Confederation of Indian Industry

POWERING YOUR ROOFTOPS 2019

in partnership with

HERO FUTURE ENERGIES

planet positive power

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Solar being a technology, the more it matures, the cost goes down further. Simply put, solar is inflation proof and future proof. In India, annual solar installations in FY2016 was 3 GW, 5 GW in FY2017, 9.5 GW in FY2018 and 7 GW in FY2019, cumulative installation at the end of FY2019 stands at 28 GW. The country needs fast paced rooftop solar (RTS) installations to achieve the target of 175GW target which constitutes 100 GW solar (including 40 GW rooftop solar), 60 GW wind, 10 GW bio-power and 5 GW in small hydro. The current rooftop installations have reached less than 10 per cent of the target 40 GW. According to Institute for Energy Economics and Financial Analysis (IEEFA) estimates, for the next three years, solar rooftop installation will grow at a CAGR of 50 per cent, suggesting a cumulative 13 GW of installed capacity by FY2022. This is well below government's targets.

Clearly, sun is not the only growth driver in this sector! Public sector undertakings (PSUs) have been the largest rooftop driver in the country, while commercial and industrial (C&I) consumers account for 70 per cent of total installed capacity. A big untapped potential which can trigger the next wave of rooftop solar adoption remain to be residential consumers. Achieving significant capacity addition in this sector is reliant on efficiently planning out the logistics and implementable, scalable financing options.

Solar rooftop plant can generate 14 per cent IRR in returns from savings over conventional power source, thus promoting RTS is a desirable policy goal. Apart from being the most sustainable option; this sector is a huge employment generator and a no-brainer for a developing country with 300 days of sunshine. Solar rooftop overall benefits all in the value chain with reduced power bills (consumers) and improved grid management resulting from generation being closer to the point of consumption (DISCOMs).

This industry should continue with their efforts to gain DISCOMs' confidence as well as bureaucratic attention against restrictive policies. Adoption of rooftop solar by residential or off-grid rural customers requires distributed solar storage solutions, better financing and supportive policies, only then can we democratise the solarisation of economy.

Mr Chandrajit Banerjee
Director General
Confederation of Indian Industry

The rooftop solar (RTS) sector in India is poised for growth, owing to the government's increasing focus on large-scale deployment of rooftop solar and the recent approval of the Phase II of the grid-connected RTS programme for achieving 40 GW rooftop solar capacity target by 2022. The falling prices of solar modules have further enhanced the growth of the sector. The programme, particularly emphasising on increased adoption by residential segment and enhanced involvement of DISCOMs, is definitely a step in the right direction.

Confederation of Indian Industry (CII) has been working actively with all the stakeholders of the solar industry to bring forth the approach needed for accelerated deployment of rooftop solar PV systems in India. To achieve this end, we encourage sharing of knowledge on technological options for promoting rooftop solar PV systems in the country. Proactive government intervention can help in boosting growth and realising the full potential of this compelling energy source.

The report on "Powering your Rooftops 2019" has been developed by CII in partnership with Hero Future Energies. The report, based on detailed research and analysis, provides a snapshot of the rooftop solar sector in India and discusses the key challenges faced by consumers, developers, financiers and DISCOMs. It specifically highlights and compares the rooftop solar policies and regulations in various states. This report also presents case studies of the industry highlighting the business models, challenges and key learnings.

CII will continue to partner with the government and key stakeholders to build an enabling environment for RTS development in the country.

Executive Summary

India is endowed with huge solar potential estimated at over 750 GW. Given the rising energy needs and the climate change commitments, India has set a target to achieve 100 GW solar power capacity through grid-connected solar energy by 2022, of which 40 GW is estimated to come through rooftop solar (RTS) installations.

Rooftop solar offers several advantages. It provides environment-friendly and cheaper back-up supply of power (compared to DG sets), saves cost and offer faster paybacks. RTS also results in lower transmission and distribution losses and improved grid management since the generation is close to the point of consumption. It also secures energy cost for the next 20-25 years.

Though RTS is relatively a new concept in India, it is gradually picking up pace. Rooftop solar in the country saw a growth of 107.57 per cent to 732.73 MW in 2018-19 over the previous year. In the last fiscal 2018-19, cumulative solar capacity reached to 28.18 GW, with rooftop solar contributing around 6 per cent to the total solar energy mix. The growth in RTS is being driven by state policies promoting RTS, the decline in solar PV module and installation costs, the policy thrust to large-scale deployment of rooftop solar PV, an enabling regulatory framework, and development in manufacturing technology of solar panels.

In the last few years, the Government of India (GoI) has taken several initiatives to encourage RTS. These include directives to central government departments to adopt RTS and mandatory RTS installations for buildings exceeding specified size and/or power consumption thresholds. So far, four states and union territories - Uttar Pradesh, Haryana, Chandigarh and Chhattisgarh have adopted these regulations. Further, the GoI offers several tax and financial incentives to support the RTS market.

Today, the majority of rooftop installations are primarily in the government and commercial and industrial (C&I) segments. RTS growth in the residential segment has been relatively slow primarily due to lack of awareness, delays in policy enforcement, putting cap on net metering, issues in disbursement of subsidies, non-availability of flexible financing (delays in subsidy payment) and bureaucratic hurdles in getting approvals.

That said, the recent Union Cabinet approval of Phase II of the grid-connected RTS programme for achieving cumulative capacity of 40 GW by 2022 with a focus on enhancing adoption by residential segment and increased involvement of discoms, is a welcome step. Grid-connected RTS systems can come up in a big way with supportive state government policies and State Electricity Regulatory Commission regulations. So far, 25 states/union territories have come out with solar policy supporting grid connected rooftop systems.

The Indian states have set aggressive targets under their respective solar policies. It is estimated that the Northern Region in the country will add the maximum capacity of the government's 40 GW target, followed by Western and Southern Regions. In the Northern Region, Uttar Pradesh has the highest RTS target at 4.3 GW and in the Western Region, Maharashtra has the highest target at 4.7 GW. In the Southern Region, Tamil Nadu has the highest target of 3.5 GW.

As of March 31, 2019, the total installed RTS capacity across all states in India stood at 1,796.36 MW. The five states – Gujarat, Maharashtra, Karnataka, Rajasthan, and Tamil Nadu – having a cumulative RTS installed capacity of 969.72 MW accounted for almost 54 per cent of total RTS installation in the country. Overall, 4.5 per cent of the 40 GW rooftop solar capacity target by 2022 has been achieved.

Region-wise, the Northern Region accounted for the highest installed RTS capacity share at 37 per cent (667 MW), followed by the Western Region and Southern Region at 32 per cent (572 MW) and 27 per cent (475 MW), respectively. In the Northern Region, maximum RTS capacity installation was carried out by Rajasthan (154 MW), Delhi (118 MW) and Uttar Pradesh (116 MW). These three states accounted for 58 per cent of total installed RTS capacity in the region. In the Southern region, Karnataka (159.5 MW) and Tamil Nadu (142.95 MW) together contributed 64 per cent of total. In the Western region, three states -- Gujarat (326.67 MW), Maharashtra (186.24 MW) and Madhya Pradesh (33.63 MW) -- accounted for a significant share of almost 95 per cent.

Currently, 29 states and 7 union territories have notified grid connectivity regulations with provision for net/gross metering. However, grid interconnection regulations and processes remain challenging in most parts of India.

Although the county is on the right track of scaling RTS to 40 GW by 2022, there is still a long way to go. To give the necessary thrust to this sector, it is important to address the challenges immediately. Consumers face issues such as higher upfront cost and lack of access to finance. Developers face issue of delay in approvals and other regulatory processes, the cap on solar system sizes due to limitations on transformer capacity and sanctioned load. Discoms face a major risk of revenue loss because most early adopters are high-paying C&I consumers. The creditworthiness of solar developers and consumers is a major concern for financiers. Further, policy design, implementation and inconsistencies in solar policies across different states pose significant challenges for rooftop solar.

To address these challenges and bolster the growth of the RTS market in the coming years, the Confederation of Indian Industry (CII) has put forward certain recommendations. In case of delayed payments by state discoms to the solar companies, CII has recommended that there is a need to introduce an institutional arrangement through which investors can be protected from uncertainties over bill payments by discoms. These include bill discounting by REC/Power Finance Corporation and backstop by state finance payments. To address the issue of net metering restrictions for RTS, especially in the C&I segment, the government can help to create a conducive environment for net metering by more active engagement with the discoms. Further, CII has recommended that four key issues need to be addressed to build consumer confidence and faster adoption of large scale RTS in the residential sector. These include organising awareness workshops by governments at state level, streamlining of collateral security by the banks, single window approval for installation of meters, and offering subsidy to the discom instead of the consumer.

Rooftop systems deliver a 3-4-year payback to C&I customers, which makes economic sense for almost every user. To set up top quality rooftop solar PV projects, one must focus on high quality balance of

system (BOS), an in-depth and deeply tested design and engineering mechanism, proper execution of methods and processes, and project management practices that are safe and repeatable. For rooftop solar PV project installers to be successful, the developers must have easy access to capital.

These advantages have percolated across the system and even government organisations like Indian Railways (IR), the single largest consumer of electricity comprising around 2 per cent share of the country's total power consumption is looking at RTS solutions. In order to increase the share of renewables in the railways, the Ministry of Railways (MoR) has targeted to set up 1 GW of solar power (500 MW of rooftop solar) by 2020-21 and has proposed to increase its target to 5 GW by 2025. Of the 5 GW solar target, 1.1 GW is planned to be rooftop solar. This target of 5 GW would see the IR procuring about 25 per cent of its electricity demand from solar by 2030. As of February 2019, IR has commissioned rooftop solar capacity of about 70 MW at various railways stations and service buildings. Further, 160 MW capacity projects are under implementation. IR also has plans to add solar panels to the rooftops of its rolling stock. As of January 2019, IR has already provided solar panels on rooftop of 19 narrow gauge coaches and 23 broad gauge non-airconditioned coaches in service.

Similarly, organisations like Delhi Metro Rail Corporation (DMRC) has plans of implementing 50 MWp solar PV plants by 2022 on flat/ curved roof of the stations, train depots and other buildings of DMRC including the upcoming stations of Phase III. As of February 2019, of the total 50 MW, 25 MW has been commissioned and another 10 MW is under implementation which is expected to be completed by July 2019. Further, Bangalore Metro Rail Corporation is planning to install 10 MW of rooftop solar in its stations and depots by 2025. The organisation will start installation of rooftop solar from 2020.

Implementation of RTS projects so far has offered certain key learnings that should be considered in future. The solar PV modules are heart of the power plant and in order to generate maximum energy, it needs to be positioned at an optimum location. In India, the suitable direction for facing the solar panels is the South direction so that it can enjoy the maximum benefits of solar energy. Any variation in the placement (in terms of orientation and inclination) may lead to loss of energy (and hence money) which may consequently damage the modules (due to differential output within modules) in the long run. It is hence important to understand the placement of solar module in the power plant. More time and energy have to be laid upon site analysis. This will result in minimising engineering amendments and reduction of execution timelines. Safety concerns and policies need to be adhered stringently.

Going forward, developers see huge potential for growth in the rooftop sector. However, the challenges like design constraints due to limited roof size and delays in net metering need to be addressed to gain the required scale in the rooftop PV sector, which shall evolve with increased penetration. There is a need for better and long-term certainty on policies and regulations to encourage RTS deployment. The RTS segment is expected to pick up momentum with the launch of the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme which addresses discoms' concerns.

It is evident from the study that the C&I segment will continue to dominate rooftop solar in the next 2-3 years. However, residential rooftop solar and storage as well as RTS projects are likely to pick up in the coming years.

In terms of business models, though most projects have been undertaken on CAPEX model so far, the RESCO (OPEX) model has started picking up pace as it is becoming one of the promising solutions to address several barriers to scaling rooftop solar PV. According to the study, this model is expected to dominate the rooftop solar market, considering the benefits to consumers in terms of no upfront capital and installation cost as well as the elimination of operational risks and management services.

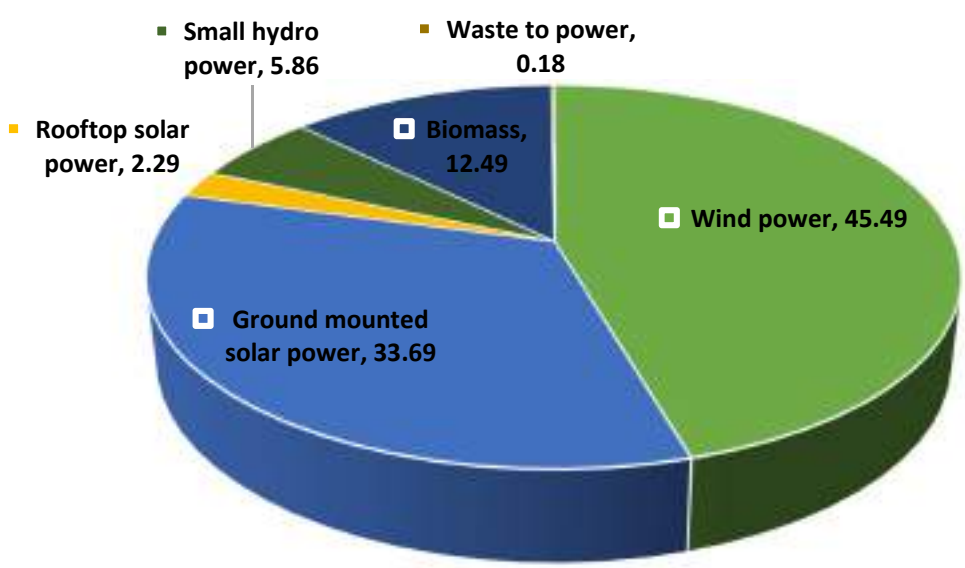
1. Rooftop Solar Overview

1.1 Current Status of Rooftop Solar Market in India

India is endowed with immense potential to produce solar energy. Recent estimates show that India's solar potential is greater than 750 GW. Given the rising energy needs and the climate change commitments, India has set a target to achieve 100 GW solar power capacity through grid-connected solar energy, of which 40 GW is estimated to come through rooftop solar (RTS) installations by 2022.

Currently, wind is the major contributor to renewable energy (RE) capacity in the country accounting for a share of 46 per cent of total; however, solar which comprises 36 per cent share is expected to overtake wind by 2020. Rooftop solar power constitutes a share of around 2 per cent with installed capacity of 1,796.36 MW as of March 31, 2019. Figure 1.1 shows the segment-wise percentage share of installed capacity of the different sources of RE as of March 31, 2019.

Figure 1.1 Segment-wise % Share of Cumulative Installed Renewable Energy Capacity (as of March 31, 2019)



Note: Cumulative capacity of Wind power (35,625.97 MW), Ground mounted solar power (26,384.30 MW), Rooftop solar power (1,796.36 MW), Small hydro power (4,593.15 MW), Biomass (9,778.31 MW), Waste-to-power (138.30 MW); Total capacity (78,316.39 MW)

Source: Ministry of New and Renewable Energy, Government of India

The development of rooftop solar projects in India began with the introduction of rooftop solar targets in Gujarat in 2009. Gujarat was one of the first states in the country to announce a solar policy and develop Gandhinagar (the capital city) as a 'solar city'. Though Karnataka, in parallel, also launched the 25,000 roofs programme for 5-10 kW rooftop systems, major success was seen in the Gujarat programme.

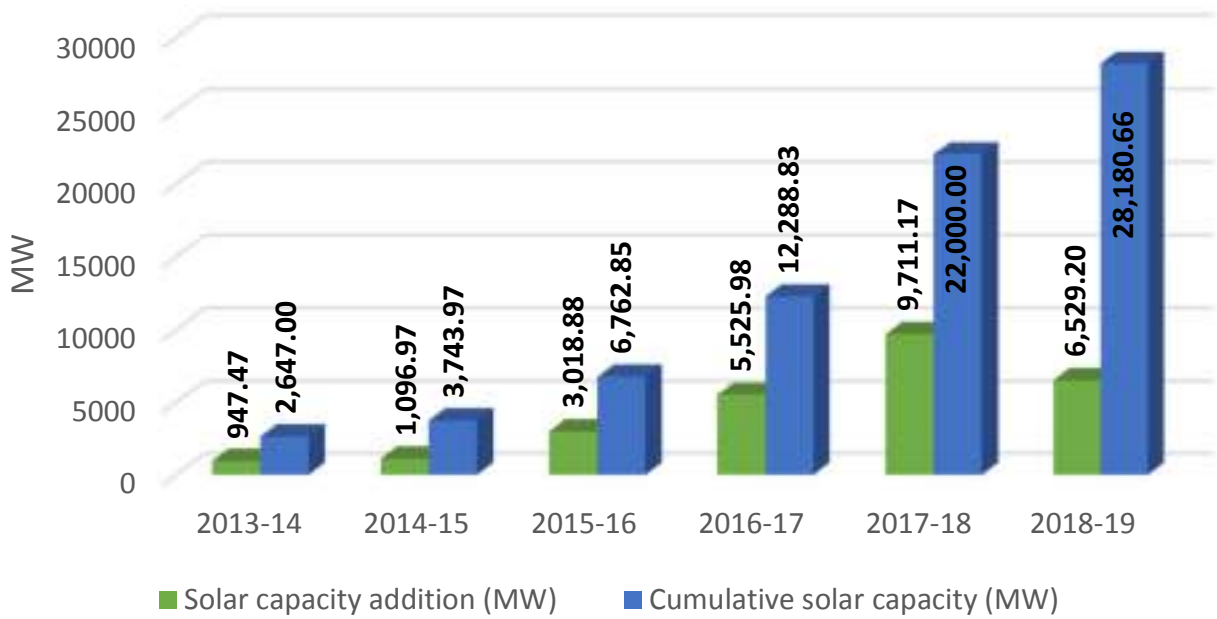
Though rooftop solar is relatively a new concept in India, it is gradually picking up pace. Solar rooftop installations in the country grew significantly by 107.57 per cent to 732.73 MW in 2018-19 over the previous year.

The Indian solar industry got off to a positive start in the year 2018 with the government allocating Rs 20.45 billion (USD321 million) for capacity addition of 11 GW in the solar power sector (10 GW for ground-mounted solar and 1 GW for rooftop solar) during the financial year 2018-19. This allocation constituted almost 41 per cent of the total allocation (Rs 50.2 billion or USD790 million) for expansion of various RE technologies for 2018-19. Of the total RE target of 15.62 GW in 2018-19, solar's share stood at 11 GW accounting for 70 per cent of the total. In addition, Rs 8.48 billion (USD133 million) was earmarked for 200 MW of solar lighting devices and 20 MW of solar thermal applications during 2018-19.

Overall, India ranks fifth in terms of installed solar capacity globally. Solar power installed capacity has grown significantly from a mere 2.6 GW in 2013-14 to 28 GW in 2018-19.

In the last six years, the year 2017-18 witnessed the highest solar capacity addition of 9.7 GW as can be seen in Figure 1.2. In the last fiscal 2018-19, cumulative solar capacity reached 28.18 GW, with rooftop solar contributing around 6 per cent to the total solar energy mix. However, with the availability of better project financing rates and decline in module/system costs, rooftop solar is expected to make huge additions in coming years and thereby achieve the target of 40 GW by 2022.

Figure 1.2: Growth of Cumulative Solar Power Installed Capacity during 2013-19 (MW)



Source: Ministry of New and Renewable Energy, Government of India

Rooftop solar offers certain advantages over large solar plants as no land and additional transmission capacity is required. It provides environment-friendly and cheaper back-up supply of power (compared to DG sets), given the persistent supply interruptions in most places. Besides generating clean and green energy, RTS saves cost and offer faster paybacks. Rooftop solar photovoltaic systems cost is cheaper than the retail tariffs for large commercial and industrial consumers and even high-use residential consumers in some states; and new rooftop solar costs are already significantly lower than the cost of diesel back-up generators and battery-inverter systems used by many consumers. Rooftop solar also results in lower transmission and distribution (T&D) losses and improved grid management since the generation is close to the point of consumption. Table 1.1 provides estimates of financial benefits of RTS installation in India.

An additional advantage is that most RE projects can be deployed within a time frame of less than three years from conceptualisation, as compared to 10 years required for conventional power projects. In fact, solar PV can be deployed in less than a year. RE can also provide access to affordable energy solutions to the India's off-the-grid population and can create employment opportunities for local skilled and unskilled manpower. Recent studies also suggest that RE creates much more jobs than conventional power, per unit of power produced, major chunk of which are local. Renewables can reduce the ever-growing dependence on imported fossil-fuels and their volatile prices, with practically no fuel costs and negligible impact on the quality of the surrounding environment.

Table 1.1: Estimates of Financial Benefits of Rooftop Solar Implementation

Item	Value
System size	100 kWp
System cost	Rs 5 million
Subsidy	Financial subsidy of 30% of project/benchmark cost in residential/ institutional/social sectors; no subsidy for private sector
Incentive	Incentive-cum-award for RTS projects in government/PSU sector
Expected electricity generation	1,40,000-1,60,000 units
Payback period at grid electricity cost	5-6 years (Rs 2-9 per unit)
Payback period with accelerated depreciation	4-5 years
Payback at diesel power cost	3-4 years
Plant life	25 years

Source: Solar Energy Corporation of India; Hero Future Energies

Currently, India is undergoing a market transformation unleashing all possibilities to harness the power of solar energy.

In India, the commercial and industrial (C&I) segments dominate rooftop solar with a share of 70 per cent, followed by the government/public sector at 21 per cent. The household sector comprised just 9 per cent. C&I consumers prefer rooftop solar as it is cheaper than grid-supplied electricity. These consumers have the financial resources to make the necessary investments, which are sizeable, to install RTS systems. Moreover, they also have access to the Renewable Energy Service Company (RESCO) model, in which developers install the system on the consumers' premises and sign a long-

term contract to sell them electricity, under which they do not need to make any investments. Of the states with sizeable RTS systems – Delhi, Gujarat, Haryana, Karnataka, Maharashtra, Rajasthan, Tamil Nadu, and Uttar Pradesh – the industrial segment has the highest share in all these states except Delhi. Public sector undertakings (PSUs) have been the largest rooftop driver in Delhi. Generally, about 10 sq metres area is required to set up 1 kWp grid-connected roof-top solar system. The average cost of such system is around Rs 80 per watt.

The dominance of large-scale rooftop installations by commercial, industrial, institutional and government/ PSU segments has meant that the potential of the residential segment has remained untapped. Distributed solar rooftop systems, installed on individual residences, offer several advantages, such as minimisation of T&D losses as the generated power is consumed locally.

1.2 Key Growth Drivers

In India, the main drivers for the adoption of solar PV have been the fall in solar PV module and installation costs against the rising cost of grid power, the policy thrust to large-scale deployment of rooftop solar PV, an enabling regulatory framework, and streamlining of the utility-grid connection process. The growth in solar power generation capacity is also driven by favourable government policies/initiatives coupled with development in manufacturing technology of solar panels. Improving manufacturing technology has led to reduction in cost of solar panels which has resulted in reduction in cost of solar power generation. With declining cost of solar power and increasingly favourable government policies, the solar power industry is expected to witness a bright future.

In addition, the ripples created by the perceived impact of the goods and services tax (GST) have subsided now. The availability of financing options and innovative funding structures aided by channel partners with lending support from banks has enhanced access to finance. The widespread adoption of the RESCO (opex) model, which constitutes about two-third of all installations, has also been one of the factors in the growth of the segment.

According to TechSci Research, the rooftop solar market in India is projected to grow at a CAGR of over 60 per cent during 2016-2021, predominantly on account of rising government focus on increasing the share of solar power in the country's energy mix. The government has announced attractive policies such as net metering, subsidies for select customers and cheaper debt financing for the segment, although there is huge scope for improvement on every front. Railways, metro authorities, airports, ports, etc. are significantly driving growth in this space. A number of other large and medium industrial/ commercial users are investing in this space to optimise their energy bills as well as to meet their RPOs.

Net metering, a concept that enables surplus power from a rooftop solar power plant to be exported to the grid and getting monetised, can be a powerful driver for rooftop solar power, especially industrial and commercial rooftop solar. This is so because industrial and commercial buildings could have 100s of kW of rooftop solar installed; while they might use most of the solar power generated during weekdays, companies that do not work during weekends could lose out on tens of thousands of units solar power per year. Net metering ensures that these extra units get their due credit, and thus makes rooftop solar a more economically feasible concept for these enterprises.

1.3 Emerging Trends

Consolidation: India's RE space is witnessing consolidation in the backdrop of considerable overseas interest. The latest instance is Malaysia's Petronas initiating talks with New York-based I Squared Capital to buy a majority stake in Amplus Energy Solutions Private Limited in a deal worth Rs 27 billion. Another RE deal in talks include PTC India's wind power valued at around Rs 20 billion that has seen interest from the Indian arm of CLP Holdings Limited, Macquarie Infrastructure and Real Assets and Hero Future Energies.

Table 1.2 provides some of the largest clean energy deals in the recent past in India.

Table 1.2: Key Renewable Energy Deals in India (2015-2018)

Year	Company	Buyer	Amount* (Rs billion)	Amount* (USD million)
2015	Suzlon Energy	Sun Pharmaceuticals	18	289
2016	SunEdison	Greenko Energy Holdings	26.07	392
2016	Welspun Renewables Energy	Tata Power	92.49	1,400
2017	Equis Energy	Global Infrastructure Partners (GIP)	-	5,000
2017	Hindustan Powerprojects	Macquarie Group	-	600
2017	Solar projects of First Solar India	IDFC Alternatives	-	300
2017	IDFC	Sembcorp	14.10	220
2017	Inox Renewables	Leap Green Energy	13.00	-
2018	Ostro Energy	ReNew Power Ventures	108.00	1,536
2018	Orange Renewables	Greenko Energy Holdings	-	922
2018	SunEdison	TerraForm/Brookfield	-	750
2018	Skeiron Green Renewables	Greenko Energy Holdings	35.00	492

* Approximate

Source: Media releases

Reduced solar tariffs: The country registered the lowest ever solar tariff of Rs 2.44 per kWh in reverse auctions carried out by the Solar Energy Corporation of India (SECI) in May 2017 for 200 MW and again in July 2018 for 600 MW. Solar tariffs had been rising for the past year due to two main reasons – the rising cost of solar panels from China, and the possibility of safeguard duty being imposed on Chinese solar imports.

Increased rooftop solar adoption by C&I segment: Commercial and industrial buildings are increasingly adopting solar panels, accounting for 70 per cent of total rooftop solar capacity. The C&I segment has the largest market share in RTS deployment today and is seeing significant traction. The primary driver is the attractive economics for this segment, which results in substantial savings in power cost on each unit replaced with solar. Other major drivers are the "green image" and "carbon neutrality" that the C&I user achieves, as well as the renewable purchase obligation compliance requirements of users procuring fossil fuel-based power under open access or from captive power plants. Favourable state policies including concessions or exemptions from open access charges and attractive models

such as group captive models have also encouraged many C&I consumers to procure solar. Households account for only 9 per cent of the total. Growth in the residential market lags due to a combination of reasons: high upfront cost, lack of financing options from banks, lack of standard products and customer awareness.

Increasing size of installations: According to Bloomberg New Energy Finance (BNEF), the average size of a rooftop system has increased from 250 kW in 2015 to 855 kW in 2018. This is due to better utilisation of rooftop space and consumers' willingness to use power generated from their own buildings rather than purchase the power from elsewhere. The increase can also be attributed to availability of net metering facility because of which rooftop project capacities have not remained limited to base load profile of consumers.

Increased international line of credit to support rooftop deployment in the country: The rooftop sector in India is lagging behind in meeting the annual installation targets set by the Government of India. The major reason identified was the lack of low-cost financing in this area. Huge upfront cost and high-cost loans contributed to the slow growth. However, for the past two years, rooftop solar has been able to gain scale with the availability of international lines of credit from various multi- and bilateral institutions to support domestic banks. The Government of India, with assistance from multilateral financial institutions such as the Asian Development Bank, World Bank and New Development Bank, has earmarked USD 1,470 million of concessional credit lines for the rooftop solar market. This has created developer and consumer interest in the rooftop solar sector and at the same time, the rooftop systems, with the availability of concessional financing, have become financially viable for end consumers.

Increasingly driven by the CAPEX model: The rooftop solar market has majorly been driven by the capital expenditure (CAPEX) model in which the consumer fully owns, finances and consumes the energy generated from the photovoltaic (PV) system. The consumer, in turn, is fully responsible for all capital expenditures and bear all risks of operations, management and maintenance. The other model which evolved lately is the operational expenditure (OPEX) model or third-party financing model in which a RESCO provides all necessary capital for installation, operation and maintenance of the rooftop system. In exchange for all services and risks, consumers sign a power purchase agreement (PPA) with the RESCO.

The OPEX model has started picking up pace as it is becoming one of the promising solutions to address several barriers to scaling rooftop solar PV. This model is expected to dominate the rooftop solar market, considering the benefits to consumers in terms of no upfront capital and installation cost as well as the elimination of operational risks and management services. However, the only challenge to the current low growth of this OPEX model is the lack of low-cost debt capital, which affects the ability of companies to advance it.

1.4 Recent Developments

The rooftop solar market in India saw certain developments related to financing, project commissioning, etc. in the past one year. Some of the key developments are highlighted below:

- In January 2019, Oakridge Energy, one of North India's leading residential rooftop solar companies, raised a first line of credit from the Indian arm of Dutch social impact investor Oikocredit for

financing a pilot of residential solar rooftop installations Oakridge intends to install. Oikocredit is among the world's leading social impact investors with total assets of about EUR1.3 billion, over 693 partners and presence across 13 countries. Manaveeya Development and Finance is the Indian arm of Oikocredit. Oakridge would be offering payment plans for residential home owners to install solar rooftop systems and provide easy repayment structures over 3-5 years. In addition, Oakridge would also be installing solar panels on the rooftops of residential societies under a scheme to be launched by the Delhi Government under the World Bank Suprabha-technical assistance programme.

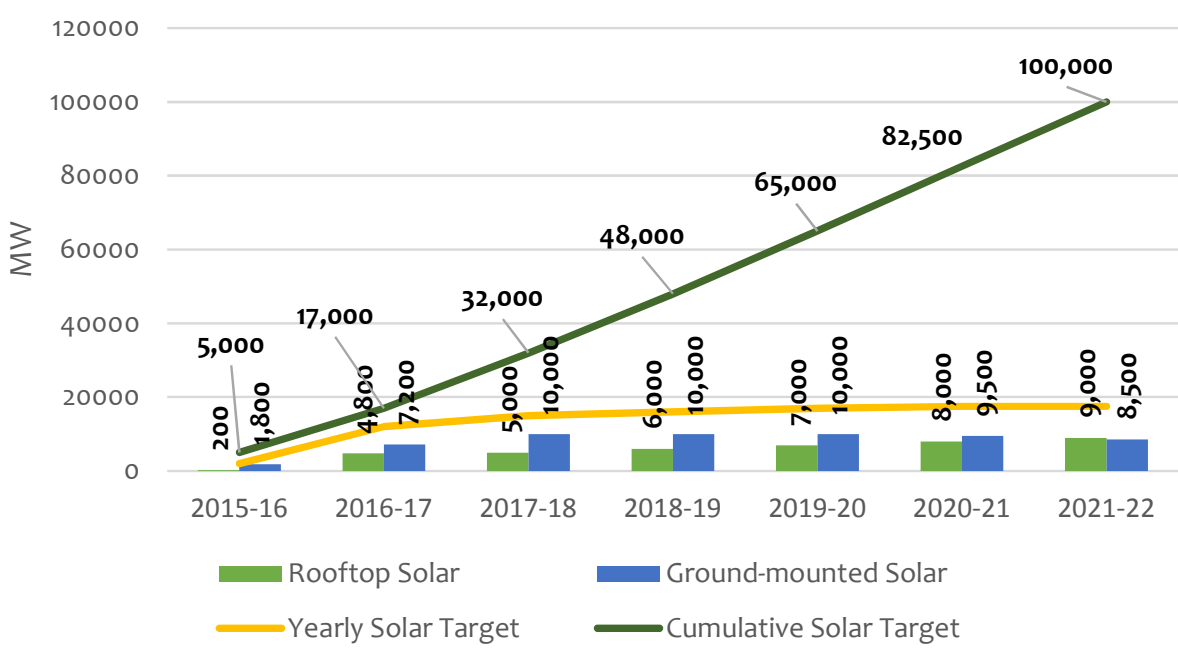
- In January 2019, the Delhi Legislative Assembly building has gone green with the recent installation of a 100kW rooftop solar system. The cost of the solar project installation is estimated to be Rs 735,000. It is expected to save Delhi assembly nearly Rs 1 million in electricity bill on an annual basis. The lifespan of the solar project is expected to be 25 years.
- In December 2018, Reliance Infrastructure Limited-promoted Mumbai Metro One has installed and commissioned a 612-kilowatt peak (kWp) capacity roof-top solar power plant atop the metro depot in D.N. Nagar, Andheri West (Mumbai, Maharashtra). The installation, consisting of 2,000 rooftop solar panels, is expected to generate 0.9 million units of energy annually. The Metro Depot solar project has been set up on RESCO model with a PPA for 25 years, besides operations and maintenance for the entire period.
- In December 2018, the National Bank for Agriculture and Rural Development (NABARD) signed an agreement with Green Climate Fund (GCF) to infuse USD100 million into an ambitious project designed to unlock private sector initiatives for creation of rooftop solar power capacity across India. The USD250 million project, to be executed by Tata Cleantech Capital, will receive the GCF support through NABARD, which is the National Implementing Entity (NIE) for the UNFCC-promoted Fund that supports the efforts of developing countries to respond to the challenge of climate change.
- In September 2018, Vikram Solar announced the commissioning of a 1,461-kW rooftop solar PV system for Century Plyboards at two locations — Kutch (Gujarat) and Chennai (Tamil Nadu). The 1,056-kW facility at Century's Chennai unit is spread over 11,000 sq m across seven factory sheds and three evacuation points. The 405-kW rooftop PV system for Century's Chirai Moti unit near the Kandla Port in Gujarat is spread over 450 sq m. The project will power the entire factory with electricity evacuated at two points.
- In September 2018, Hindustan Shipyard Limited (HSL) in Visakhapatnam, Andhra Pradesh inaugurated its 2-MW rooftop solar power plant. The solar plant, the largest rooftop solar plant in the state, will help the shipyard to save Rs 4.8 million per annum in energy costs, while also reducing environmental footprint.
- In August 2018, Bangalore International Airport Limited (BIAL) in Karnataka commissioned a 3.35-MW rooftop solar plant. The airport already had a small 500 kW rooftop plant and 3 MW elsewhere on its premises — carports and airside lands. The plant built by Pune-based Sunshot Technologies will be owned by the company and the power it produces will be sold to the airport under a 25-year PPA.
- In August 2018, Tata Power Solar commissioned a 820.8kWh rooftop solar project in the Cricket Club of India, Mumbai. The project was completed in 100 days. The installation of the solar rooftop project will help to generate over 1.12 million electricity per year which will lead to 25 per cent of savings in the power consumption cost.

- In July 2018, Enerparc India, a subsidiary of global solar solution provider Enerparc AG, announced the commissioning of 980 kWp rooftop solar project at Bharat Fritz Werner Limited (BFW) located at Bengaluru, Karnataka. The project has been financed, constructed and executed by Enerparc through its investment special purpose vehicle, which would sell the solar power to BFW on a long term.
- In June 2018, Azure Power raised USD135 million in debt financing from a consortium of development finance institutions. The proceeds will be used to finance approximately 200 MW of Azure Power's rooftop solar photovoltaic (PV) projects across India. The line of credit was led by International Finance Corporation, a member of the World Bank Group and attracted the participation of leading institutions, including FMO – the Dutch development bank, Société de Promotion et de Participation pour la Coopération Economique (Proparco) – the French development finance institution, and Oesterreichische Entwicklungsbank AG (OeEB) – the development bank of Austria.
- In January 2018, state-run gas transmission utility GAIL India (GAIL) commissioned the country's second-biggest rooftop solar power plant in Uttar Pradesh. The 5.76-megawatt peak (MWp) captive solar plant at its petrochemical complex at Pata will generate over 7.9 million-kilowatt hour (KWh) of electricity.

1.5 MNRE's Plans and Targets

The Ministry of New & Renewable Energy (MNRE) has targeted to achieve solar capacity of 100 GW by 2022. In April 2016, the ministry had chalked out year-wise and cumulative target to achieve 100 GW by 2021-22 under the National Solar Mission as shown in Figure 1.3. Of 100 GW, the target for rooftop solar is 40 GW.

Figure 1.3: Year-wise Solar Capacity Target till 2021-22 (MW)



Source: Report of the Expert Group on 175 GW RE by 2022, NITI Aayog, 2015; Ministry of New and Renewable Energy, Government of India

It is estimated that the Northern Region will add the maximum capacity, followed by Western and Southern Regions. In the Northern Region, Uttar Pradesh has the highest RTS target at 4.3 GW and in the Western Region, Maharashtra has the highest target at 4.7 GW. In the Southern Region, Tamil Nadu has the highest target of 3.5 GW. Table 1.3 provides the state-wise break-up of grid-connected rooftop solar power target by 2022.

Table 1.3: Tentative State-wise Break-up of Rooftop Solar Power Target by 2022 (MW)

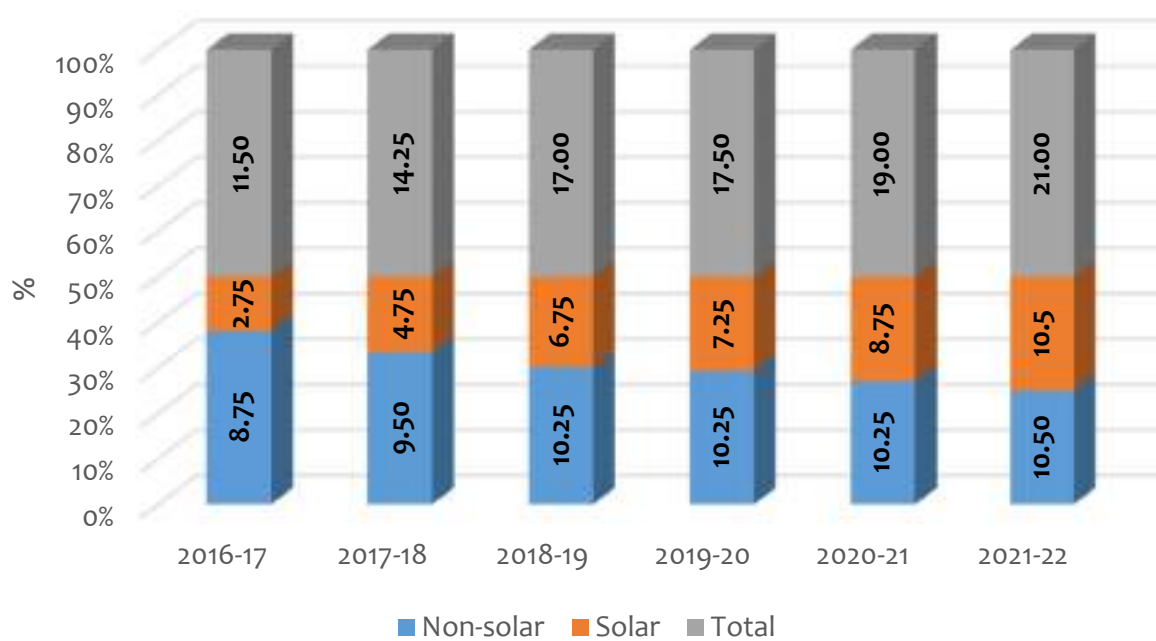
State/Union territory	Solar capacity target	Grid-connected rooftop solar capacity target
Delhi	2,762	1,100
Haryana	4,142	1,600
Himachal Pradesh	776	320
Jammu & Kashmir	1,155	450
Punjab	4,772	2,000
Rajasthan	5,762	2,300
Uttar Pradesh	10,697	4,300
Uttarakhand	900	350
Chandigarh	153	100
Northern Region	**31,119**	**12,520**
Goa	358	150
Gujarat	8,020	3,200
Chhattisgarh	1,783	700
Madhya Pradesh	5,675	2,200
Maharashtra	11,926	4,700
Dadra & Nagar Haveli	449	200
Daman & Diu	199	100
Western Region	**28,410**	**11,250**
Andhra Pradesh	9,834	2,000
Telangana	-	2,000
Karnataka	5,697	2,300
Kerala	1,870	800
Tamil Nadu	8,884	3,500
Puducherry	246	100
Southern Region	**26,531**	**10,700**
Bihar	2,493	1,000
Jharkhand	1,995	800
Odisha	2,377	1,000
West Bengal	5,336	2,100
Sikkim	36	50

State/Union territory	Solar capacity target	Grid-connected rooftop solar capacity target
Eastern Region	**12,237**	**4,950**
Assam	663	250
Manipur	105	50
Meghalaya	161	50
Nagaland	61	50
Tripura	105	50
Arunachal Pradesh	39	50
Mizoram	72	50
North Eastern Region	**1,206**	**550**
Andaman & Nicobar Islands	27	20
Lakshadweep	4	10
All India	**99,534**	**40,000**

Source: Ministry of New and Renewable Energy, Government of India

In June 2018, the Ministry of Power notified the long-term growth trajectory of Renewable Purchase Obligation (RPO) to be adopted by all the states and union territories for the three-year period from 2019-20 to 2021-22. The trajectory has been notified in line with the renewable capacity target of 175 GW by FY2022. As shown in Figure 1.4, the overall RPO target is set to increase from 17 per cent in 2018-19 to 21 percent in 2021-22 and is a positive development for the RE sector. The Ministry had last notified the RPO trajectory in July 2016, for the three-year period from 2016-17 to 2018-19.

Figure 1.4 Long-term RPO Trajectory (%)



Source: Ministry of Power, Government of India

The notification of long-term RPO trajectory provides visibility for growth of renewable energy-based generation capacity and is a beneficial move. However, the timely adoption of these targets by the state electricity regulatory commissions (SERCs) remains the key. This is given that only six out of the 29 states have stipulated RPO norms in line with the trajectory approved by Ministry of Power for 2018-19. In this context, the implementation of the draft amendments to the National Tariff Policy remains crucial as it includes a provision requiring SERCs to adopt the RPO trajectory issued by the central government.

While the extent of RPO compliance at all India level has improved in the recent years with the significant addition of wind and solar power capacities, it continues to remain less than 100 per cent. Moreover, the compliance level varies across the states, with the states having high wind and solar generation potential reporting higher compliance to RPO norms. Along with adoption of the RPO trajectory approved by the Ministry of Power, the SERCs must enforce the compliance to these norms by the obligation entities including state distribution utilities, captive power consumers and open access consumers.

1.6 Barriers to Adoption of RTS

Despite the favourable policy environment, the rate of adoption of rooftop solar remains very low due to several market challenges. Even though the market is becoming increasingly favourable for most consumer categories, it has yet to reach a point where rooftop solar gains a commodity status. Rooftop solar continues to be viewed as an investment, and the falling prices of solar, the longer payback periods, and the lack of confidence in the 25-year life of rooftop stand in the way of higher penetration, especially in the residential sector. There is also a supply gap in this sector created by the major solar players, which target niche markets with high credit ratings, leaving out a large proportion of consumers.

The conventional rooftop business offerings are ineffective in addressing the challenges that exist in the market and hence there is a need for innovative business interventions to make rooftop solar a viable option for all consumer segments. Indian discoms could potentially play an important role in the rooftop solar market by leveraging their close relationship with consumers and institutions, thereby maintaining their position in the market while addressing several of the challenges faced by the stakeholders.

All stakeholders in the rooftop solar industry face various challenges that need to be addressed by any intervention that is being planned. According to the Report on Scaling Rooftop Solar by Council on Energy, Environment and Water (CEEW), June 2018, the different market challenges faced by the stakeholders are as follows.

Consumers: Consumers who wish to install RTS face issues like higher upfront cost and lack of access to finance. The majority of consumers still lack awareness about the benefits of, and the processes involved in, installing rooftop systems. There are also consumers who do not have roof ownership or lack access to suitable roof spaces. The long roof lock-in period of 25 years is a major concern for some consumers.

Developers: For developers, the smaller size of the rooftop system, the non-uniform characteristics of rooftops, and the fragmented distribution of installations contribute to higher costs of procurement

and installation of the systems. For the same reason, access to finance for small rooftop developers becomes a challenge. Delay in approvals and other regulatory processes, the cap on solar system sizes due to limitations on transformer capacity and sanctioned load, and consumer inertia are some of the other challenges faced by developers. The collection of payments from a decentralised consumer base also presents a high transaction cost for developers.

Financiers: The creditworthiness of solar developers and consumers is a major concern for financiers when it comes to RTS owing to its small and distributed nature. It also requires disproportionately high transaction costs and is an administrative hassle for banks, due to which the latter are reluctant to undertake large-scale RTS financing for the residential sector. The total funding requirement for installing 40 GW of RTS systems by 2022 is estimated at over Rs 2,800 billion (USD40 billion).

Discoms: Discoms face a major risk of revenue loss because most early adopters are high-paying consumers. This also affects the cross-subsidy because the tariff collected from the high-end consumers is insufficient to cover the subsidies to the subsidised consumers and the burden eventually falls on all segments of the consumers as the overall tariff increases.

1.7 The Way Forward

One of India's major advantages today and going forward is that its RE potential is vast and largely untapped. Recent estimates show that India's solar potential is greater than 750 GW. India Energy Security Scenarios 2047 show a possibility of achieving a high of 479 GW of solar PV by 2047. From a pure macro-economic perspective, reaching 175 GW RE by 2022 could dramatically reduce the coal import bill in 2022. Further, there are environmental benefits (less pollution), social benefits (local employment opportunities) and investment inflows, which may need to be monetised to assess the complete range of benefits.

According to the Report of the Expert Group on 175 GW RE by 2022, NITI Aayog, 2015; it is evident that solar rooftop tariffs are already at parity based on tariffs of electricity for commercial consumers across various states. In cases, where the users can avail accelerated depreciation (AD), the cost of solar is actually lower than the commercial tariffs in many states. Hence, it is expected that no subsidy will be necessary for solar installations by commercial segments in most states.

As per existing scheme of the Government of India, 15 per cent capital subsidy is allowed for residential and institutional segments. At Rs 80 million/MW, it is estimated that a Central Financial Assistance of a total of Rs 120 billion may be required by 2022 to achieve 10 GW of rooftop capacity through residential/ institutional segments. Remaining 30 GW is expected to be deployed through commercial and industrials segments, which would require no subsidy but enabling policy and regulatory environment and support from utilities. The quantum of financial assistance required for 10 GW of rooftop by 2022 must be considered as an upper bound since the reduction in capital costs of rooftop systems is not considered.

In India, the solar rooftop market is still in its nascent phase, and the market is expected to grow at a robust pace over the next five years backed by favourable government measures and abundant solar resources. In order to boost solar power generation in the country, the Government of India has announced various policies and regulations such as Accelerated Depreciation, Capital Subsidies,

Renewable Energy Certificates (RECs), Net Metering Incentives, Assured Power Purchase Agreement, etc. These schemes have been introduced by the government to reduce the capital expenditure in building a solar power plant and subsidise solar power generation in order to make it economically viable for the stakeholders involved in the solar power business.

In large cities, solar rooftop can act as a back-up, replacing polluting diesel generator sets. Solar rooftop can be harnessed for demand-side management. For instance, time-of-day pricing to match household demand with solar generation. With falling solar prices and steadily increasing tariffs of discoms, rooftop solar systems are being seen as financially attractive. Achieving significant capacity addition in rooftop solar will require close engagement with several small consumers, which is a challenging task in itself. Concerted efforts will be required for raising consumer awareness about the benefits of rooftop solar systems and PV technology and their installation.

Processes for approving net metering applications and disbursing subsidies will need to be efficient and seamless to motivate consumers to invest in this new technology. Loans need to be made available, which requires significant capacity building of retail bank branches. So far, the government has largely relied on subsidies (70 per cent for hill and north-eastern states and 30 per cent for other states) to drive rooftop solar installation.

Clearly, RTS systems provide several benefits to households, grid and even to discoms. Promoting these systems is a desirable policy goal. Sustained and broad-based efforts are required to promote RTS.

The RTS segment is expected to pick up momentum with the launch of the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme which addresses discoms' concerns. Recognising that discoms are central to reach the goal, the MNRE has announced an achievement linked financial support scheme to them to accelerate rooftop solar deployment in the targeted segments: residential, commercial, social, governmental and institutional. Further, to make rooftop solar attractive to the residential segment, 30 per cent capital subsidy on the MNRE bench marked price for a max size of 5KW is proposed. The scheme is planned to be implemented with a provision of Rs 234.5 billion.

2. Policy and Regulatory Framework

2.1 Current Scenario

Grid-connected rooftop solar (RTS) systems can come up in a big way with supportive state government policies and State Electricity Regulatory Commission (SERC) regulations. The recent Cabinet Committee on Economic Affairs (CCEA) approval of Phase II of the grid-connected rooftop solar programme for achieving cumulative capacity of 40 GW by 2022 with a focus on enhancing adoption by residential segment, is a welcome step. The programme will be implemented with total central financial support of Rs 118.14 billion.

So far, 25 states/union territories have come out with solar policy supporting grid connected rooftop systems as shown in Table 2.1.

In 2014, the Ministry of Urban Development (MoUD), which is now Ministry of Housing and Urban Affairs, suggested that all states and union territories (UTs) should issue necessary directives for using rooftop of buildings under their control for solar power generation on mandatory basis. All building facilities under different central government departments are also being urged to adopt rooftop solar. A potential of 6 GW capacity has been identified so far in government buildings.

Further, the MoUD also issued Model Building Bye-Laws, 2016, which has recommended mandatory rooftop solar installations for buildings exceeding specified size and/or power consumption thresholds. So far, four states and union territories - Uttar Pradesh, Haryana, Chandigarh and Chhattisgarh have adopted these regulations.

At present, the Government of India is offering several tax and financial incentives to support the rooftop solar market. These include the following:

- Capital subsidy: 30 per cent subsidy for residential and institutional consumers (Rs 50 billion)
- Accelerated depreciation: 40 per cent depreciation
- Tax holiday: 10-year tax holiday (MAT payable)
- Low cost funding: USD1.5 billion funding from World Bank, ADB and KfW

In order to install an off-grid solar PV system, no permissions are required. But in order to integrate the solar system with the grid to avail net metering option, certain permissions are required to be taken from the respective DISCOM and the state government. The area requirement for installation of RTS system depends on various factors such as the shadow-free area available, the orientation of

the roof etc. However, as a thumb rule, it is assumed that 1kW plant requires 12 sq meters of shade-free area.

Table 2.1: State wise Solar Policies for Grid Connected Rooftop Solar Panels in India

Sr. No.	State/UT	Policy/Scheme
1	Andhra Pradesh	Andhra Pradesh Solar Policy 2018
2	Assam	Assam Solar Policy 2015
3	Bihar	Bihar Solar Policy 2015
4	Chhattisgarh	Chhattisgarh Solar Energy Policy 2012-2017
5	Delhi	Delhi Solar Energy Policy 2016
6	Gujarat	Gujarat Solar Power Policy 2015
7	Haryana	Haryana Solar Policy 2014
8	Himachal Pradesh	Himachal Pradesh Solar Power Policy 2016
9	Jharkhand	Jharkhand Solar Power Policy 2015
10	Karnataka	Karnataka Solar Policy 2014-2021
11	Kerala	Kerala Solar Policy 2013
12	Madhya Pradesh	Madhya Pradesh Policy for Decentralised Renewable Energy Systems, 2016
13	Maharashtra	Maharashtra Solar Energy Policy 2016
14	Manipur	Manipur Solar Policy 2014
15	Meghalaya	Meghalaya Solar Policy 2015
16	Odisha	Odisha Solar Policy 2013
17	Punjab	Punjab Solar Rooftop Policy 2014
18	Rajasthan	Rajasthan Solar Energy Policy, 2014
19	Tamil Nadu	Tamil Nadu Solar Energy Policy 2019
20	Telangana	Telangana Solar Power Policy 2015
21	Uttar Pradesh	Uttar Pradesh Rooftop Solar Photovoltaic Power Plant Policy, 2014
22	Uttarakhand	Uttarakhand Solar Policy 2013
23	West Bengal	West Bengal Policy on Co-generation and Generation of Electricity from Renewable Sources of Energy 2012
24	Andaman and Nicobar	Andaman and Nicobar Islands Solar Policy
25	Puducherry	Puducherry Solar Energy Policy 2015 (notified on March 1, 2016)

Source: Government websites

Solar power tariffs in India have declined significantly in recent years, making RTS an attractive investment for commercial and industrial (C&I) consumers. This has led to increased deployment of RTS systems among consumers in these categories, primarily to hedge the risk against increasing tariffs of grid electricity. However, in the residential category, even though RTS systems are economically viable for higher-tariff consumption slabs, adoption has been minimal, with scale-up not growing as expected.

Approximately 49 per cent of the total RTS potential in the National Capital Territory (NCT) of Delhi is in residential buildings, followed by the industrial, commercial, and government building sectors. This presents a huge market opportunity, especially with RTS systems becoming cheaper year-on-year. In addition, the rising trend of electricity tariff and a conducive policy landscape make the RTS option quite attractive in the residential segment.

2.2 Recent Policy and Regulatory Developments

India has unveiled the 'Grid-Connected Rooftop and Small Solar Power Plant Programme' with the aim of installing 40 GW of grid-interactive rooftop solar by 2022. These rooftop plants would be set up in residential, commercial, industrial and institutional sectors, and government and state-owned sector enterprises. The government offers 30 per cent subsidy for rooftop projects in residential, social and institutional buildings and a 15-25 per cent incentive for projects in government and state-owned enterprises (public sector undertakings or PSUs). However, no subsidies or incentives are offered for rooftop solar projects in the C&I segment.

On February 19, 2019, the CCEA approved the second phase of grid-connected rooftop solar programme for achieving cumulative capacity of 40 GW from such projects by 2022. The programme will be implemented with total central financial support of Rs 118.14 billion. The key highlights are as follows:

- The Phase-II programme Central Financial Assistance (CFA) for the residential sector has been restructured with availability of 40 per cent support for RTS systems up to 3 kW capacity and 20 per cent for RTS system capacity beyond 3 kW and up to 10 kW.
- For Group Housing Societies (GHS)/Residential Welfare Associations (RWA), the assistance will be limited to 20 per cent for RTS plants for supply of power to common facilities, however, the capacity eligible for support for GHS/RWA will be limited to 10 kW per house with maximum total capacity up to 500 kWp, inclusive of RTS put in individual houses in the GHS/RWA.
- The CFA under residential category will be provided for 4,000 MW capacity and the same will be provided on the basis of benchmark cost or tender cost, which is lower. The financial support will not be available for other category i.e., institutional, educational, social, government, commercial, industrial, etc.
- Under Phase-II Programme, focus will be on increased involvement of discoms. Performance-based incentives will be provided to discoms based on RTS capacity achieved in a financial year (i.e. 1st April to 31st March every year till the duration of the scheme) over and above the base capacity i.e. cumulative capacity achieved at the end of previous financial year.
- Discoms and its local offices shall be the nodal points for implementation of the programme. Since, DISCOMs are required to incur additional expenditure for implementation of scheme in terms of additional manpower, creating infrastructure, capacity building, awareness, etc. It is approved to compensate them by providing performance linked incentives. These incentives will be provided to enable discoms to create an enabling ecosystem for expeditious implementation of RTS programme in their area.

- The incentives to the discoms will be available only for initial capacity addition of 18,000 MW under the scheme. The Programmes will have substantial environmental impact in terms of savings of carbon-dioxide emission. Considering average energy generation of 1.5 million units per MW, it is expected that addition of 38 GW solar rooftop plants under Phase-II by year 2022 will result in carbon-dioxide emission reduction of about 45.6 tonnes per year.
- The programme has directed employment potential. Besides increasing self-employment, the approval is likely to generate employment opportunity equivalent to 9,39,000 job years for skilled and unskilled workers for addition of 38 GW capacity under Phase-II of the scheme by the year 2022.

2.3 State-wise RTS Policies and Targets

Till March 31, 2019, a total of 1,796.36 MW rooftop solar capacity was installed in India. The states of Gujarat, Maharashtra, Karnataka, Rajasthan, and Tamil Nadu are the top five states having high installed rooftop solar capacity, with a total installed capacity of 969.72 MW.

Individual states in India have set aggressive targets under their respective solar policies. As of March 31, 2019, 4.5 per cent of the 40 GW rooftop solar capacity target by 2022 has been achieved. While the target is stiff, the central and the state governments have been making constant efforts and endeavours through various policies as well as financial incentives to ensure that the country achieves the rooftop solar targets. Since each state in India today has a different energy requirement as well as solar potential, each state has come up with its own individual solar policies and net metering regulations.

The following section provides analysis of RTS policies and targets in the leading five states based on installed rooftop solar capacity amounting to 703.6 MW as of December 31, 2018. Maharashtra, Karnataka, Gujarat, Tamil Nadu, and Delhi.

(a) Maharashtra

Maharashtra approved its solar energy policy in January 2016, encouraging both public and private entities to go solar. The off-grid policy aims to save minimum 500 MW of power in the next five years. In addition to this, the Civic Development authorities were asked to ensure that construction permission is only given to those buildings, government colonies, etc who pledge to install solar at rooftop. As much as 100 per cent subsidy has been offered to government and semi-government offices. However, there is no subsidy available to the private sector.

There is a substantial thrust and incentives from the government to achieve this target. The residential rooftop solar power plants are crucial to make people energy efficient and more importantly, it can be achieved at the individual level and with comparatively lower investment. The state has seen a steady growth in the adoption of rooftop solar in C&I segment. Since last year, the strong demand from educational institutions and government buildings in Maharashtra has driven the industry.

(b) Karnataka

Karnataka is rich in solar resources and solar energy will complement the conventional sources of energy in a big way. The state is blessed with about 240 to 300 sunny days with good solar radiation of 5.4 to 6.2 kWh/m2/day. Karnataka was the first southern state to notify its solar policy

in 2011 and was the first state to commission utility scale solar project in India. The solar energy potential in the state is estimated in excess of 24,700 MW. However, the actual potential for solar energy is significantly higher than the estimated capacity, considering the recent technological advances and increasing efficiencies brought in solar energy segments.

The Karnataka Solar Policy 2014-2021 encourages public private participation in the solar sector and aims to promote solar rooftop generation and technologies. The government promotes grid connected solar rooftop projects on public buildings, domestic, commercial and industrial establishments through net metering and gross metering methods based on tariff orders issued by Karnataka Electricity Regulatory Commission from time to time.

(c) Gujarat

With a proposed target of 3200 MW, Gujarat will become the fourth largest state in India when it comes to installed rooftop solar capacity by 2022.

Under the Gujarat Solar Power Policy 2015, the state will facilitate rooftop solar PV systems with net metering on government, residential, industrial and commercial buildings. This includes projects which are funded and owned by developers. Industrial, commercial and other consumers will be provided with two options for contractual arrangement as a part of promotion for rooftop solar systems. However, a setback in the policy is that it does not allow OPEX model/third party sale model to function in rooftop solar.

(d) Tamil Nadu

Recently on February 4, 2019, the Tamil Nadu Energy Development Agency announced its new solar energy policy 2019 that aims at generating 9,000 MW for the state by 2022, of which 40 per cent is intended to come from rooftop solar plants. The policy is applicable to both utility and consumer category systems. Earlier, the state had Tamil Nadu Solar Energy Policy 2012 (one of the first solar energy policies in the country). Under the new policy, RTS plants will be exempted from electricity-tax for two years from the date of the policy announcement. Further, the tariffs will be based on market-based competitive bidding and net feed-in tariff will be decided by Tamil Nadu Electricity Regulatory Commission (TNERC) from time to time. TNERC may introduce Time of Day (TOD) solar energy Feed-in tariffs to encourage solar energy producers and solar energy storage operators to feed energy into the grid when the energy demand is high.

However, the drawback in the policy is that net metering is allowed for project sizes only up to 40 kWp as compared to most other states which allow maximum capacity of 1 MW.

(e) Delhi

In September 2018, the Delhi Cabinet approved the "Mukhyamantri Solar Power Scheme" for domestic consumers which offers residents who install rooftop solar panels a subsidy on their electricity bill for a period of five years from the existing three. Under the scheme, domestic consumers will get a generation-based incentive (GBI) of Rs 2 per unit for a period of five years.

2.4 State-wise Tariffs, Subsidies and Incentives

Several states in India have released solar policies that incentivise rooftop solar. Table 2.2 provides snapshot of RTS tariffs, subsidies and incentives in the five states -- Maharashtra, Karnataka, Gujarat, Tamil Nadu, and Delhi.

Table 2.2: Summary of Tariffs, Subsidies and Incentives in Key States

	Maharashtra	Karnataka	Gujarat	Tamil Nadu	Delhi
Policy/Scheme	Maharashtra Solar Energy Policy 2017	Karnataka Solar Policy (2014-21)	Gujarat Solar Power Policy 2015	Tamil Nadu Solar Energy Policy 2019	Delhi Solar Energy Policy 2016
Rooftop solar target by 2022 (MW)	4,700	2,300	3,200	3,600	1,100
Rooftop solar installed capacity as of December 31, 2018 (MW)	160.49	151.05	146.64	130.17	115.25
Consumer segment	All buildings with rooftop space	All buildings with rooftop space	80% government; 20% residential	Residential and commercial	Government / public sector, commercial /industrial sector, domestic sector
Project type	NA	Rent-a-Roof	Rent-a-Roof	Owner owned/ Rent-a-Roof	Owner owned
Tariffs	Rs 3.22/kWh (August 2018)	Rs 4.15/kWh (December 2018)	NA	Rs 3.11/kWh (March 2018)	NA
Subsidies	The subsidy available on installation of grid connected solar rooftop power plants is 30% of benchmark cost. i.e. Rs. 18,300/ kW (benchmark cost is Rs 61,000/kW) or project cost whichever is minimum	30% government subsidy for non-commercial and non-industrial categories for using domestic solar panels.	For rooftops and vacant areas of buildings in residential/ social/ institutional sectors, capital subsidy at the rate of up to 30% of project cost or benchmark cost whichever is lower for the General Category States and up to 70% of project cost or benchmark cost whichever is lower for Special Category States/ Islands.	Subsidy of Rs 20,000/kWp for individual applicants for only 1 KWp plants for residential purpose	Societies can avail subsidy under Ministry of New & Renewable Energy (MNRE) scheme for which solar plant has to be installed through empanelled vendors selected by tender process.

	Maharashtra	Karnataka	Gujarat	Tamil Nadu	Delhi
Incentives	The rooftop solar PV project should have a minimum capacity of 1 kW and maximum capacity of 500 kW for an individual, or at a single beneficiary location	(1) Rs 3.40/KWh (2) Net metering (3) Any other incentives available to rooftop systems	(1) 5 MW rooftop programme on the PPP model in the capital which is now extended to about 5 more cities and towns (2) Monthly incentive of Rs 3/kWh for the roof owner	Consumer category solar energy to be exempted from electricity tax for 2 years from the policy date	(1) An incentive of Rs. 2 per unit will be paid on gross energy generated from your rooftop system. (2) The minimum eligibility criteria for GBI will be 1,100 solar energy units (kWh) generated per annum per kWp. The annual solar energy generation that is eligible for GBI shall be capped at 1,500 kWh per kWp, irrespective of the readings of the solar generation meter.
Offtaker/Power purchaser	Captive and state distribution agency	State distribution agency	State distribution agency	Captive and state distribution agency	NA

NA: Not available

Source: State Solar Policies

2.5 Salient Features of Net Metering Regulations

Net Metering is a billing arrangement that allows the consumer to sell excess energy to the utility company or buy deficit energy from the utility company using a meter to track this energy exchange. Currently, 29 states and 7 union territories have notified grid connectivity regulations with provision for net/gross metering. Notably, Tamil Nadu is the first state to offer net metring policy in India.

Table 2.3 provides analysis of net metering regulations in the five states -- Maharashtra, Karnataka, Gujarat, Tamil Nadu, and Delhi.

Table 2.3: Analysis of Net Metering Regulations of Key States

	Maharashtra	Karnataka	Gujarat	Tamil Nadu	Delhi
General conditions	Net metering agreement to be endorsed by the distribution licensee on a non-discriminatory and 'first come, first serve' basis to the eligible consumer who intends to install a RTS system connected to the network of distribution licensee.	Net metering arrangements are proposed (at multiple voltage levels) to focus on self-consumption of energy generated from RTS PV. The concept is a combination of captive consumption and exchange of power with the utility.	The distribution licensee to provide the net metering arrangement to the eligible consumer, who intends to install grid connected RTS PV system, in its area of supply on non-discriminatory and first come first served basis.	The distribution licensee shall permit the net metering arrangement to an eligible consumer who has installed or intends to install the grid connected RTS PV system in its area of supply on a non-discriminatory and first come first serve basis.	The distribution licensee to allow connectivity to the renewable energy system, on first come first serve basis, subject to operational constraints.
Eligible consumer	All the eligible consumers in the area of supply of the distribution licensee may participate in the rooftop solar net metering arrangement.	Eligible consumers intending to install RTS PV with capacity equivalent to 100% of the sanctioned load of the respective consumer's installation.	Eligible consumer for the RTS PV system with net metering shall be a consumer of the local distribution licensee; own or be in legal possession of the premises including the rooftop or terrace or building or infrastructure or open areas of the land or part or combination thereof on which the solar PV system is proposed to be installed; connect the proposed RTS PV system to the distribution system of the licensee; consume all of the electricity generated from the RTS PV system at the same premises.	An eligible consumer intending to install a RTS PV system having the capacity in excess of 75 kW shall insure the RTS PV system.	All consumers who are a buyer of energy/electricity from the distribution licensee in its area of supply and the distribution licensee.

	Maharashtra	Karnataka	Gujarat	Tamil Nadu	Delhi
Individual project capacity	The maximum RTS system capacity to be installed at any eligible consumer's premises shall be governed by the available capacity of the service line connections of the eligible consumer's premises and the cumulative capacity utilized at particular distribution transformer; provided that the capacity of the rooftop solar system to be connected at eligible consumer's premises shall not exceed his contract demand or connected load of the eligible consumer	The maximum capacity of the project shall be as per regulations to be issued by KERC in this regard from time to time, to address technical, safety and grid security issues.	The maximum capacity to be installed at any eligible consumer's premises shall be up to a maximum of 50% of consumer's sanctioned load/contract demand; provided that the installed capacity shall not be less than 1 kW and shall not exceed 1 MW.	The capacity of the RTS system to be installed at the premises of an eligible consumer shall not be less than 1kWp and a maximum of 1 MWp.	The capacity of renewable energy system to be installed at any premises shall be subject to feasibility of interconnection with the grid; available capacity of the service line connection of the consumers of the premises; and the sanctioned load of the consumer of the premises.
Net metering arrangement	Two meters including one bi-directional meter which is also known as net meter. The net meter will be single-phase or three-phase as per the requirement	In case of solar rooftop PV systems connected to the grid of a discom on a net basis, the surplus energy injected shall be paid by the ESCOMs at a tariff determined by KERC from time to time		A bi-directional meter of the same accuracy class as the eligible consumer's existing meter before the commissioning of the RTS PV system shall be installed in replacement of the existing meter. A single bidirectional meter shall be installed for export and import.	The net meter shall be, as per single-phase or three-phase requirement. All the meters to be installed for net metering shall be of the same or better Accuracy Class Index than the existing meter installed at its premises.

Source: State Solar Policies

2.6 Implementation Status of Net Metering Regulations

Today, grid interconnection regulations and processes remain challenging in most parts of India despite almost all states announcing net- and gross-metering policies for rooftop solar. Net metering not only incentivises the end-users to adopt a distributed renewable generation technology but also helps the end users/consumers reduce their energy bills. Further, it is also expected to help stabilise the national, regional and state grids, provide financial relief to the distribution companies (discoms) through consumer default risk mitigation and reduction of AT&C losses, and help cut down the per-capita energy footprint.

Broadly, rooftops can be divided into four categories — residences, commercial, educational institutions and industries (factories). Of these, solar is still not very attractive to the 'residence' segment even with subsidies. Commercial establishment have very little roof space to spare, as they need the space for other activities, such as air-conditioner outdoor units, or cafeteria. However, solar plants could easily come up on educational and industrial roofs, provided net metering rules are friendly.

There are regulation drawbacks in the policies across states. For instance, Tamil Nadu does not allow net metering for industries. This means, if a factory with a large roof puts up a solar plant, it has to consume all the power the solar plant generates or waste it. Moreover, if the electricity is put back to the grid, the meter does not recognise the direction of flow of current and treats the electricity supplied as consumed. Another drawback is that most states like Maharashtra, Kerala and Rajasthan allow net metering only up to 1 MW; therefore, if these states have a larger rooftop plant, they have to consume the power themselves or let it go waste. West Bengal is the only state that offers net metering up to 2 MW. This becomes critical under 'opex model' where the solar plant is owned by a third party – a power company – who invests in the plant and sells power, thus selling every unit of electricity generated matters a lot for the power company. Table 2.4 summarises the net metering regulations in different Indian states.

Table 2.4: Summary of Net Metering Regulations across Indian States

State / UT	Cap on PV export (%)	Capacity with respect to contract load (%)	Maximum capacity (kWp)	Minimum capacity (kWp)
Andaman & Nicobar Islands	100	100	500	1
Andhra Pradesh	100	NA	1,000	NA
Arunachal Pradesh	NA	NA	1,000	1
Assam	NA	40	1,000	1
Bihar	90	100	1,000	1
Chandigarh	100	100	500	1
Chhattisgarh	150	100	1,000	50
Dadra & Nagar Haveli	100	100	500	1
Daman & Diu	100	100	500	1
Delhi	NA	100	NA	NA
Goa	100	100	500	1

State / UT	Cap on PV export (%)	Capacity with respect to contract load (%)	Maximum capacity (kWp)	Minimum capacity (kWp)
Gujarat	100	50	1,000	1
Haryana	90	100	1,000	NA
Himachal Pradesh	NA	80	1,000	1
Jammu & Kashmir	90	50	1,000	1
Jharkhand	NA	100	1,000	1
Karnataka	NA	150	1,000	1
Kerala	NA	100	1,000	NA
Lakshadweep	100	100	500	1
Madhya Pradesh	100	100	NA	NA
Maharashtra	NA	100	1,000	1
Manipur	90	NA	1,000	1
Meghalaya	NA	100	1,000	1
Mizoram	NA	100	1,000	NA
Nagaland	NA	NA	NA	NA
Odisha	90	100	NA	NA
Puducherry	100	100	500	1
Punjab	90	80	1,000	1
Rajasthan	NA	80	1,000	1
Sikkim	NA	100	1,000	1
Tamil Nadu	90	100	40	NA
Telangana	100	100	1,000	1
Tripura	110	100	NA	NA
Uttar Pradesh	100	100	1,000	1
Uttarakhand	95	NA	500	1
West Bengal	90	NA	2,000	5

NA: Not available

Source: TERI

2.7 Key Issues and Challenges

Policy design, implementation and inconsistencies in solar policies across different states pose significant challenges for rooftop solar. Further, retrospective changes in policies is a concern for RTS developers. There is a need for the government to develop the residential off-grid capacity through a robust regulatory and policy framework, which should include a remunerative net metering policy.

Another issue is that neither the Centre nor the state governments have clarity about their net metering policies, which hold the key to the widespread adoption of rooftop solar across the country. For instance, the solar policy in Uttar Pradesh excludes the C&I segment in net metering. There is a need to come out with uniform policies on net metering that allow users to sell surplus power to utilities.

The net metering policy continues to be a drag on India's rooftop solar sector. One of the larger hurdles is the system size as most states have an upper limit (usually 1 MW) on the size of a rooftop solar project. Although a 1 MW rooftop project is relatively large, the size limit sidelines a large number of commercial and industrial consumers from installing rooftop solar to meet their power needs.

Currently confined to industrial rooftop projects, the MNRE is still working on how to make the solar policy more attractive for users in the residential category. While commercial and industrial rooftop projects are already cost-effective without net metering, having effective net metering policies in place assumes critical importance for the residential category, where much of the daytime electricity remains unutilised. In what is acting as a deterrent for potential users in the residential domain, even states which allow net metering have imposed a cap on the amount of power that can be fed back into the state grid.

The implementation of policies presents the biggest challenge even when the guidelines are in place. For instance, 12 states and six union territories have still not put the distribution licence mechanism in place to streamline the procedures for grant of connectivity to rooftop solar plants. It may take applicants three to four months to receive grant of connectivity for residential rooftop solar systems. The system of approvals and clearances leaves a lot to be desired with multiple departments like regulatory commissions, state nodal agencies, discoms and urban local bodies made part of the process, which is causing inordinate delay. There is no reason why consumers, particularly those in the residential category, will not be inclined to save on their electricity bills by adopting rooftop solar, but the lack of awareness among them about the associated benefits and the cumbersome and time-consuming procedures for net metering approvals are proving to be a dampener.

Net metering is important for residential consumers as their panels create a lot of surplus power during the day when the households themselves draw less power. While net metering is mandatory in many states, it is unregulated in states like Andhra Pradesh, Odisha, Tamil Nadu, and West Bengal, where they only have legally non-binding guidelines.

Another major reason why rooftop solar is not becoming popular is that the current electricity tariff structure renders it an unviable option. This is largely in cases where power purchase agreements (PPAs) have been signed but not executed. State utilities and distribution companies across India are reluctant to adhere to PPAs as it could hurt their finances, especially in the wake of falling tariffs subsequent to the signing of PPAs. If more and more C&I users, who bring maximum revenue to state discoms, take to solar power, the revenues of electricity generators and distributors will fall. However, discoms

should only view it as a short-term problem since the cost of thermal and solar power is expected to reach parity soon.

2.8 The Way Forward

Fundamental drivers for rooftop solar are becoming more compelling by the day and the government has shown a very strong desire to drive growth in this sector. It is already offering a generous mix of capital subsidies, tax incentives and cheaper debt financing schemes for the sector. The government is also substantially ramping up demand in the public sector. All these efforts will fail to produce the desired results unless net-metering policy framework is urgently reformed. International examples show that effective net-metering implementation can increase rooftop solar adoption by as much as 50 per cent. Further, solar rooftop adoption is currently facing challenges related to delays in tendering, involvement of multiple stakeholders, reluctance of discoms due to revenue loss and lack of uniform regulation.

Recognising the challenges being faced in the rooftop sector, the central government has now prepared single window clearance online portal with a feature to track the approval process for different agencies such as state nodal agencies, electricity distribution companies, chief electrical inspector, urban local bodies, etc. For capacity building of discoms, state nodal agencies, chief electrical inspectors, lenders, etc., special training programmes are being organised under technical assistance programs of multilateral and bilateral agencies. On the financing side, different mechanisms are being explored including the RESCO model, leasing a roof, demand aggregation, credit risk guarantee mechanism, etc.

The proposed scheme of the MNRE to incentivise the installation of roof top solar projects in India — Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) — is a step in the right direction. The scheme, once approved, will bring discoms to the forefront in the implementation of RTS projects by providing them financial support which will be linked to their performance in facilitating the deployment of RTS. The total outlay is Rs 234.5 billion for 40 GW of roof top solar installations by 2021-22. Segment-wise, it is proposed that C&I segment will set up 20,000 MW, while the government, residential, social and the institutional segments will set up 5,000 MW each. Discoms are expected to play a key role in the expansion of rooftop solar as they maintain a direct contact with the end-user and provide approval for installation, manage the distribution network and also have billing interface with rooftop owner. The recent Union Cabinet approval of Phase II of the grid-connected rooftop solar programme for achieving the 40 GW RTS target is a step in the right direction.

Going forward, there is a need for better and long-term certainty on policies and regulations in rooftop solar. Strengthening the opportunities and overcoming challenges will bolster investor confidence and streamline the path to achieving the 2022 target of 40 GW. Rooftop solar PV has huge potential and the government policies and regulations should be enabling to promote large scale deployment.

3. State-wise Analysis

3.1 Background

Rooftop solar (RTS) systems are changing the dynamics and economics of the energy sector across the world. The Government of India (GoI) has ambitious plans of adding 100 GW of solar power by 2022, of which 40 GW is planned to be generated through grid-connected RTS. Several policies and incentive schemes are being formulated to upscale RTS in the country. Mapping the RTS potential of various regions of India can provide a sound basis for creating a roadmap to achieve the goals set by the government.

The power sector is a concurrent subject provided in the Seventh Schedule of the Indian Constitution and hence both Centre and State have the power to regulate this domain. The Central Electricity Regulatory Commission and the respective State Electricity Regulatory Commissions govern this domain.

It has been estimated by The Energy and Resources Institute (TERI) that India has a rooftop solar energy generation potential of 124 GW. Even if only 1.3 per cent of India's total households (total 248.41 million) are solarised with rooftop technology, more than 30 per cent of that estimated energy capacity can be harnessed. Understanding this potential, the Centre is providing a strong push to RTS installation by setting mandatory installation targets and policies.

The Ministry of New and Renewable Energy (MNRE) defined that RTS plants on rooftops and vacant area of buildings in residential/social/ institutional/Government/PSU sectors will be developed based on subsidies/incentives as mentioned below:

- For rooftops and vacant areas of buildings in residential/social/institutional sectors, capital subsidy will be offered at the rate of up to 30 per cent of project cost or benchmark cost, whichever is lower, for general category states and up to 70 per cent of project cost or benchmark cost, whichever is lower, for special category states/islands.
- For rooftops and vacant areas of buildings in Government/ PSU sectors, financial incentive will be provided at rates as mentioned in Table 3.1.

Table 3.1: Financial Incentives for Rooftops & Vacant Areas of Buildings in Government/PSU sectors

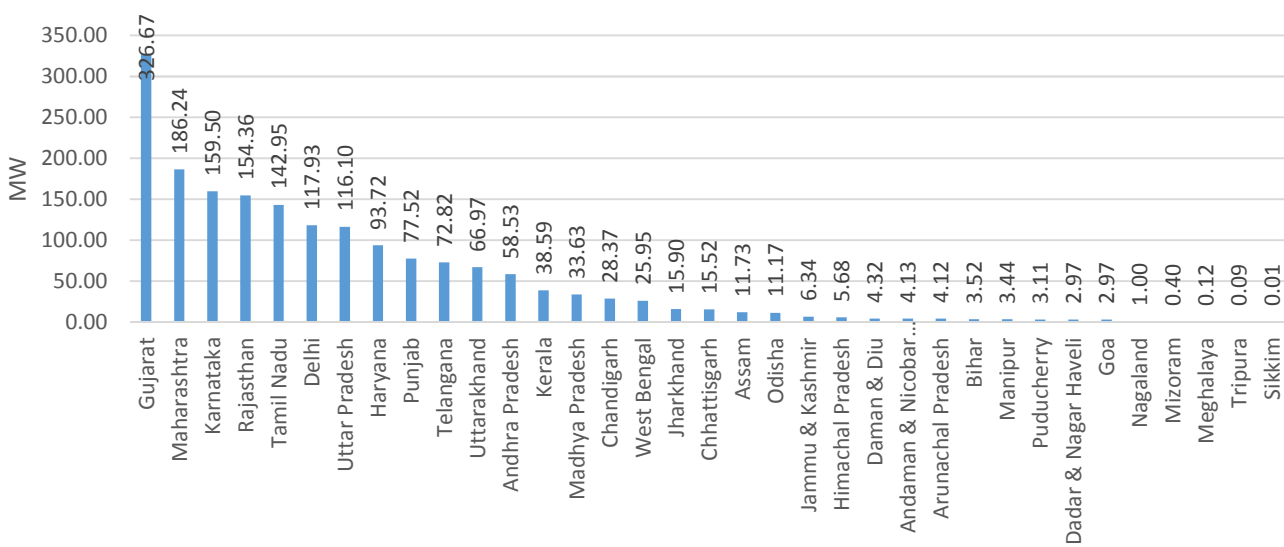
Achievement vis-à-vis Target Allocation	General Category States (Rs per kW)	Special Category States/Union Territories (Rs per kW)
80%	18,750	45,000
> 50% and < 80%	11,250	27,000
Below 50% or delayed commissioning up 6 months beyond sanctioned period	7,500	18,000
Definitions:		
Special Category States: North Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Lakshadweep, Andaman & Nicobar Islands	**General Category States:** All other States/Union Territories not covered under special states	**Type of buildings:** a. Residential buildings, including group housing. b. Institutional buildings including schools, hospitals, etc. c. Social sector including community centres, etc.

Source: Ministry of New & Renewable Energy, Government of India

3.2 State-wise installed capacity

As of March 31, 2019, the total installed RTS capacity across all states in India stood at 1,796.36 MW. Figure 3.1 shows the state-wise installed RTS capacity. The five states – Maharashtra, Karnataka, Gujarat, Tamil Nadu, and Delhi – having a cumulative RTS installed capacity of 969.72 MW accounted for almost 54 per cent of total solar rooftop installation in the country.

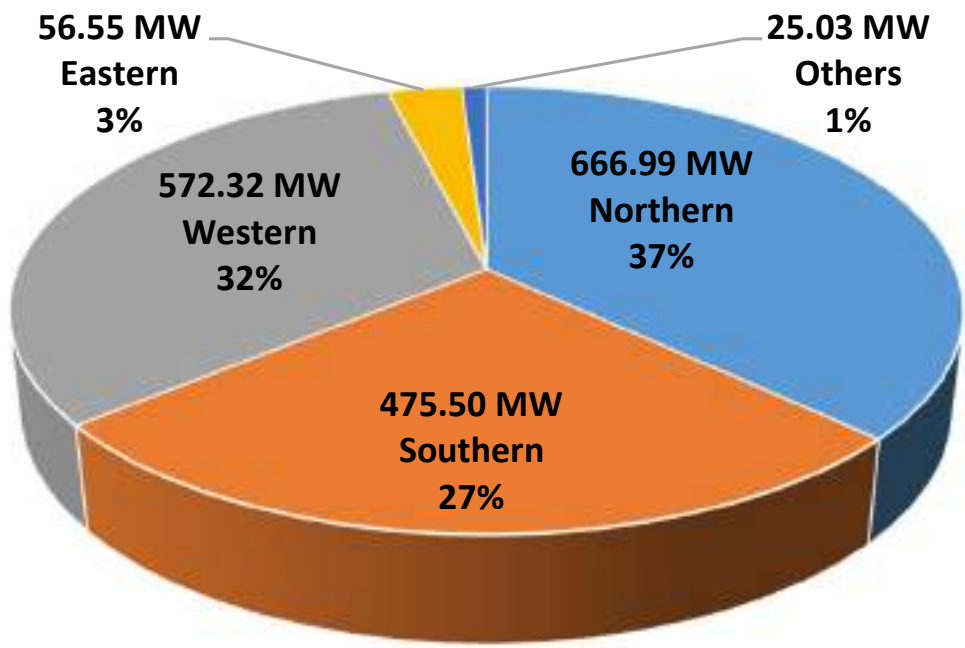
Figure 3.1: State-wise Installed Rooftop Solar Capacity (as of March 31, 2019)



Source: Ministry of New and Renewable Energy, Government of India

Region-wise, the Northern Region accounted for the highest installed RTS capacity at 37 per cent, followed by the Western Region and Southern Region at 32 per cent and 27 per cent, respectively. Figure 3.2 represents the region-wise percentage share of installed RTS capacity.

Figure 3.2: Region-wise % Share of Installed Rooftop Solar Capacity (as of March 31, 2019)



Others include North-Eastern states and Andaman & Nicobar Islands

Source: Ministry of New & Renewable Energy, Government of India

Northern Region: In the Northern Region, maximum RTS capacity installation has been carried out by Rajasthan (154 MW), Delhi (118 MW) and Uttar Pradesh (116 MW). These three states comprise 58 per cent of total installed RTS capacity in the region.

In September 2018, the Delhi cabinet approved the 'Mukhyamantri Solar Power Scheme', which offered residents who install rooftop solar panels a subsidy on their electricity bill for a period of five years from the existing three. Under the RESCO model, the domestic consumer will not have to spend any money for the installation of solar panels; it will be done by select service providers. The cost of electricity generated through the solar power for group housing societies will be Rs 1 per unit. The Delhi government will provide a subsidy of Rs 2 per unit to the societies. At present, nearly 105 MW of solar power installed in Delhi covers mostly government buildings such as Delhi Metro Rail Corporation, Delhi Jal Board, and technical institutions (Delhi Technological University, Netaji Subhas Institute of Technology, Guru Gobind Singh Indraprastha University, and Indira Gandhi Delhi Technical University for Women).

The state of Rajasthan is promoting development of rooftop PV solar power plants connected to LT under Net Metering Scheme as per guidelines of Rajasthan Electricity Regulatory Commission. The state government will allow the Net Metering mechanism for grid connected systems to the consumers of

the discoms installing such systems subject to technical consideration and execution of net-metering agreement between such consumers and discoms.

In Haryana, the state Renewable Energy Department issued new guidelines in 2017 for the installation of rooftop solar projects in the state. The guidelines apply to all rooftop solar projects with capacities ranging from 1 kW to 500 kW. Under the new guidelines, rooftop solar systems for residential, institutional, and social sectors will all be eligible for central financial assistance (CFA). The state government will provide the installations with CFA equal to either 30 per cent of the benchmark project cost or Rs 20,000/kW (USD 312/kW), whichever is less.

The Punjab government allows installation of solar rooftop under net metering, which refers to an agreement that allows a consumer to sell excess solar energy to the utility. Over the last three years, the state has installed 1,105 RTS plants of 24 MW capacity on different types of buildings — residential, commercial, government, industrial, educational and social.

In July 2018, the Uttar Pradesh government announced an additional subsidy of Rs 15,000 per kW or a maximum of Rs 30,000 to residential consumers for installation of RTS plants. The objective was to make RTS installation more affordable for residential consumers. However, the state excludes the commercial and industrial segment for net metering.

Southern Region: With total installed RTS capacity of 475.5 MW in the Southern region, Karnataka (159.5 MW) and Tamil Nadu (142.95 MW) together contributed 64 per cent of total.

Karnataka government is laying special emphasis on the production of rooftop solar energy. In 2018, the state government exempted rooftop solar power plants with production capacity below 1 MW from the regular electrical inspections by the state's electricity authority. Further, the RTS plants installed or owned by Central Government will also be exempted from the inspections by the Electrical Inspector of the state.

Recently, in February 2019, the Tamil Nadu state government announced its new Solar Energy Policy 2019 which provides an inclusive policy framework that promotes both utility category and consumer category solar energy generation through various enabling mechanisms. The policy aims to generate 9,000 MW of solar energy for the state by 2022. Of the total 9,000 MW, 40 per cent would be earmarked for consumer category solar energy systems.

Andhra Pradesh announced its Solar Power Policy 2018 superseding its earlier policy of 2015. The new policy aims to achieve a minimum total solar power capacity addition of 5,000 MW in the next five years in the state. Under the policy, the government will promote solar rooftop systems on public buildings, domestic, commercial and industrial establishments on gross and or net meter basis. The consumers are free to choose either net or gross meter option for sale of power to discom under this policy. The projects of capacity up to 1 MW at a single location will be permitted.

Western Region: Three states, namely, Gujarat (326.67 MW), Maharashtra (186.24 MW) and Madhya Pradesh (33.63 MW) accounted for almost 95 per cent of total installed RTS capacity of 572 MW in the Western Region.

Maharashtra approved its solar energy policy in January 2016, encouraging both public and private entities to go solar. The off-grid policy aims to save minimum 500 MW of power in the next five years. Currently, the state leads in RTS installation in the country. Maharashtra has seen a steady growth in

the adoption of rooftop solar in commercial and industrial segment. Since last year, the strong demand from educational institutions and government buildings in the state has driven the industry.

In Gujarat, the state government provides a subsidy of Rs 10,000 per kW for maximum 2 kW for residential rooftop solar installation. However, the state offers net metering and other incentives only to house owners setting up solar rooftop plants, and not to solar developers.

The government of Madhya Pradesh introduced a policy for decentralised renewable energy systems in 2016 with a particular focus on rooftop solar PV. While this policy aims to promote all decentralised and distributed RE technologies and is technology neutral, for the purposes of discussion and application, the focus would be mostly on decentralised and distributed solar PV rooftop systems, since amongst all technologies, solar PV rooftop has the largest potential for mass replication amongst consumers and small independent power producers.

Eastern Region: West Bengal and Jharkhand accounted for 74 per cent of total installed RTS capacity of 56.55 MW in the Eastern region. Installed RTS capacity in West Bengal and Jharkhand stood at 25.95 MW and 15.9 MW, respectively.

In West Bengal, the Policy on Co-generation and Generation of Electricity from Renewable Sources of Energy, 2012 stated that all existing and upcoming commercial and business establishments having more than 1.5 MW of contract demand will be required to install solar rooftop systems to meet at least 2 per cent of their total electrical load. Further, all the existing and upcoming schools and colleges, hospitals, large housing societies and government establishments having a total contract demand of more than 500 kW will be required to install solar rooftop systems to meet at least 1.5 per cent of their total electrical load. Rooftop solar PV sources of capacity ranging between 100 kW-2 MW will be allowed connectivity at LV or MV or 6 kV or 11 kV of the distribution system of the licensee as considered technically and financially suitable by the licensee and the developer.

The Jharkhand government has prepared a framework for the state rooftop solar power policy 2018 with an objective to produce 500 MW power through grid-connected rooftop solar plants by 2022. The state's solar rooftop policy, after its notification, will certainly help in setting up solar power projects to achieve the solar rooftop targets of Ranchi and Jamshedpur.

3.3 State-wise RTS Capacity Targets

In June 2015, the MNRE had release the state-wise tentative targets for installation of the grid connected solar rooftop systems as given in Table 3.2. This has been arrived at by dividing the 40,000 MW country target in proportion of the state-wise power consumption and consequent solar power requirement to meet the corresponding renewable purchase obligations (RPO).

Maharashtra is expected to add the highest capacity at 4.7 GW by 2021-22, followed by Uttar Pradesh (4.3 GW), Tamil Nadu (3.5 GW), Gujarat (3.2 GW), Rajasthan (2.3 GW), and Karnataka (2.3 GW). These six states together will contribute half of the total RTS capacity target.

Table 3.2: State wise and Year wise proposed targets for 40 GW Grid Connected RTS Projects

S. No.	State/UT	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
1	Andhra Pradesh	10	240	250	300	350	400	450	2,000
2	Bihar	5	120	125	150	175	200	225	1,000
3	Chhattisgarh	4	84	88	104	120	140	160	700
4	Delhi	5	132	138	165	190	220	250	1,100
5	Gujarat	15	385	400	480	560	640	720	3,200
6	Haryana	5	200	200	235	280	320	360	1,600
7	Himachal Pradesh	2	38	40	48	56	64	72	320
8	Jammu Kashmir	2	54	55	74	80	90	95	450
9	Jharkhand	4	96	100	120	140	160	180	800
10	Karnataka	10	275	290	344	403	460	518	2,300
11	Kerala	4	96	100	120	140	160	180	800
12	Madhya Pradesh	10	265	275	330	385	440	495	2,200
13	Maharashtra	20	565	588	704	823	940	1,060	4,700
14	Odisha	5	120	125	150	175	200	225	1,000
15	Punjab	10	240	250	300	350	400	450	2,000
16	Rajasthan	10	275	288	344	403	460	520	2,300
17	Tamil Nadu	15	420	438	524	613	700	790	3,500
18	Telangana	10	240	250	300	350	400	450	2,000
19	Uttarakhand	2	42	44	52	60	70	80	350
20	Uttar Pradesh	20	510	538	650	752	860	970	4,300
21	West Bengal	10	252	263	315	370	420	470	2,100
22	Arunachal Pradesh	2	5	5	8	10	10	10	50
23	Assam	4	30	30	38	42	50	56	250
24	Manipur	4	3	6	8	9	10	10	50
25	Meghalaya	1	6	6	8	9	10	10	50
26	Mizoram	1	6	6	8	9	10	10	50
27	Nagaland	1	6	6	8	9	10	10	50
28	Sikkim	1	6	6	8	9	10	10	50
29	Tripura	1	6	6	8	9	10	10	50
30	Chandigarh	1	12	12	14	18	20	23	100
31	Goa	1	20	20	22	23	30	34	150
32	Dadra & Nagar Haveli	1	24	25	30	35	40	45	200
33	Daman & Diu	1	12	12	14	18	20	23	100
34	Puducherry	1	12	12	14	18	20	23	100
35	Andaman & Nicobar Islands	1	2	2	2	5	4	4	20
36	Lakshadweep	1	1	1	1	2	2	2	10
	Total	**200**	**4,800**	**5,000**	**6,000**	**7,000**	**8,000**	**9,000**	**40,000**

Source: Ministry of New and Renewable Energy, Government of India

3.4 State-wise Mandatory Installation of RTS

To enable RTS development from planning stage, the Ministry of Urban Development (MoUD) requested all states and UTs, in 2014 to issue necessary directives to all state government departments for using rooftop of buildings under their control for solar power generation on mandatory basis. The ministry has also asked all states/UTs to mandate RTS on all new buildings through the urban local bodies. Further, the MoUD also issued Model Building Bye-Laws, 2016, in which suitable provisions for installation of RTS on buildings have been incorporated. The guidelines for Smart City programme also require at least 10 per cent energy to be sourced from solar energy.

So far, four states/UTs -- Chandigarh, Chhattisgarh, Haryana, and Uttar Pradesh -- have already issued mandatory notifications for installation of RTS in different categories of buildings. Further, Chief Electrical Inspector to Government (CEIG) inspection has been made optional by states of Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Odisha, Haryana, Delhi, Maharashtra and Rajasthan for solar rooftop plants up to certain capacity. According to the Delhi Solar Policy, 2016, it is mandatory to install RTS on all government buildings/institutions having rooftop area of 500 sq. metres or above.

Chandigarh

The Chandigarh administration, in a notification issued on May 18, 2016, made installation of rooftop solar power plants mandatory in residential and non-residential buildings in Chandigarh. The details of category of building and capacity is provided in Table 3.3.

No approval will be required from Chandigarh municipal Corporation or Estate Office for putting up solar plants in existing or new buildings. This will be applicable on new buildings to be constructed in Chandigarh. The existing buildings will have to install solar photovoltaic (SPV) panels within 2 years of the issue of notification. Further, existing housing complexes developed by Group Housing Societies, builders, housing board will be exempted from installation of solar plants.

Table 3.3: Policy Details of Mandatory RTS Installation in Chandigarh

Category	Capacity of solar photovoltaic plant
Residential buildings	All residential buildings (new construction/reconstruction) within limits of Municipal Corporation, Chandigarh: a. 500 sq yards to 999 sq yards – 1 kWp SPV b. 1,000 sq yards to 2,999 sq yards – 2 kWp SPV c. 3,000 sq. yards and above 3 kWp SPV
All private educational institutes, schools, colleges, hostels, technical/vocational education institute, universities, etc. having connected load of 30 kW and above	Minimum 5 kWp or 5% of connected load, whichever is higher
All government buildings and offices and government colleges, government educational institutions, universities having connected load of 30 kW and above	Minimum 2 kWp or 5% of connected load, whichever is higher
All private hospitals and nursing homes, industrial/commercial establishments, malls, hotels, motels, banquet halls, and tourism complexes, having connected load of: a. 50 kW to 1,000 kW b. Above 1,000 kW	a. Minimum 10 kWp or 5% of connected load, whichever is higher b. Minimum 50 kWp or 3% of connected load, whichever is higher
All new buildings to be constructed by housing complexes, developed by group housing societies builders, housing boards on a plot size of: a. 0.5 acre-1 acre b. 1 acre-2 acres c. 2 acres-5 acres d. More than 5 acres	a. Minimum 10 kWp b. Minimum 20 kWp c. Minimum 30 kWp d. Minimum 40 kWp

Source: Chandigarh Administration

Chhattisgarh

In Chhattisgarh, the state government announced that rooftop solar panels will be mandatorily installed with effect from January 1, 2016 in all new buildings of government, semi-government establishments and institutional bodies. Solar power plants with the capacity of 10-50 kW will be installed in various buildings of the state.

Haryana

In Haryana, all new residential buildings built on a plot size of 500 square yards and above falling within limit of municipalities, including Haryana Urban Development Authority (HUDA) sectors, will have to install solar photovoltaic power plant with a capacity of minimum 1 kW in the houses which have sanctioned load up to 20 kW. The owners will have to install a plant with a capacity of 5 per cent of the sanctioned electricity load, if the building has higher power consumption than of 20 kW.

According to a notification issued by Haryana Renewable Energy Development Agency (HAREDA), the sectors of Haryana State Industrial and Infrastructure Development Corporation will have to follow the norms. All new private educational institutes, schools, colleges, hostels, technical or vocational educations institutes, universities having sanctioned load of 30 kW and above will have to install similar plant having capacity of minimum 5 kWp or 5 per cent of sanctioned load, whichever is higher.

All new private hospitals and nursing homes, industrial and commercial establishments, malls, hotels, motels, banquet halls and tourism complexes having sanctioned load of 50 kW to 1,000 kW and above 1,000 kW will have to install plant of minimum 10 kWp or five per cent of sanctioned load and minimum 50 kWp or 3 per cent of sanctioned load. Instructions have been issued for government buildings also.

Uttar Pradesh

The Uttar Pradesh government, in order to promote solar power in the state, has made installation of roof top solar panels mandatory for residential and offices constructed on an area of more than 5000 sq feet. A building owner will have to reserve 25 per cent of the area for the purpose.

3.5 Conclusion

Significant efforts have been made by the states to install roof top solar. As of March 31, 2019, the states have achieved 4.5 per cent of the government's RTS capacity target of 2021-22. The RTS segment is expected to pick up momentum with the launch of the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme which addresses the concerns of discoms. Given the commitment being displayed by the Government and the industry to ramp up solar capacities in mission mode, the long-term scenario looks positive in terms of reducing India's dependence on coal for its energy needs. This has obvious environment benefits, apart from building sustainable capacities to meet India's energy needs over the long term.

4. Financing Rooftop Solar

4.1 Background

The Government of India (GoI) is encouraging adoption of solar energy by every Indian. To promote convenient adoption and use of solar energy, both public sector and private banks have been given statutory instruction by the Ministry of Finance to offer loan at reasonable cost. Ease of accessing funds for installation of rooftop solar (RTS) in India is an important aspect, both in commercial and industrial (C&I) as well as in residential segments. So far, most of the investment in the solar power sector has been made by the private sector.

At present, the government is promoting development of solar energy in the country by providing various fiscal and promotional incentives such as accelerated depreciation, waiver of Inter State Transmission System (ISTS) charges and losses, financing solar rooftop systems as part of home loan, and permitting foreign direct investment (FDI) up to 100 per cent under the automatic route. Notably, during April 2000 and December 2018, the renewable energy sector (including solar) received FDI to the tune of Rs 457.31 billion (USD 7.6 billion).

The Reserve Bank of India (RBI) has included renewable energy projects under priority sector lending for which bank loans up to a limit of Rs 150 million to borrowers is available for renewable energy projects including grid connected RTS systems. For individual households, the loan limit is Rs 1 million per borrower.

At present, financing is the biggest challenge faced by most developers. While the specifics of the challenge might be different for small developers from those for the large developers, the ability to raise financing at optimal terms is a critical factor for the success of solar power plants in India. The need of the hour is more attractive debt financing solutions for RTS project developers.

Most RTS projects in India are undertaken under the RESCO model. In solar plants, the largest capital investment goes towards the installation of solar panels which must be made upfront. At today's prices, this amounts to an investment of about Rs 50 million to produce 1 MW of power.

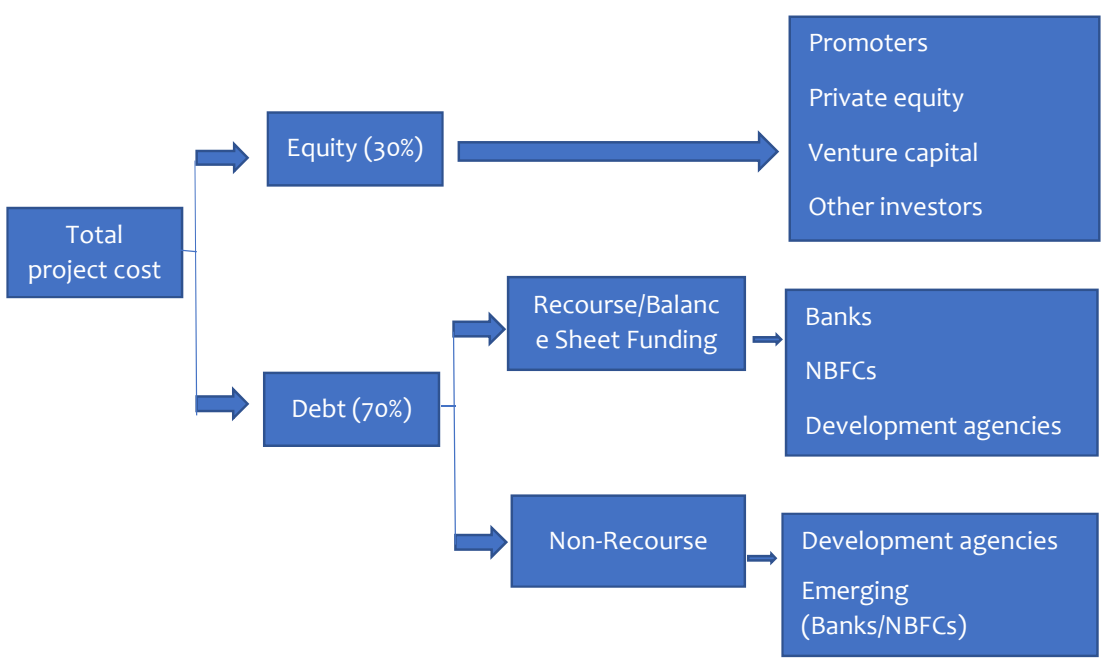
4.2 Funding Mechanism and Strategy

Rooftop solar power plants in India are typically financed through a mixture of debt and equity in the ratio of 70:30, from various sources, as shown in Figure 4.1.

Equity is primarily contributed by the promoter of the plant. Some private equity infusion is also possible. In case of debt, most financial institutions only offer with recourse (i.e., collateral will be required) debt. Both domestic and international debt is available. Foreign debt may provide lower interest rate, but cost of hedging for foreign exchange rate risk should be taken into account. Domestic debt is typically for 10-15 years (a few banks go up to 20 years) while foreign debt could have a tenure of 16-18 years. It typically takes 6-9 months to close financing depending. According to financing experts, loan for RTS is usually provided based on the credentials and past experience of the developer. A loan approval for a renowned company may take just a few weeks while the same for a start-up firm will take several months.

With regard to multilateral financing, a concessional loan of USD 625 million has been provided by the World Bank to the State Bank of India (SBI) and of USD 500 million by the Asian Development Bank (ADB) to the Punjab National Bank (PNB) for financing of grid connected rooftop solar projects in industrial and commercial sectors. Technical assistance is also available for promotion of rooftop systems under World Bank, ADB, USAID and GIZ assistance. The assistance under such schemes are available to all states/UTs depending on requirement and demand.

Figure 4.1: Sources of Funds for Rooftop Solar Plants



4.3 Funding Challenges

Meeting the GoI's target to add 40 GW of rooftop solar capacity will require an investment of USD34 billion during 2016-22. Assuming a debt-equity ratio of 70:30, rooftop solar will need USD24 billion of debt capital.

Currently, two main business models prevail in the rooftop solar sector in India: the Capex model and the RESCO model (Opex model). Earlier, the capex model had a higher market share at around 86 per cent in RTS installation. At present, the RESCO or Opex model has captured a higher share than the Capex model.

The RESCO model is expected to be the most successful way to expand solar installations in India. The four main advantages of the RESCO model are:

- RESCO model is less capital-intensive than the Capex model, wherein the owner has to pay the entire upfront cost of components and installation. In contrast, in a RESCO model, the entire system is owned by the developer and rooftop owners just must pay a monthly pre-determined tariff based on their consumption of electricity.
- In the RESCO model, the responsibility of operations and maintenance (O&M) is entirely on the developer.
- Installations under the RESCO model enjoys more central and state government agencies' support in the form of subsidies.
- There is better monitoring of load and consumption which help consumers to manage their energy consumption.

At present, rooftop solar PV project developers find it difficult to access debt financing, particularly at an appropriate cost and tenor for four main reasons:

- Banks are unsure of the credit quality of rooftop solar systems deals and thus reluctant to lend
- Most rooftop solar systems are too small to attract significant institutional investor attention
- Low solar energy tariffs are making bankers and other financiers cautious about funding RTS projects
- Most project developers are small in size and lack a track record (apart from a few that are backed by big corporates), making it difficult to attract capital at a favourable rate.

There are additional areas of concern for potential investors, including concern about the enforceability of long-term contractual agreements, and long-term performance risk associated with the PV systems dissuade banks from financing this sector. Small project developers' lack of collateral security is another key barrier. These developers do not have strong asset bases to meet the demands of banks that often require 100 per cent or more of bank debt in collateral. The lack of collateral also makes banks reluctant to offer non-recourse project financing loans. In addition, a lack of technical standards and standardised power purchase agreements (PPAs) agreements and loan documentation all increase transaction costs and consequently cost of financing.

According to the Report of the Expert Group on 175 GW RE by 2022, NITI Aayog, RE project developers in India often struggle to access the large amount of financing they require and even when available, the cost of financing is often high. Renewable energy technologies, unlike conventional energy technologies, often tend to have high (as much as twice or more) capital costs and very low operating costs (less than 10 per cent in few cases). Thus, the cost of capital (finance) emerges as one of the most significant contributors to the delivery of clean energy. In contrast, conventional energy sources are less capital-intensive, and the cost of capital has much less contribution to cost of delivered energy (fuel costs are most significant contributors).

The cost of capital is inherently high in India – debt costs in India is typically 12-14 per cent, vis-à-vis 3-7 per cent range in the developed economies, equity return expectations are even higher. This can mostly be attributed to the inherent structure of India's financial sector and the state of the economy which influences factors such as the cost of money, its variability and tenor, and inflation. These terms adversely affect RE projects.

GoI targets to achieve 100 GW solar capacity by 2022. Out of this, 40 GW is planned to be deployed through rooftop PV plants. According to the existing scheme of the Government of India, 15 per cent capital subsidy is allowed for residential and institutional segments. At Rs 80 million/MW, it is estimated that a Central Financial Assistance of a total of Rs 120 billion may be required by 2022 to achieve 10 GW of rooftop capacity through residential / institutional segments. Remaining 30 GW is expected to be deployed through C&I segments, which would require no subsidy but enabling policy and regulatory environment and support from utilities. The quantum of financial assistance required for 10 GW of rooftop by 2022 must be considered as an upper bound since the reduction in capital costs of rooftop systems is not considered.

4.4 Key Financiers' Perspective

Some of the commercial banks and financial institutions actively involved in renewable energy financing (including rooftop solar) in India are ADB, DEG - The German Investment and Development Company, DBS Bank, ICICI Bank, IDFC Bank, International Finance Corporation (IFC), Indian Renewable Energy Development Agency Limited (IREDA), Power Finance Corporation (PFC), Proparco, Rabobank, SBI, SBI Capital Markets, and Yes Bank. Lending institutions like the SBI, PNB, and IREDA have got rooftop specific credit lines from multilateral agencies and are providing loans at concessional rates. Both private sector and nationalised banks have been very forthcoming in providing debt for financing good quality rooftop solar project portfolios.

Typically, 1 kW solar rooftop system for residential consumers costs around Rs 50,000-60,000. A small-ticket size and uncertainty over the quality of the RTS systems in the long term are some of the reasons preventing large lenders from opening up to the sector. This is a sector with very low entry barriers, and hence, a large number of players have entered with everyone driving prices down; therefore, the quality is compromised. The financiers prefer larger-ticket sizes and standard products with assured quality. The problem in rooftop solar is that there are several equipment manufacturers and installers in the country.

Over the past two years, the government has also secured several large credit lines from the World Bank, ADB and Germany's KfW for the rooftop solar sector to be channeled via India's PSU lenders. However, according to experts, only a portion of these funds have been actually sanctioned, with only AA or AAA-rated corporates becoming the recipients of these funds, leaving small industries and residential consumers out of the picture.

Despite the significant initiatives from the central and state governments, residential consumers are by and large, still not adopting rooftop solar in a big way. There is a need for clear, credible and objective information about rooftop solar PV that can be accessed by consumers. Basic information is needed like how much rooftop area is required to generate a unit of electricity, who will provide after sales service, what is covered by warranty, how does one obtain net or gross metering benefits, how much time it takes to install a rooftop solar PV system, etc. At present, there is no single credible source of such information that is independent or reliable for consumers.

Further, banks that offer finance for installation of rooftop solar PV systems often demand disproportionate collateral security, perhaps because of the absence of resale value of the systems. Some ask consumers for the title deeds of their homes, which is several times the cost of the solar PV system. Consumers have

also complained about the tough terms and conditions, which work as deterrents for the consumers, who are looking for some finance to help reduce their capital costs for installation.

Despite best efforts at single window approvals and so on, multiple permissions and approvals are needed to obtain net or gross metering benefits. Consumers who have installed solar PV systems on their roofs complain of having to make multiple visits for getting the necessary approvals and arranging for inspections to certify completion of work – which is both tedious and time consuming. This is one of the key reasons for deterrent in adoption of RTS.

4.5 Conclusion

As financing is one of the main challenges faced by RTS developers, there is a need for attractive debt financing solutions. In particular, financing residential rooftop for small businesses is extremely challenging. Due to low or non-existent credit ratings, it is difficult for a developer to raise debt from banks for these customers as well as get into a power purchase agreement of 20-25 years, which is necessary to make the project cost effective. It is typically the relatively smaller project sizes and lack of confidence on performance monitoring of these systems that banks see as a challenge. Although public sector banks like PNB and SBI have tied up credit lines from ADB and World Bank, on-ground adoption has been quite slow.

Higher interest rate is another challenge. Interest rates for solar projects have risen by a percentage point over the last year making loans expensive.

Going forward, financing and service have to become an integral part of the solar solution offerings. If solar companies can eliminate the performance risk by using quality products, sound engineering and great after-sales service, then the short to mid-term financing to end-users can make a huge impact in attaining India's rooftop solar potential. Installers will need to partner with financial institutions and the government needs to put some policies in place to absorb some of the risk and prod banks to lend since a credit rating system is not well established in the country for individuals or small businesses. The market also needs to innovate when it comes to financial instruments that are customised for the Indian market conditions.

5. Industry Perspective

5.1 Background

Rooftop solar (RTS) installations in India have been growing steadily, albeit at a slow pace. The majority of rooftop installations are primarily in the government and commercial and industrial (C&I) segments. So far, the residential segment has a negligible market share. The reasons behind slow pace in rooftop solar growth, especially in residential segment, are delays in policy enforcement, disallowing important policies like net metering in Tamil Nadu, putting cap on net metering, lack of clarity in disbursement of subsidies, lack of clarity in policies (net metering), lack of flexible financing (delays in subsidy payment), bureaucratic hurdles in getting approvals, and lack of awareness.

Rooftop systems deliver a 3-4-year payback to C&I customers, which makes economic sense for almost every user. To set up top quality rooftop solar PV projects, one must focus on high quality balance of system (BOS), an in-depth and deeply tested design and engineering mechanism, proper execution of methods and processes, and project management practices that are safe and repeatable. For rooftop solar PV project installers to be successful, the developers must have easy access to capital. Distribution companies (discoms) present hurdles to rooftop solar adoption, as the RTS sector has a negative impact on their business models. In rooftop, cost pressures, limited training, and a fragmented network of installers present severe quality challenges.

Going forward, developers see huge potential for growth in the rooftop sector. However, the challenges like design constraints due to limited roof size and delays in net metering need to be addressed to gain the required scale in the rooftop PV sector, which shall evolve with increased penetration.

Section 5.2 presents case studies of key rooftop solar consumers (Indian Railways and Delhi Metro), solar rooftop developer – Hero Future Energies, and rooftop solar panel manufacturer – Vikram Solar. This section also briefly covers rooftop solar plan of Bangalore Metro. The case study covers a snapshot of the project, challenges faced during execution and steps taken to address the issues. Section 6.3 provides the key learnings from the projects executed.

5.2 Case Studies

Indian Railways

Indian Railways (IR) is the single largest consumer of electricity comprising around 2 per cent share of the country's total power consumption. In 2016-17, IR consumed about 18.05 billion kWh of electricity in 2016-17. With rail traffic projected to increase in the coming years, it is estimated that the demand for

electricity by the IR will go up manifold over the next decade. The Railways' locomotives also consume 2.6 billion litres of diesel annually. Diesel accounted for around 70 per cent of the fuel bill.

In September 2018, the Union Government approved 100 per cent electrification of IR's route network by 2021-22. This is expected to reduce the transporter's dependence on diesel, leading to reduction in oil imports and cutdown of carbon emissions. As of April 2018, 45 per cent of IR's route network of 67,368 km stood electrified.

Currently, around two-thirds of freight and more than half of passenger traffic in IR moves on electric traction. Traction energy is the energy required for hauling electric and diesel passenger and freight locomotives across the railway network, while non-traction energy is the energy required to run railway operations which include diesel loco sheds, railway workshops, railway stations, level-crossing gates, railway offices and buildings, etc.

Traction energy consumes nearly 85 percent of the total railway energy consumption, while non-traction energy accounts for the remaining 15 percent. However, electric traction accounts for just 37 per cent of the total energy expenses of IR. Due to this advantage, post electrification, IR is likely to save Rs 135.1 billion per annum in fuel bill and the same will improve its finances.

With the solar prices have been falling significantly in the recent years, it makes an economic case for the railways to further reduce their electricity costs and at the same time, increase the share of renewable energy, particularly, solar, in their energy consumption mix. Further, open access procurement of power from renewables could further bring down the cost of power for the railways, with solar tariffs being at par or lower in many cases than the conventional grid tariff for the IR.

With the objective of increasing the share of renewables in the railways, the Ministry of Railways (MoR) has targeted to set up 1 GW of solar power (500 MW of rooftop solar) by 2020-21 and has proposed to increase its target to 5 GW by 2025. Of the 5 GW solar target, 1.1 GW is planned to be rooftop solar. This target of 5 GW would see the IR procuring about 25 per cent of its electricity demand from solar by 2030. As of February 2019, IR has commissioned rooftop solar capacity of about 70 MW at various railways stations and service buildings. Further, 160 MW capacity projects are under implementation.

IR also has plans to add solar panels to the rooftops of its rolling stock. As of January 2019, IR has already provided solar panels on rooftop of 19 narrow gauge coaches and 23 broad gauge non-airconditioned coaches in service. The rooftop solar systems provide power for around four to five hours, charging battery systems during this time. The systems do not work at full capacity during fog/rain and winter season and battery backup goes down to two to three hours depending upon weather conditions.

Railway Energy Management Company Limited (REMCL) was incorporated on August 16, 2013 as a joint venture (JV) company of MoR with equity participation of IR (49 per cent stake)) and RITES Limited (51 per cent stake). In order to harness the untapped potential of solar roof top at railway buildings, stations, hospitals etc., IR has decided to install 500 MW RTS plants. REMCL is the bid process coordinator for the designated task and has awarded contracts for 120 MW of RTS projects in phases for several zonal railways, production units/workshops and Kolkata Metro. Most of these projects are supported by viability gap funding (VGF) / Central financial assistance (CFA) from the Ministry of New and Renewable Energy (MNRE). Upon commissioning, this will result into saving of about 1,30,000 tonnes of carbon-dioxide per annum.

The company has been mandated to install 323 MW solar rooftop projects for IR without any VGF/

CFA from MNRE. Of the 323 MW, bids for 80 MW has already been invited and the balance is in progress.

As of February 2019, the **Delhi Division of Northern Railway** has commissioned 5.53 MW of rooftop solar at various stations and service buildings in the states of Delhi, Uttar Pradesh, and Haryana. This has resulted in railways' annual power savings of 7.76 million units and Rs 72.61 million. Another 5.5 MW is under implementation which is expected to be completed by June 2019. All the RTS projects are undertaken on RESCO model.

Table 5.1 provides the details of rooftop solar installation by Delhi Division, Northern Railway as of February 2019.

Table 5.1 Details of Rooftop Solar Installation by Delhi Division, Northern Railway

Sr. No.	Location	Station / Service building	State	Capacity (KWp)	Date of installation
1	Rohana Kalan	Station	Uttar Pradesh	10	January 2012
2	Diwana	Station	Haryana	10	June 2013
3	Bahadurgarh	Station	Haryana	20	November 2012
4	Bahadurgarh	Station	Haryana	10	June 2013
5	Gurgaon	Station	Haryana	25	January 2014
6	Gurgaon	Station	Haryana	7.5	September 2014
7	DRM Office	Service Building	Delhi	10	July 2013
8	DRM Office	Service Building	Delhi	32.5	October 2014
9	Delhi Cantonment	Station	Delhi	25	October 2014
10	Sahibabad	Station	Uttar Pradesh	30	October 2014
11	Rail Bhawan	Service Building	Delhi	10	October 2014
12	Baroda House	Service Building	Delhi	10	October 2014
13	Central Hospital	Service Building	Delhi	10	October 2014
14	NRWWO School Delhi Kishan Ganj	Service Building	Delhi	10	October 2014
15	NRWWO School Paharganj	Service Building	Delhi	10	November 2014
16	NRWWO School Tughlakabad	Service Building	Delhi	10	April 2015
17	RPSF Dayabasti	Service Building	Delhi	50	December 2015
18	EMU Car Shed Ghaziabad	Service Building	Uttar Pradesh	10	August 2016
19	Sonipat	Station	Haryana	10	August 2016
20	Panipat	Station	Haryana	10	September 2016
21	Baroda House	Service Building	Delhi	50	February 2017
22	New Delhi Platform No 2/3	Station	Delhi	140	May 2017
23	Sahibabad	Station	Uttar Pradesh	16	October 2017
24	Anand Vihar Terminal	Station	Delhi	800	October 2017
25	New Delhi	Station	Delhi	2,005	October 2017
26	Delhi	Station	Delhi	1,500	October 2017
27	Hazrat Nizamuddin	Station	Delhi	700	October 2017
	Total				

DRM: Divisional Railway Manager; NRWWO: Northern Railway Women Welfare Organization; RPSF: Railway Protection Special Force; EMU: Electrical multiple unit

Source: Delhi Division, Northern Railway

Project case study I: 5 MWp Solar Project at Four Stations over Delhi division, Northern Railway

Location	Anand Vihar	Old Delhi	New Delhi	Hazrat Nizamuddin
Capacity	0.8 MW	1.5 MW	2 MW	0.7 MW
Energy generation per month	1, 00,000 units	2, 00,000 units	2,50,000 units	1,00,000 units
Environmental benefit (reduction in carbon emission per month)	80 tonnes	160 tonnes	200 tonnes	75 tonnes
No. of installed solar modules	3,200 (Poly crystalline) (Sova Solar)	4,800 (Poly crystalline) (Sova Solar)	7,400 (Poly crystalline) (Sova Solar & EMVEE Solar)	2,800 (Poly crystalline) (EMVEE Solar)
Inverter	16 nos. of 50 kW inverters (Sungrow)	25 nos. of 60 kW inverters (Sungrow)	15 nos. of 50 kW inverters & 20 nos. of 60 kW inverters (Sungrow)	15 nos. of 50 kW inverters & 1 no. of 60 kW inverters (Sungrow)
AC distribution board	3	7	8	4
Compact secondary substation (CSS)	1 (ABB)	3 (ABB)	2 (ABB)	2 (ABB)
Installed CSS capacity	11KV, 1000KVA ONAN	-11KV, 600KVA ONAN -11KV, 675KVA ONAN -11KV, 600KVA ONAN	-11KV, 1450KVA ONAN -11KV, 1125KVA ONAN	11KV 625KVA ONAN -11KV, 250KVA ONAN
Metering System	Net metering			
Date of project award	October 20, 2016			
Date of commissioning	November 9, 2017			
Estimated annual cost saving	Rs 42.14 million			
Estimated reduction in carbon-dioxide emission per annum	6,082 tonnes			

As a part of National Solar Mission of India, Delhi division of Northern Railway awarded a tender under public-private partnership (PPP) model to Vivaan Solar Private Limited for manufacturing, supply, erection, testing and commissioning of total 5 MWp Solar Project at four stations over Delhi division – Anand Vihar, New Delhi, Nazrat Nizamuddin, and Old Delhi. The entire cost of project is Rs 374.5 million. The project was awarded on October 20, 2016 and was commissioned on November 9, 2017.

The Northern Railway set up solar rooftop plants of total 5 MW capacity at four stations over Delhi division – Anand Vihar, New Delhi, Nazrat Nizamuddin, and Old Delhi – with the objective of generating electricity for self-use. The power purchase agreements (PPAs) for the same have been signed between

Vivaan Solar and Northern Railway for a 25-year period at a tariff of Rs 4.14 per kWh. The PPA was signed on November 16, 2016. The entire cost of project is Rs 374.5 million. Vivaan Solar was responsible for manufacturing, supply, erection, testing and commissioning of total 5 MWp Solar Project including operation and maintenance (O&M) for 25 years at the four stations.

Annual solar generation from the project is 7.65 million units per year. The project has resulted in annual saving of Rs 42.14 million and reduction of 6,082 tonnes of carbon dioxide emission per year. Cost of per unit as per PPA is Rs 4.14 while cost of supply from discom was Rs 10.16 per unit, thereby saving per unit was Rs 6.02.

2 MW Rooftop Solar at New Delhi Railway Station

0.8 MW Rooftop Solar at Anand Vihar Terminal Station

Project case study II: 16 kW solar Roof Shelter/Shed at Sahibabad railway station on Northern Railway

Capacity	16 kWp
Location	Sahibabad Railway Station, Uttar Pradesh
Date of project start	June 2017
Date of commissioning	September 2017
Type of module	Crystalline Silicon
No. of modules	68 x 25 Wp
Inverter type	String
No. of inverters	1 x 16 KVA
AC distribution board	1
Estimated annual saving (units)	0.23 units (kWh)
Estimated annual cost saving	Rs 206,000
Estimated reduction in carbon-dioxide emission per annum	18 tonnes

Central Electronics Limited was awarded the contract to install 16 kW solar panels at Sahibabad railway station in Uttar Pradesh. For the first time, solar panels have been provided as shelter/shed at Sahibabad station on Northern Railway with a capacity to produce 16 kW solar power. This will reduce the cost of platforms and in addition provide solar power.

The solar array of solar plants has been installed in place of existing asbestos sheet at Platform No. 1 without base sheet. These panels play dual role of passenger shelter/shed and solar panels. The modules have been mounted on the roof of the existing shed with the help of specially designed structures. The generation of the solar power plant is being fed into the grid substation and consumed internally. Further proliferation of this system will be done on new and existing platforms.

16 kW solar Roof Shelter/Shed at Sahibabad railway station

16 kW solar Roof Shelter/Shed at Sahibabad railway station

Delhi Metro Rail Corporation

Delhi Metro Rail Corporation Limited (DMRC) is registered under Companies Act, 1956 with equal equity participation of Government of National Capital Territory of Delhi and Government of India to construct and operate a world class mass rapid transport system (MRTS). Currently, DMRC has an operational network of 9 lines with 250 stations covering a distance of 343 km in Delhi and National Capital Region (NCR).

The organisation takes all possible steps to preserve environment at all stages from construction to operation. DMRC was certified by the United Nations in 2011 as the first metro rail and rail-based system in the world to get "carbon credits for reducing greenhouse gas emissions" and helping in reducing pollution levels in the city by 630,000 tonnes every year. Delhi Metro has a daily peak power requirement of 150 MW, which is likely to go up to 250 MW after the third phase becomes operational. In order to reduce carbon footprints and to mitigate the impact of rising electricity tariffs, in 2014, DMRC decided to explore the possibility of using idle rooftops for harnessing solar energy to meet substantial part of the energy requirement.

Today, DMRC is the first ever metro system in the country to install rooftop solar power plants at its metro stations. The organisation provides an environment-friendly system to the city of Delhi and National Capital Region. As part of this endeavour, DMRC has set its solar mission, for which DMRC is installing solar (photo voltaic) power plants at various locations in the existing and upcoming networks of DMRC.

DMRC is planning to implement a total of 50 MWp solar PV plants by 2022 on flat/curved roof of the stations, train depots and other buildings of DMRC. As of February 2019, of the total 50 MW, 25

MW has been commissioned and another 10 MW is under implementation which is expected to be completed by July 2019. In addition, DMRC has signed PPA on April 17, 2017 for procuring 345 million units per annum for 25 years from 750 MWp ground-mounted solar plant at Rewa, Madhya Pradesh. Power flow is likely to start from April 2019. However, for this project, DMRC is navigating a lot of regulatory and procedural challenges.

All solar power plants pursued by DMRC are based on RESCO model, wherein the capital cost is invested by solar developer and DMRC has signed the PPA for 25 years. DMRC will only pay the energy charges for actual energy generated as per mutually agreed tariff. In this whole arrangement, no capital expenditure is borne by DMRC. The O&M by developers, helps in achieving better yield from the installed capacity.

On July 16, 2014, a solar policy was formulated with a plan to install 20 MWp capacity rooftop solar plants by August 15, 2017, and the target was achieved ahead of schedule in July 2017.

The solar PV power plant at metro stations of the Faridabad Corridor is a significant effort to install solar PV power plants at the construction stage itself, making it an integral part of the system of upcoming network of DMRC.

Project Case Study: 1.86 MW Rooftop solar installation on Depot and Station Roofs on Faridabad Metro Corridor

Capacity	1,860 kWp
Location	Faridabad Metro Corridor
Roofwise details	151 kWp on 8 stations, 200 kWp on Sarai station and 452 kWp on roofs of depot sheds and buildings
Energy generation	2.02 million units (2016-17), 2.06 million units (2017-18)
Solar modules installed	6,200 Nos., 300 Wp each (Poly crystalline)
Inverters	25 kWp – 68 nos. 30 kWp – 5 nos.
Date of project start	May 22, 2015
Date of commissioning	July 24, 2015; December 9, 2015 (Sarai station)
Business model	Renewable Energy Service Company (RESCO)
Environmental benefit	Saving in carbon-dioxide emissions: 1,920 tonnes (2016-17) 1,966 tonnes (2017-18)

In April 2015, Badarpur-Escorts Mujesar (Faridabad) stretch of DMRC, an extension of the already operational Violet Line (Line 6) between ITO and Badarpur was under advanced stage of execution and a decision was taken to install solar panels on the roofs of station and depot, before opening the line for public use. DMRC also decided to implement this corridor as a Green Corridor, with special green features. Finally, this Green Metro corridor was dedicated to the nation by Hon'ble Prime Minister of India on September 6, 2015.

This became the first metro rail corridor in the world to meet daytime auxiliary power requirement

from solar power and all its stations are rated 'PLATINUM' by Indian Green Building Council (IGBC). This is in line with the Government of India's mission on solar energy and to reduce carbon footprints as ratified by India by the enactment of the landmark Paris Agreement on climate change (COP 21).

Green buildings are environmentally efficient. Delhi Metro is building upcoming metro stations as 'green buildings' with specific provisions for conservation of energy as well as with enhanced water saving, waste management, energy management and with optimised building design to reduce size of station, in turn reducing use of construction material.

To protect the environment, DMRC has followed two-pronged strategy – to incorporate energy conservation measures during design stage and to tap the potential of renewable sources like solar. In this Green Corridor, special energy conservations measures such as LED-based lighting, regeneration features in elevators, V3F drive in escalators, maximise use of natural ventilation, day lighting etc. have been incorporated. Since Delhi NCR is blessed with 300 days of clear sun, it was also decided to provide solar PV plants on all stations and train depot.

DMRC has installed about 1.9 MWp capacity solar plant on the roof tops of the Green Faridabad Corridor. Efforts were made to integrate solar PV power plants with the station structures from construction stage itself. Installation of rooftop solar plants on curved/inclined roofs of Faridabad Corridor is an innovative initiative; no such plant existed on any metro/Railways either in India or abroad. The structures for mounting solar modules and features for accessibility to these difficult roofs were designed through application engineering and associated challenges were carefully navigated.

Besides being a successful model of clean energy generation, this initiative of DMRC has resulted in financial savings as well as in reducing carbon-dioxide emissions. This initiative of DMRC was shortlisted in Top 20 innovations for Prime Minister's Awards for Excellence in Public Administration for 2017 under Innovations' Category (Stage-1). The initiative was appreciated by national and international media, institutions and government agencies, thereby further enhancing the image of DMRC.

After the Faridabad corridor, DMRC has successfully commissioned various unique rooftop installations, like 1,575 kWp capacity roof-top solar plant on stabling shed at Najafgarh Depot (which is the single largest rooftop plant in Delhi), 505.90 kWp plant on parking area at Airport Line Depot of DMRC in Dwarka (single largest plant in parking area in Delhi NCR) and a 1,500 kWp Solar power plant on raised structure at elevated metro stabling lines in Jasola.

After the success of these projects, similar projects are now being taken up by Indian Railways, Kochi Metro, Chennai Metro, Lucknow Metro and Noida Metro.

Challenges and steps taken

DMRC has its own 33 kV power supply distribution network and the solar energy generated from rooftop plants is fed in the 415 Volts system. Generally, the entire solar energy generated from rooftop plants is consumed within the DMRC power network and no energy is exported to the grid/discoms.

Roofs of metro stations/sheds have curved/inclined roofs instead of conventional RCC roofs and have 25 kV overhead conductor below these roofs for powering the trains. These required special innovations for design of solar panels mounting structures and to create accessibility to these roofs. These issues were addressed by DMRC's team during design stage.

Moreover, below the station roofs, as 25 kV overhead conductor for providing traction power to the trains is available, therefore the roof tops can be accessed only after getting power shutdown during non-revenue hours (i.e. in night from 2 AM to 5 AM).

For module mounting structures, special requirements included the following:

- Suitable sealing arrangement with EPDM gaskets and silicon sealants were used.
- Module structure has been designed to withstand a wind load of 150 kmph (which is rare in Delhi) and pull-out tests have been conducted at site.
- Special arrangements using cage ladders and lifelines were provided to ensure safety of the personnel involved in installation and maintenance activities.
- Water supply and power points near the roof were provided for extending temporary power for cleaning of solar modules at night. The cleaning/maintenance of modules has to be done during power block in non-revenue hours from 2 AM to 5 AM.

Efforts were made to integrate solar PV power plants with the station structures of metro corridors which are under construction. In light of the Faridabad corridor, DMRC has so far been successful in the endeavour and is striving to make all future rooftops "Solar ready," i.e. fully equipped for installing solar panels/plants even at a later date. The facilities like ladders, life line, and plumbing arrangement for maintenance are being included in design of new constructions.

1.86 MW Solar Installation on Depot and Station Roofs on Faridabad Metro Corridor

Bangalore Metro Rail Corporation

Bangalore Metro Rail Corporation (BMRC) is planning to install 10 MW of rooftop solar in its stations and depots by 2025. The organisation will start installation of rooftop solar from 2020. It will initially start with installation of 2 MW on CAPEX model. The planned rooftop solar spread over area is 60,000 sq metres. Crystalline modules will be used. BMRC is planning to adopt both OPEX and CAPEX models. Installation of RTS in BMRC will result in cost saving of Rs 2 per unit.

Hero Future Energies Private Limited

Hero Future Energies Private Limited (HFEPL), which came into existence in the year 2012, is one of the leading independent power producers in the country. HFEPL is part of the Hero Group. Hero Solar Energy Private Limited (HSEPL) is the solar holding company of the Hero Group. It is 100 per cent owned by HFEPL. HFEPL has received an equity commitment of USD125 million from IFC and IFC GIF, which are World Bank Group companies.

In rooftop solar, the company has plans to implement 100 MW by 2018-19. The company is planning to build a robust portfolio of 3.5 GW by 2022.

HSEPL, through its 100 per cent subsidiaries, has an aggregate commissioned/implemented solar capacity of over 300 MW and has under-implementation/development projects with an aggregate capacity of about 500 MW. In total, the operational and planned capacity of HSEPL is over 800 MW, spread across a number of states and a number of contractors.

Project Case Study I: 884 kW Rooftop Solar Plant for Naavya Fashions

Capacity	884 kW
Location	Neemrana, Rajasthan
Date of project start	June 14, 2018
Date of commissioning	January 7, 2019
Business model	RESCO (OPEX)
Module type	Polycrystalline
No. of modules	2,720
Inverter	String inverters
Annual energy generation	13,26,000 units
Rooftop solar spread over area	11,000 sq metres
Cost saving per unit	Rs 2.50
Environmental benefit	Reduced carbon-dioxide emissions by 9,54,720 kg

The 884 kW RTS project faced certain challenges during project execution. The quality of water available at site was not conducive for module cleaning. A notable step taken by Hero Future was that it installed RO plant for enhanced O&M practice.

Another challenge was to make the site more conducive to the direction. Several trees in the location were casting shadows; consequently, trees had to be trimmed.

884kW Rooftop Solar Plant for Naavya Fashions

Project Case Study II: 2.67 MW RTS Plant at Kochi Metro's operation control centre at Muttom

Capacity	2.67 MW
Location	Kochi, Kerala
Date of project start	July 4, 2016
Date of commissioning	May 22, 2018
Business model	RESCO (OPEX)
Module type	Polycrystalline
No. of modules	8,580
Inverter	String Inverters
Annual energy generation	35,08,380 units
Rooftop solar spread over area	32,200 sq metres
Environmental benefit	Reduced carbon-dioxide emissions by 25,26,034 kg

Hero Solar won the rooftop project at a cost of Rs 5.51 per kWh of energy drawn, for the next 25 years. Kochi Metro Rail Limited (KMRL) has received a part of the Central financial assistance of 15 per cent of the total project cost for the rooftop project from the Ministry of New and Renewable Energy (MNRE). On July 5, 2016, KMRL and Hero Solar endorsed a PPA for 4 MWp of solar power, which comprises installation of solar panels on the rooftop of 22 metro stations and buildings in the metro yard. This is the first RESCO model project in Kerala. Under this model, Hero Solar will make the entire investment of nearly Rs 270 million, and take up O&M, while KMRL will buy power from the company.

The 2.67 MW RTS project for Kochi Metro faced some challenges during execution. These include power block unavailability during metro operations, safety constraints at each site, material storage at site, and installation work at top of station buildings in view of shed inclination, heights and lengths.

To address these challenges, Hero Solar coordinated with KMRL for in future dates of power block unavailability and scheduling accordingly. Safety nets, lifelines, ladders and walkways were deployed. Just-in-time (JIT) concept was followed reducing the number of days of storage at site. There was strict adherence to HSEPL safety manuals.

2.67 MW Rooftop Solar Plant at Kochi Metro's Operation Control Centre at Muttom

Vikram Solar Limited

Kolkata-based Vikram Solar Limited, a subsidiary of Vikram Group, was founded in 2006. The company's primary business focus is manufacturing solar PV modules. It also carries out engineering, procurement and construction (EPC) services and O&M of solar power plants. As of February 2019, the company EPC capacity portfolio comprised 950 MW including commissioned and under execution, rooftop and ground-mounted, and floating solar projects. Currently, Vikram Solar has a rooftop portfolio of 62 MW, of which 32 MW has been installed. The company has installed and commissioned projects in educational institutions, FMCG organisations, government buildings, airports, railway stations, and temples.

The company's manufacturing facility imports machinery and equipment from the United States, Switzerland, Germany and Japan. The company offers both business models – Capex and Opex. The CAPEX model is the most common business model for solar deployment in India.

Vikram Solar is the first company to build solar PV rooftop array on world's first 100 per cent solar powered airport - Cochin International Airport. It has commissioned India's then largest airport rooftop installation in Kolkata - 2 MW at NSCBIA (Kolkata Airport, West Bengal).

Project Case Study: 18.5 kW Rooftop Solar Plant for Century Ply, Kolkata

Capacity	18.5kW
Location	Century Ply (India) Limited (CPIL)- headquarter in Taratala, Kolkata
Date of project start	December 24, 2018
Date of commissioning	January 24, 2019
Business model	CAPEX
Module type	325Wp polycrystalline solivo modules with smart junction box and optimisers
No. of modules	57
Inverters	15 kW delta
Rooftop solar spread over area	160 sq metres
Annual energy generation	27 MWh per year
Environmental benefit	23 tonnes of carbon-dioxide offset annually
Cost saving per unit	Rs 3.5 per unit (can improve with increasing thermal and DISCOM tariffs)

Vikram Solar commissioned a rooftop solar plant for Century Ply (India) Limited (CPIL) at the company's new headquarter in Taratala, Kolkata, India. The solar plant has a capacity of 18.5 kW. The project is spread across 160 sq meters and 57 nos. of 325 Wp smart modules and a 15-kW delta inverter were used in the project.

For this project, Vikram Solar has used its optimiser integrated smart Solivo modules. Solivo modules can harvest more power through module-level power tracking technology, where each module can be optimised to decrease the effect of shading, soiling or mismatch loss. With facilities like "Rapid Shutdown" and "Smart Ready", Solivo smart modules can offer 30 per cent more yield, increased reliability, lower O&M costs, increased safety, and remote monitoring, making solar projects highly reliable. This is one of the four solar rooftop projects for CPIL that Vikram Solar has executed since 2018, adding solar capacity totalling in excess of 2.5 MW.

The project faced certain challenges during its execution. The roof was inclined towards North while the best roof alignment is East and West or South. Due to North facing roof, there was always a challenge of generation and string outage due to shadow.

To address this challenge, Solivo Smart modules integrated with Smart Junction Box and optimisers were used to improve generation under shadows and avoid string outage. The Solivo Smart module powered by Tigo is a special module, which comes with power optimiser. These Solivo modules run independently of each other, thus decreasing the effect of shading, soiling, or mismatch and increasing the total energy yield. Alert notifications enable one to proactively intervene early and maximise system up-time. This resulted in enhanced energy yield, maximised roof usage, and shade and age tolerance.

Further, the system could be remotely monitored by smart phone app in module level, PC/phone browser making O&M easier. This will help to remotely detect and diagnose performance issue. Alert notifications will enable to proactively intervene early and maximise system up-time.

18.5 kW Rooftop Solar Installation at Century Ply, Kolkata

5.3 Lessons Learnt

The solar PV modules are heart of the power plant and in order to generate maximum energy, it needs to be positioned at an optimum location. In India, the suitable direction for facing the solar panels is the South direction so that it can enjoy the maximum benefits of solar energy. Any variation in the placement (in terms of orientation and inclination) may lead to loss of energy (and hence money) which may consequently damage the modules (due to differential output within modules) in the long run. It is hence important to understand the placement of solar module in the power plant. More time and energy have to be laid upon site analysis. This will result in minimising engineering amendments and reduction of execution timelines. Safety concerns and policies need to be adhered stringently.

The orientation of solar module may be defined by two parameters -- azimuth and tilt angle. Tilt angle of solar module is defined as angle between the horizontal ground and the solar module. Azimuth angle of solar module is an indicator of alignment of the module with respect to (true) south. There are certain considerations required before installing the system in particular orientation and tilt. Firstly, increasing the tilt angle (and sometimes installing it at latitude angle) would lead to decreased shadow-free area at any given rooftop space. Such reduction would lead to significant reduction in capacity of solar power plant and reduced energy generation. It is therefore important to optimise the tilt angle to maximise energy generation while maintaining the performance of the plant. Secondly, while the south facing modules perform best, there may be various instances where due to constraints (for instance, a tall building in South direction) or an East-West building (where south facing modules may lead to reduced capacity and increased cost of under-structure), the modules may have to be placed East-West. While the energy output of East-West facing module decreases with an increase in tilt angle, the dust accumulation decreases with an increased tilt angle.

Government support with respect to policy is a major support for awareness as well as pushing initiatives towards the renewable space. Further, solutions are customisable as per client need and the technology is changing rapidly to cater to all customer needs.

5.4 CII Recommendations

Delayed payment by discoms: Typically, there is a delay of 7 to 8 months in bill payments by state discoms to the solar companies. Delayed payments by state discoms have put immense liquidity pressure on these companies who have to service large bank debts. Due to severe liquidity crunch, companies are unable to invest in new or existing projects. This impact credit ratings of solar companies, thus impairing their ability to raise capital from market and drying up of private investments. Several companies have to resort to financial restructuring.

According to CII, there is a need to introduce an institutional arrangement through which investors can be protected from uncertainties over bill payments by discoms. These include bill discounting by REC/Power Finance Corporation and backstop by state finance payments.

Issue of net metering restrictions for RTS, especially in the C&I segment: Net metering restrictions for RTS hinders and limits the growth of the rooftop segment in the C&I space. Some states have caps on plant sizes while some do not allow net metering for industrial customers at all.

According to CII, the government can help to create a conducive environment for net metering by more active engagement with the discoms. One of the major factors behind the relatively slow growth of the rooftop segment is the lack of support from the discoms. Growth in rooftop solar in both C&I as well as the residential segments can help to achieve the RTS target of 40 GW. Apart from employment during the construction phase, it is estimated that operation and maintenance (O&M) jobs in this segment can provide full time long-term (25 years) employment to about 150,000 skilled and semi-skilled persons.

Challenges in implementation of RTS in residential segment: There is a still a lack of awareness and less financial assistance provided to residential consumers for adoption of RTS in large scale. Apart from a tedious and inconvenient process for disbursement for the domestic consumer, this creates complications in market pricing.

CII recommends that four key issues need to be addressed to build consumer confidence and faster adoption of large scale RTS in the residential sector. These issues are:

- **Lack of single credible source of information:** At present, there is no single credible source of basic information that is independent or reliable for consumers. Basic information like how much rooftop area is required to generate a unit of electricity, who will provide after-sales service, what is covered by warranty and what isn't, how does one obtain net or gross metering benefits, how much time it takes to install a rooftop solar PV system, etc. are not available. There should be more awareness workshops that should be done by Government at state levels to make the consumers understand the benefits of RTS.
- **Disproportionate collaterals for finances:** Banks that offer finance for installation of rooftop solar PV systems often demand disproportionate collateral security, perhaps because of the absence of resale value of the systems. This need to be streamlined by the banks to ensure to build consumer confidence to setup RTS system in their residences.
- **Multiple levels of approvals for installation of meters:** There is a lack of clarity on net or gross metering benefits. There is a need for a single window approval in order to make installation of meters less time consuming for customers.

- **Removal of subsidy to the consumer:** CII recommends that the subsidy should to given directly to the discom instead of the consumer. This will simplify the process and lead to an uptake in all segments, including the residential segment.

5.5 Future Outlook of Rooftop Solar

The future outlook for solar sector looks sunny and bright in the near to medium term. With new schemes, both central and state, there is a huge push towards achieving the 100 GW solar target by 2022. India has a lot of solar radiation during the year which can be harnessed.

Over the past few years, the C&I segment has been way ahead of the residential segment in solar installations, including rooftop solar. However, with Government of India focusing on the residential solar to raise awareness and to involve common man into the fold, residential solar adoption has picked up recently.

According to solar developers, the C&I segment will continue to dominate rooftop solar in the next 2-3 years. However, residential rooftop solar and storage as well as RTS projects are likely to pick up. Residential solar capacity, which is currently at 130 MWp, is expected to go 10 times higher and beyond the current capacity within the next couple of years. Government policies need to be more supportive and a lot more proactive, supporting developers and manufacturers to fully cater the growing need. Millions of households can benefit with improved rooftop schemes and the right subsidy support. The recent cabinet approval of Phase II of the grid-connected rooftop solar programme for achieving the 40 GW RTS target with a focus on residential rooftop solar installation is a welcome step in this regard.

In terms of business model, the RESCO (OPEX) model has started picking up pace as it is becoming one of the promising solutions to address several barriers to scaling rooftop solar PV. According to the industry, this model is expected to dominate the rooftop solar market, considering the benefits to consumers in terms of no upfront capital and installation cost as well as the elimination of operational risks and management services.

Acronyms

CFA	Central Financial Assistance
C&I	Commercial and industrial
DMRC	Delhi Metro Rail Corporation
GoI	Government of India
HFEPL	Hero Future Energies Private Limited
IR	Indian Railways
MNRE	Ministry of New and Renewable Energy
MoR	Ministry of Railways
MoUD	Ministry of Urban Development
O&M	Operation and maintenance
PPA	Power purchase agreement
PSU	Public sector undertaking
RE	Renewable energy
RESCO	Renewable Energy Service Company
RPO	Renewable purchase obligation
RTS	Rooftop solar
SECI	Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SPV	Solar photovoltaic
SRISTI	Sustainable Rooftop Implementation for Solar Transfiguration of India
UT	Union territory

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Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering industry, Government, and civil society, through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has around 9000 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 300,000 enterprises from around 265 national and regional sectoral industry bodies.

CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

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