costs. These have a significant impact on the residential market. There are challenges linked to financing infrastructure and standardised information, which underline the inadequacies in the market.

8.A. Policy and Regulatory Bottlenecks

A major challenge that added to the hesitation of installers and consumers in setting up rooftop solar systems was the uncertainty and inconsistency of rooftop solar-related policies and regulations. This is especially true for net metering policies across many states.

In some states, the delay in approving net metering connections by DISCOMs is a huge impediment. This sometimes leads to residential customers reversing their decision to purchase a rooftop solar system.

Under the centre's Grid-Connected Rooftop Solar and Small Solar Power Plants Programme (Phase 2), the installers received a subsidy. However, DISCOMs often delay subsidy payments to the installers, disrupting the latter's working capital flow.

8.B. Sub-Optimal Benchmark Cost

The benchmark system's costs fixed by many states every year have been substantially lower than the actual cost of the rooftop solar system. The poor feasibility of installation due to the sub-optimal state-assigned pricing became a major obstacle for many good quality developers or installers. This has been prevalent across all states except Gujarat and Kerala.

In addition, developers have observed that the benchmark pricing determined by most states did not cover the entire cost of rooftop solar system components. It must also be noted that a five-year comprehensive maintenance contract (CMC) and insurance from installers are also integral components of the benchmark cost.

Further, the benchmark costs of rooftop solar systems remained unchanged for 12–18 months. The MNRE notified the benchmark cost for FY2021/22 in August 2021, posing a severe challenge to installers considering the high volatility of solar equipment prices. Given all these issues, many top-tier installers sidelined the option of setting up rooftop systems via the subsidy route.

However, the new CFA structure fixes subsidy rates for different categories of system capacity that applicable across India, thus independent of state-determined benchmark costs. This has the potential to be a game-changer for the residential market.

8.C. Mandate of Domestic Modules under Subsidy Schemes

The mandate of using domestically manufactured, or domestic content requirement (DCR), modules in subsidy-based residential rooftop solar projects has been a deterrent. First, DCR modules are more expensive than imported modules. Second, these modules typically have low performance in terms of wattage, and the energy generation per unit of these modules is underwhelming.

In addition, in the past two years, many residential consumers have opted for solar systems with a high degree of differentiation in terms of quality and aesthetics of solar equipment technologies. Invariably, subsidy-based offerings, including DCR modules, do not fulfil the demands of these consumers. This is especially true for consumers in the high-income category.

In the past two years, many residential consumers have opted for solar systems with a high degree of differentiation in terms of quality and aesthetics of solar equipment technologies.

8.D. Increase in System Cost

The global commodity supply crunch, which struck in early 2020 owing largely to COVID-19-induced market disruption, raised solar equipment prices exorbitantly. In addition, an increase in goods and services tax (GST) and customs duties on such equipment further inflated the cost of solar systems. The per kW cost of residential

rooftop solar systems jumped by 10-15% because of basic customs duty (BCD) on imported cells and modules.[6]

Currently, a residential rooftop solar system costs between Rs45,000/kW (US$550.69/kW) and Rs65,000/kW (US$795.45/kW).[7] The variation in system costs primarily depends on the type of solar module. In subsidy-linked systems using DCR modules, the cost of a rooftop system (before subsidies) varies between Rs45,000/kW (US$550.69/kW) and Rs50,000/kW (US$611.88/kW). For subsidy-free systems using high-quality non-DCR modules, the cost would lie between Rs50,000/kW (US$611.88/kW) and Rs65,000/kW (US$795.45/kW).

8.E. Weak Financing Support

High product-side risks compel third-party financiers to avoid lending in the residential rooftop solar segment. Rooftop solar solutions are viewed as 'high-risk' because the quality of rooftop solar products and the delivery of allied services are under the purview of the installer.

Further, the lack of standardisation of loans for residential rooftop solar solutions is another critical barrier to the growth of the residential market. Due to the relatively smaller scale of residential solar projects, banks or other financial institutions (FIs) are generally reluctant to finance them. Since there are very few cases of third-party financing for this segment, there is limited relevant data available to financiers.

Financiers are also generally reluctant to disburse loans to this market due to the poor resale value for rooftop solar systems.

8.F. Lack of Standardised and Digitised Information

Most consumers and financiers alike are not well-versed with a number of the technical terms relevant to the residential rooftop solar market. A lack of simplified information communicated between installers, financiers and consumers can delay the buying process.

Further, unlike other product classes, such as consumer durables, the residential rooftop solar market has a huge dearth of publicly accessible digital platforms with all the necessary information about various offerings for residential consumers.

Thus, the lack of digitalised experience for consumers inhibits the adoption rate of residential rooftop solar systems. The

The lack of digitalised experience for consumers inhibits the adoption rate of residential rooftop solar systems.

[6] Insight from primary research.
[7] The system cost is inclusive of GST.

central government launched the national portal for rooftop solar installation in July 2022. It can help alleviate some of these challenges by providing a common digital platform for all related activities like system installation, vendor selection, subsidy disbursal status etc.

Keeping these challenges in mind, it is important to delve into some successful residential rooftop solar development cases. Some (if not all) of the key measures/actions taken in these cases to boost solar adoption may help alleviate the impact of the residential market's challenges.

9. Success Stories

Rooftop solar development in Gujarat is undoubtedly the most successful in the Indian residential segment. Naturally, considering the domestic (Indian) market, the landmark Gujarat model needs to be studied. In this section, we provide a case study that examines the implementation strategy in Gujarat's residential rooftop solar scheme.

Another success story that has intrigued renewable energy stakeholders globally is the solarisation drive in California, the US. California is one of the oldest solar markets in the world. This section also provides a case study that explores the current status of its robust residential rooftop solar segment.

These two case studies show two different markets making remarkable progress in terms of rooftop solar adoption. For India to achieve a similar adoption rate, the domestic market needs to evolve much more.

9.A. SURYA - Gujarat: An Exemplary Indian Solar Story

Background

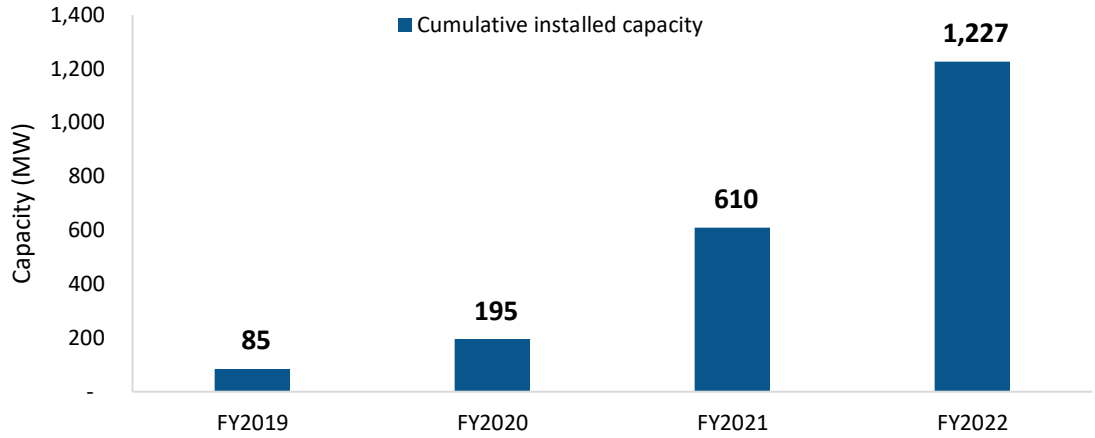
In 2010, the government apportioned the NSM's target of 100GW capacity by 2022 to all states and UTs. Gujarat had a target of 8,024MW of solar capacity, of which 3,200MW was from the rooftop solar segment.

In August 2019, the state government introduced a subsidy scheme for installing solar rooftop systems called the SURYA Gujarat (Surya Urja Rooftop Yojana Gujarat) scheme, developed exclusively for the residential category. The scheme's target was to install 1,600MW of solar rooftop systems, covering rooftops of 800,000 households by FY2022.

While Gujarat Urja Vikas Nigam Limited (GUVNL) is the nodal agency for the SURYA-Gujarat, the state's DISCOMs implement the scheme and disburse the subsidy.

Gujarat's residential rooftop solar segment grew from 85MW in FY2019 to 1,227MW in FY2022. Though the state only achieved 77% of the target capacity, the residential market of Gujarat achieved an impressive CAGR of 143% between FY2019 and FY2022.

Figure 10. Installation Trends in Gujarat Residential Rooftop Solar Market



Source: JMK Research

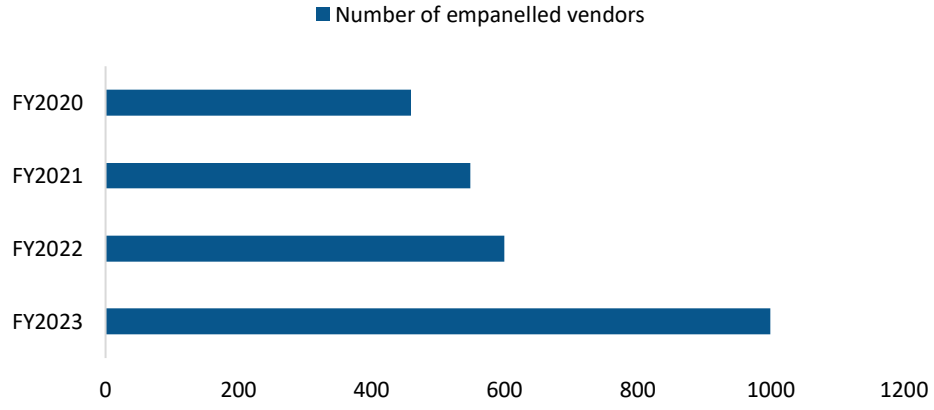
Strategy

The Gujarat government followed four essential steps to achieve large-scale deployment of residential rooftop solar in the state.

Step 1: Ensure adequate supply (building a large base of empanelled EPC contractors)

The state DISCOMs empanelled vendors as "preferred vendors" for residential consumers. A consumer seeking the rooftop solar subsidy could select a vendor only out of the list of empanelled vendors, and by FY2022, the list had more than 600 vendors. For installations during FY2023, about 1000 vendors have been empanelled.

Figure 11. Number of empanelled vendors: Annual trend



Source: JMK Research

Step 2: Ensure adequate demand (Executing consumer awareness initiatives)

The government used the following channels to disseminate relevant information:

- SMS: Messages were broadcasted to 20 million residential consumers
- Radio spots and advertisements
- Advertisements on news channels and in cinema
- Banners displayed at various government offices
- Flyer distributed with residential consumers' electricity bills
- Door-to-door public awareness programmes were arranged. Similar programmes were arranged at the Town Hall, the Nagar Palika and the municipal corporation
- Newspaper advertisements
- Hoardings
- Messaging through an AI-based WhatsApp chatbot
- Social media communications on platforms such as Facebook, Instagram and YouTube

Step 3: End-to-end digitization (from registration to subsidy disbursement)

The state government created a unified single-window rooftop solar portal to facilitate the hassle-free implementation of the scheme. The web portal offers auto-generated e-mail and SMS delivery systems and different types of auto-generated reports on various aspects, such as solar system design, plant performance etc. The portal also integrates with the E-urja, SAP and the chief electrical inspectorate (CEI) portals.

Step 4: Timely disbursal of subsidy

The portal also monitors subsidy disbursement. As soon as the portal 27eceives a subsidy claim, the concerned division office of a DISCOM checks the same. The portal then generates the status on the subsidy. The status is available on the portal on a daily basis.

Key Insights

- Aggregating demand through strong public outreach initiatives has significantly contributed to Gujarat's success in residential solar development.
- The proactive participation of state government agencies, especially the DISCOMs, enhanced the market's demand and supply aspects.
- The digitization of due processes simplified both the consumers' and vendors' roles, enabling transparent and streamlined transactions.

9.B. The 2020 Solar Mandate: The Case of California

Background

California has consistently been at the forefront of adopting solar energy for many years. The Million Solar Roofs Initiative, flagged off in 2006, promoted the setting up of distributed solar systems on residences, businesses and farms. This state on the west coast of the US achieved its target of one million solar roofs in 2015, much ahead of the target year, i.e., 2019. Even afterwards, the adoption of rooftop solar installations continued in the state.

California has consistently been at the forefront of adopting solar energy for many years.

In 2018, California created a new mandate for installing solar panels in new single-family and multi-family homes up to three stories high. This is the first such mandate in the US. The mandate took effect on 1 January 2020 and has been integrated into the state's building codes.

About the Mandate

- Solar systems on new residential projects must have adequate capacity to meet all the electricity needs annually. Builders, therefore, must estimate the electricity needs for these homes based on the climate zone and the building's floor area.
- Existing homes do not require solar panel installation unless they are undergoing extensive renovations.
- For new residential projects, solar systems are mandatory. However, there is flexibility regarding the size of the rooftop solar system. By integrating BESS with the solar system, builders can reduce the solar system size by up to 25%.
    - In addition, by incorporating energy efficiency and demand-response measures into the building design, the solar system size can be further downsized by 40% or more.

Incentives

Residential consumers in California can avail of multiple incentives (as shown in Table 6), which make adopting rooftop solar systems affordable.

Table 6. Rooftop Solar Incentives for Residents of California

Incentive	Description
Federal solar investment tax credit (ITC)	This allows deductions from federal tax by up to 26% of the cost of the solar system.
Solar energy system property tax exclusion	Section 73 of California's revenue and taxation code excludes property tax on solar systems. Therefore, installing solar panels would not cause an increase in property taxes, despite enhancing the property value (which can go up by 3 to 4.4%).
Self-generation incentive program (SGIP)	A rebate (as high as US$1,000/kWh) is offered for buying BESS and integrating it with a rooftop solar system.
Single-family affordable solar housing (SASH) program	This is a one-time, upfront cash incentive of US$ 3/watt to all qualifying low-income, single-family homeowners
Local utility company rebates*	San Francisco residents can avail of a cash incentive of US$100–2,000/kW of capacity installed for up to 4kW. Sacramento residents can receive solar incentives of US$300 from their local utility company for a new rooftop solar system.

Note: *Applicable only in the cities of San Francisco and Sacramento.
Source: JMK Research

Impact

Through a cost-effectiveness study, the California Energy Commission (CEC) determined that though the upfront costs of new homes would increase, consumers would realise (estimated) savings of US$40 per month. We explain this in Table 7.

Table 7. Net Cost Savings Calculation for a New Single-Family Home in California

Parameter	Value
Increase in the cost of a newly constructed single-family home	US$ 8400
Mortgage payment required to cover US$8,400	US$40 per month
Electricity bill savings (owing to a rooftop solar system)	US$80 per month
Net cost savings	**US$40 per month**

Source: JMK Research

The current solar mandate in California will be updated effective 1 January 2023. As per this new mandate (known as the 2022 Energy Code), all new high-rise residential buildings must have integrated rooftop solar and battery storage systems. These new homes will need electrical wiring to transition from gas appliances to all-electric ones easily.

Key Insights

- Stringent building codes recognising rooftop solar systems as an integral component can be highly effective in spurring the residential rooftop solar market growth.
- Offering an array of incentives, such as tax credits, rebates, cash payments, etc., is necessary to boost residential consumers' transition to "greener' (but higher upfront cost) new homes.
- It is also essential to incorporate forward-thinking policies and regulations and upgrade relevant (residential buildings, power transmission and distribution) infrastructure. This will enable easier adoption of upcoming mainstream technologies such as lithium-ion BESS.

10. Way Forward

The hunger of residential consumers for cheaper and greener power sources will drive the market in the coming years. As most residential spaces have limited space, consumer preference for high-wattage modules supported with battery storage is bound to pick momentum. Maturity in financing options in this sector will address the current financing woes. Innovative business models involving DISCOMs also look very promising regarding demand aggregation benefits.

The hunger of residential consumers for cheaper and greener power sources will drive the market in the coming years.

Availability of Holistic Rooftop Solar Solutions

While an installation-plus-insurance offering exists in the residential segment in India as an adjacency, a more holistic solution is bound to create more profound value for both customers and installers/developers.

We expect embedded financing[8] to become popular in the coming years. The consumer buying process can become more streamlined by bundling various business aspects, such as financing, insurance, installation, O&M, equipment supply, etc. This will certainly be a strong catalyst for solarizing residential rooftops.

Shift in Consumer Preferences Towards High-End Offerings

We expect two notable trends to become mainstream in the near term.

High-Wattage Modules

First, an increasing number of customers are opting for high-wattage solar modules along with high-quality BoS (micro-inverters, optimizers, etc.), aiming to get best-in-class rooftop solar products.

Solar-Plus-Storage

Second, in Tier 2 cities, owing to the lower reliability of the retail power supply, the purchase of hybrid solutions (solar-plus-storage) is on the rise in the residential segment. In the not-so-distant future, with falling battery costs, battery storage may become a critical component in all solar residential rooftop solar solutions.

New and Emerging Models under DISCOM-Centric Approach

The DISCOM-centric approach, as the term suggests, implies the direct facilitation by DISCOMs in developing solar systems on residential rooftops. Models under this approach are slowly emerging in the Indian context. Depending on the responsibilities of a DISCOM, there can be different models in this approach, including the DISCOM as:

1. A demand aggregator
2. A demand aggregator and EPC provider
3. A demand aggregator with a third-party acting as the RESCO
4. A demand aggregator and as the RESCO

Today, very few business models use the DISCOM-centric approach. However, a few states, such as Delhi, Kerala, and Andhra Pradesh, have approved or implemented examples of the different models under this approach. Additionally, a DISCOM-centric RESCO model is in the works for the residential segment in the city of Chandigarh.

BSES[9] Rajdhani Power Limited (BRPL) of Delhi and the Kerala State Electricity Board (KSEB) have executed the two most distinct cases of the DISCOM-centric

[8] Embedded Financing – The integration of financial services or tools into a traditionally non-financial service by non-financial entities
[9] BSES stands for Bombay Suburban Electric Supply.

approach. Table 8 describes the key features of the popular and unique DISCOM-led rooftop solar models in the two states.

Table 8. Unique Business Models of DISCOM-centric Approach for Residential Rooftop Solar Installation in Delhi and Kerala

<table>
<tr><th>Particular</th><th>Delhi</th><th>Kerala</th></tr>
<tr><td>Business model</td><td>Community solar-based RESCO model for cooperative group housing society (CGHS)</td><td>Kerala (hybrid) model</td></tr>
<tr><td>Overarching rooftop solar initiative</td><td>BRPL Solar City Initiative</td><td>SOURA Solar Subsidy Scheme, Phase 2</td></tr>
<tr><td>Business model description</td><td>• DISCOM acts as a demand and supply aggregator
• Aggregates roofs and also aggregates solar power demand from residential consumers
• DISCOM selects RESCO based on a competitive bidding process
• RESCO, DISCOM and roof owner sign a tripartite agreement for the overall arrangement
• DISCOM compensates roof owner with power credit (optional)
• Residential consumers pay:
  ○ the competitively bid tariff plus a trading margin, if any (solar tariff) to DISCOM for solar power
  ○ the DISCOM determined tariff for balance grid power to the DISCOM
• DISCOM issues electricity bills with two-part payments</td><td>• Consumer pays only a part of the total implementation cost of the solar panel
• KSEB bears the other part
• Consumer is eligible for a part of the energy generated from the plant based on investment
• Based on the consumer’s average monthly electricity consumption, three options for consumer contribution are available:
<table>
<tr><th>Average monthly consumption (units)</th><th>Consumer contribution (% of cost)</th><th>Return (% of plant generation)</th></tr>
<tr><td>Up to 120</td><td>12% (max Rs 6,200/kW)</td><td>25%</td></tr>
<tr><td>Up to 150</td><td>20% (max Rs 11,000/kW)</td><td>40%</td></tr>
<tr><td>Up to 200</td><td>25% (max Rs 14,000/kW)</td><td>50%</td></tr>
</table></td></tr>
<tr><td>Benefit to consumer</td><td>• No upfront investment
• No asset liability
• No PPA with RESCO</td><td>• Assured offtake of solar power
• Minimal initial investment
• Return on investment (RoI) by consumer = 2 times of investment</td></tr>
</table>

Source: MNRE, International Institute for Energy Conservation (IIEC), JMK Research

Delhi’s DISCOM-led rooftop solar experience shows that rooftop solar installations made a net positive impact on the DISCOM (BRPL). Specifically, it aided in reducing the wire losses of the DISCOM and prevented the low-voltage distribution network from being congested, especially during peak summer days.[10]

[10] Abhishek Ranjan. Rooftop Solar PV Projects – Saviour of Discoms or vicious cycle of death?. June 2021.

Implementing a DISCOM-centric model successfully necessitates a forward-thinking approach from the DISCOM. It is a prerequisite that the DISCOMs' overall financial and operational performance be, at the very minimum, moderately good. Unfortunately, however, most of India's DISCOMs do not have sound infrastructure and financial health, leading them to resist the facilitation of rooftop solar installation in their respective network areas.

All the business models discussed so far have a certain degree of involvement from the respective DISCOMs. However, a niche model without any DISCOM involvement exists –the plug-and-play model.

Plug-and-Play Model

A plug-and-play system can be purchased, installed and made fully operational within three days. It has a battery storage component and is designed for 100% self-consumption.

Table 9. Comparison Between a Traditional Rooftop PV System and a Plug-and-Play PV System

Features	Traditional system	Plug-and-play system
Type of installation	Fixed	Portable
Installation time	45-90 days	3 days
Interconnection with grid	Separate electrical wiring	Direct plug into 16 Amp socket
Back-up power	No back-up power	Critical load can work during grid outage
Approval from DISCOM	Required	Not required

Source: MNRE, JMK Research

Currently, the plug-and-play model has an insignificant share in the Indian residential rooftop solar market. However, we expect the market demand for this model to increase considerably in the long term.

Though the residential rooftop solar market prospects look bright, it will require additional effort from policymakers, suppliers, etc., to develop the market further. Henceforth, we describe some potential measures that could facilitate this development.

Minimising DISCOM Intervention

DISCOMs' role as implementing agencies for subsidy-linked projects is a conflict of interest for them. When a consumer installs a rooftop solar system, the DISCOM stands to lose revenue. Given the highly distressed financial state of India's DISCOMs, the latter would inherently oppose its customers' solarisation initiatives.

Thus, it is imperative to limit the DISCOMs' involvement in adopting residential rooftop solar systems to a considerable degree. For example, with regard to a net metering connection, a DISCOM's responsibilities need to be restricted to only the inspection of solar plants and sealing of the net meters.

It is imperative to limit the DISCOMs' involvement in adopting residential rooftop solar systems to a considerable degree.

Efficient Subsidy Disbursal to Consumers

Adopting the DBT mechanism for the transfer of subsidies was long overdue. Now, it is imperative that government agencies implement this mechanism effectively. Transparency with regard to the DBTs and timely disbursement of the subsidy is critical to sustain, if not augment, the market demand in the near future.

Digitisation of Consumer Experience

The whole of a rooftop solar solution, especially for the residential segment, needs to be accessible on digital platforms, considering the residential market is still in a nascent stage. It is necessary to provide a completely digitised and transparent customer experience, right from registration to issuance of meters, emulating the Gujarat model.

Along with pre-installation digital tools being available with select financiers, it is important to have post-installation performance monitoring tools available with the FIs. The data thus collected and collated by such a digital tool can be relayed to customers to assure them of the performance quality of the rooftop solar solution (including O&M activities).

Enhance Back-end Infrastructure and Channel Partner Networks

Strong back-end infrastructure is critical for tightly bundled product offerings with seamless financing service, performance guarantees and other original equipment manufacturers' (OEM) commitments.

It is a key requisite to build a wide local network of well-trained channel partners strictly monitored by developers or EPC companies. This will ensure the delivery of quality products and services and, more importantly, frugal and viable rooftop solar solutions.

Building a Rooftop Solar-Friendly Ecosystem

Going forward, updating the relevant policies and regulations with a forward-thinking approach is essential. Each state and UT must revise their building codes to mandate solar installation-capable buildings. Furthermore, the amended building codes should be tailored to streamline the procedure of adding BESS in residential buildings.

In time, residential solar+BESS will be a significant boon for the grid. Harmonized solar+storage power can help in supporting the grid during peak demand periods.

12. Conclusion

The Indian residential rooftop solar segment is at the cusp of a robust growth phase. From the 2GW cumulative installed capacity (as of FY2022), the residential market will likely reach 3.2GW by FY2023. Enhanced policy incentives and substantial growth and advancement in the demand and supply side of the market will drive the expected 60% year-on-year rise in installations.

So far, residential installation under the central government's rooftop solar programme has been subpar. However, the new simplified subsidy scheme (introduced by the centre in July 2022) has the potential to significantly catalyse the growth of the installed capacity in the residential segment. In addition, the new CFA scheme will allow residential consumers to buy rooftop solar systems from any registered supplier of their choice. This broadens consumers' options for quality products and services. Further, the provision of the DBT mechanism will help smooth the subsidy disbursal process as it removes the DISCOM from the subsidy equation.

The provision of the DBT mechanism will help smooth the subsidy disbursal process as it removes the DISCOM from the subsidy equation.

Concerning the residential solar regulations, all DISCOMs must grant net metering approvals to the consumers within a strict and short timeline. In the case of residential rooftop solar systems, DISCOMs, in general, need to be restricted to carrying out two activities: inspecting solar plants and sealing the net meters.

The key drivers of the demand side of the market, apart from government subsidies, are the brightening prospect of savings on electricity costs and heightened consumer awareness. To augment the demand of the residential market in the future, it will be critical to promote the communication of relevant and simplified information through digital media (as in the case of Gujarat's SURYA scheme). In addition, there is a need to disburse standardised loans for residential rooftop solar

solutions. This warrants reliable digital tools for FIs for market assessment, pre- and post-installation monitoring of solar plants, etc.

The residential rooftop solar market's supply side is currently far from being adequately developed. Very few established brands (such as Tata) offer highly reliable residential solutions. The market's entire value chain (covering business aspects such as financing, insurance, equipment supply, installation, O&M, etc.) needs to enhance to provide quality rooftop solar solutions. In this respect, the simplified subsidy scheme is a booster to the sales and service infrastructure of the residential market. Further, suppliers' integration or bundling of multiple business aspects could ease the consumer buying process.

Notably, there is an increasing trend of adoption of 'high-quality and highly aesthetic' rooftop solar systems. However, there is a lack of domestically manufactured high-wattage modules that high-end residential systems can use. Another emerging trend is the adoption of battery storage systems in the residential solar segment, especially in areas of low power reliability. We expect the use of BESS-integrated solar systems, such as plug-and-play systems requiring no DISCOM involvement, to become mainstream in the long term.

It is imperative that the existing supply chain infrastructure upgrades to enable the seamless adoption of future mainstream technology such as BESS. This calls for the implementation of forward-looking initiatives by relevant policymakers, suppliers, DISCOMs, and other stakeholders in the future.

Annexure

Table 1: State-Level Rooftop Solar Subsidies (Applicable Over and Above the MNRE Subsidy)

State	State-level subsidy
Bihar	25% subsidy on benchmark cost
Goa	Up to 3kW – 10% state financial assistance (SFA) From 3kW to 10kW - 20% SFA Above 10kW and up to 90kW – 50% SFA
Himachal Pradesh	Rs6,000/kW (US$73.43/kW)
Jharkhand	Only for beneficiaries whose annual income is less than Rs300,000 (US$3,761.30), Up to 3kW - 60% subsidy on system cost From 3kW to 10kW - 80% subsidy on system cost
Tamil Nadu	Rs20,000/kW* (US$244.75/kW) **Subsidy will be limited to 1kWp per home*
Uttar Pradesh	Rs15,000/kW* (US$183.56/kW) **Maximum (central+state) subsidy limit of Rs30,000 (US$367.13) per consumer*
Jammu and Kashmir	Below 3kW – 25% of the benchmark cost

Source: Respective state energy development authorities, JMK Research

Table 2: State-Wise Net Metering Regulations – Residential Rooftop Solar

State	Rooftop solar system capacity limit	Rooftop solar system capacity limit for net-metering	System capacity limit (as a % of sanctioned load)	System capacity limit (as a % of distribution transformer (DT) capacity)
Telangana	1kWp to 1MWp	1kWp to 1MWp	80%	50%
Karnataka	1kWp to 1MWp	1kWp to 500kWp	100%	80%
Tamil Nadu	Above 1kW	Above 1kW	100%	90%
Andhra Pradesh	1kWp to 1MWp	1kWp to 1MWp	100%	LT - 80%; HT - Not specified
Maharashtra	1kWp to 1MWp	1kWp to 1MWp	100%	70%
Madhya Pradesh	1kWp to 1MWp	1kWp to 500kWp	100%	30%
Gujarat	1kWp to 1MWp	1kWp to 1MWp	100%	50%
Chhattisgarh	From 1kWp up to permissible limit as per the electrical system	1kWp to 500kWp	100%	100%
Rajasthan	1kWp to 1MWp	1kWp to 500kWp	80%	100%
Uttar Pradesh	1kWp to 2MWp	1kWp to 2MWp	100%	100%
Haryana	Above 1kWp	1kWp to 500kWp	100%	50%
Delhi	Above 1kWp; For group & virtual net metering – 5kWp to 5MWp	Above 1kWp; For group & virtual net metering – 5kWp to 5MWp	100%	
Punjab	1kWp to 1MWp	1kWp to 500kWp	70%	30%
Himachal Pradesh	1kWp to 1MWp	1kWp to 1MWp	80%	30%
West Bengal	Above 1kWp	1kWp to 5kWp	100%	
Bihar	1kWp to 1MWp	1kWp to 1MWp	80%	80%
Odisha	1kWp to 1MWp	1kWp to 500kWp; For group & virtual net metering – 5kWp to 500kWp	100%	75%

Source: Respective state electricity regulatory commissions, JMK Research

About JMK Research & Analytics

JMK Research & Analytics provides research and advisory services to Indian and International clients across Renewables, Electric mobility, and the Battery storage market. www.jmkresearch.com

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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