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**Working Paper**

## India's ongoing rooftop solar journey 2017-2022

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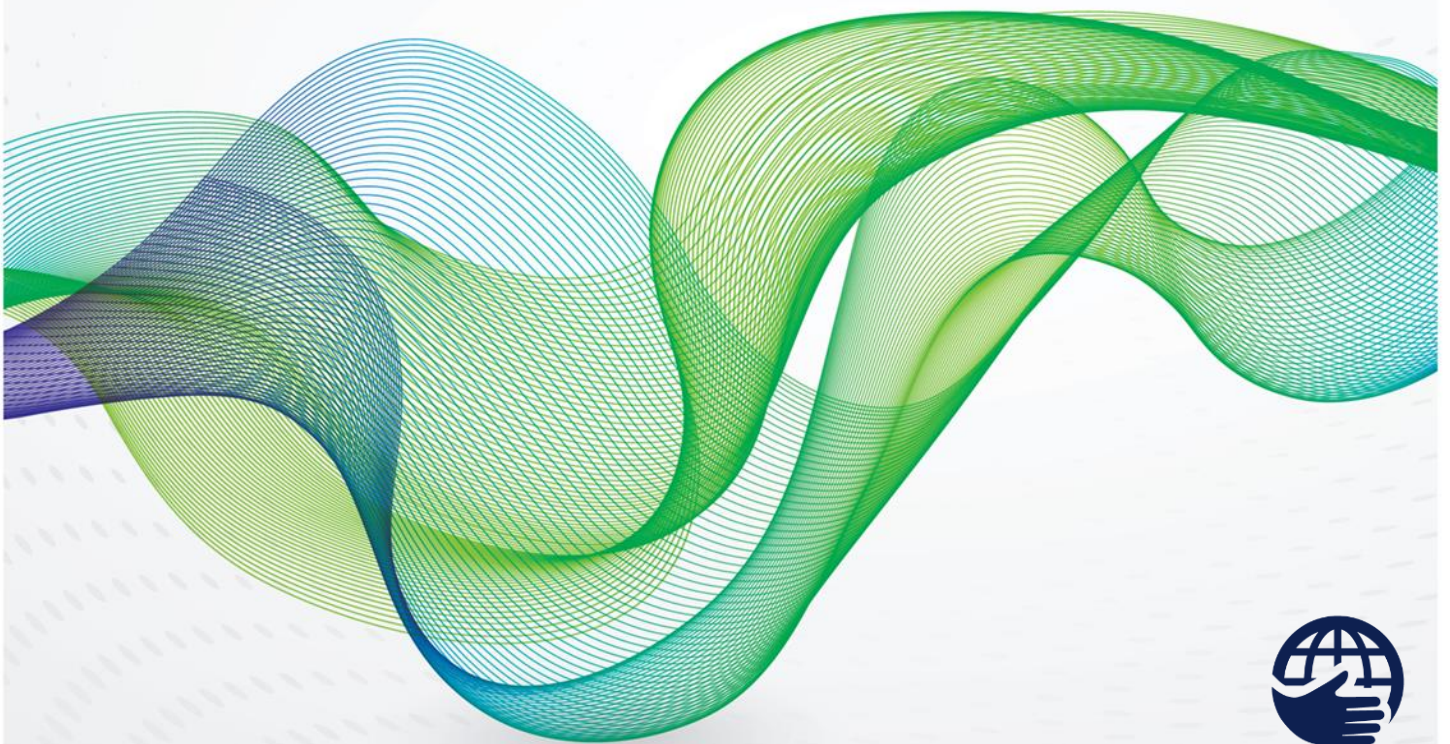
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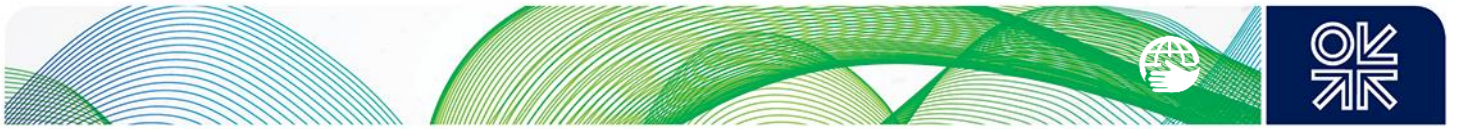
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November 2022

# India's Ongoing Rooftop Solar Journey 2017–2022



Energy  
Transition



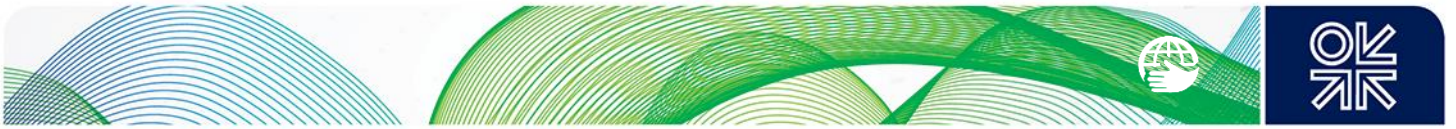
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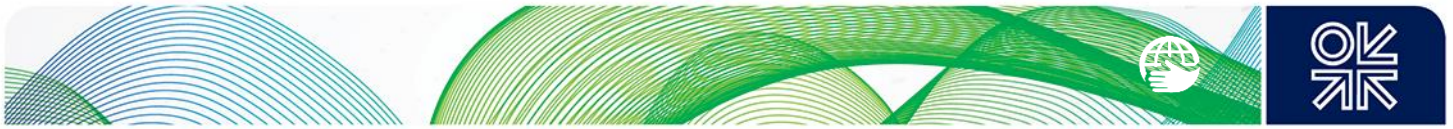


## Abstract

India is often taken as a microcosm for much of the developing world because people living in many different circumstances in the country are representative of what is found in large parts of the developing world. This is particularly relevant for clean technologies that are consumer-led and therefore require an upfront financial contribution from consumers, such as rooftop solar which is the subject of this paper.

India's early experience with its nascent rooftop solar market has revealed two significant barriers to market growth that are directly linked to (i) equity and political economy factors and (ii) institutional factors in the electricity distribution sector. Unlike ground-mounted solar, rooftop photovoltaic (PV) requires individual consumers to make an investment in the hardware. The affordability of clean technologies is still a major issue in India, even though global rooftop PV prices have been tumbling over the past decade and rooftop PV is one of the most mature technologies. As a result, only the richest commercial and industrial (C&I) consumers have access to rooftop solar under the initial support schemes. In addition to equity, the institutional role of the electricity distribution sector in the growth of the rooftop sector is another barrier. The electricity distribution tariffs in Indian states are used as an income redistribution tool. The political economy of this aspect is very sensitive, and the central government's role is limited since the electricity distribution sector is controlled by the elected governments in each of the 28 states. Furthermore, distribution companies (discoms) are bundled meaning that in addition to owning and operating distribution grids, they are retailers responsible for customer service delivery and payment collection. As the growth of grid-connected solar rooftops could affect the financial viability of these companies, they have a tendency to resist or slow down penetration of rooftop solar PV, unless incentives are provided, enabling discoms also to benefit from the deployment of these resources. The best solution to reforming the distribution sector and possibly privatizing discoms is unlikely to happen in the near future. Therefore, second-best solutions must be identified in order to move ahead with rooftop installations and achieve targets for deploying these resources in order to advance the clean energy transition.



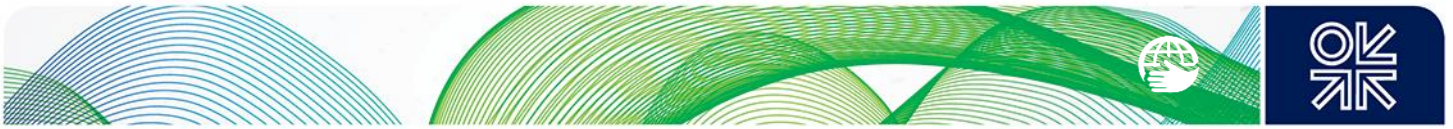


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## 1. Introduction

Like most developing countries, India still has an unfinished energy security agenda that is needed to power its economic growth ambitions. It seeks, at the very least, to double its per capita energy consumption by 2030. Today, India's annual average per capita energy consumption of 1,100 kWh is less than a quarter of the global per capita annual average consumption of 4,500 kWh. India also has ambitions to meet the 17 United Nations Sustainable Development Goals (SDGs) by 2030, and to decarbonize its economy. Meeting the SDGs and pursuing its GDP growth target requires increased energy consumption, which should preferably be clean and affordable.

Rooftop solar<sup>1</sup> reduces the need for centralized generation, which is land intensive. This is important in a densely populated country with many competing uses for the limited expanses of open land suitable for ground-mounted solar projects. Decentralized generation also reduces the need for new investment in transmission and distribution network capacity since electricity is generated at the point of consumption.

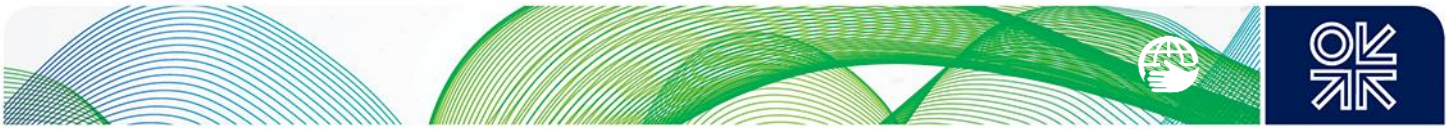
End-user electricity bills are also reduced as customers are able to consume a portion of their electricity requirement from a source that does not require a costly and recurrent fuel input such as coal, natural gas, or diesel. Rooftop solar therefore appears to be a perfect solution to increase per capita energy consumption and improve affordability for end users. It is a mature technology with falling costs and presumably well suited to developing countries, many of which have more than 300 sunny days a year. Yet it turns out that very few countries, apart from the G-7 economies and Australia, have been successful at establishing a well-functioning, consumer-led grid-connected rooftop solar sector. This paper will investigate some of the hidden challenges developing country power sectors face in introducing decentralized generation through rooftop solar, with a focus on India.

Since 2016, India has been a rare example of a developing country that has joined the small global group of rooftop solar aspirants by including an ambitious rooftop PV target of 40 GW as part of its clean energy transition strategy. The Indian Government's challenge for any part of the clean energy transition is how to make it affordable and relevant to the 800+ million poor people in a country of 1.3 billion. The first five years (2016–2021) of Indian rooftop PV sector experience demonstrated to the government that it was the most well-off electricity customer group (commercial and industrial, or C&I, customers) which helped to catalyse the Indian rooftop market, again underlining the limited affordability for mainstream consumers.

Despite its per capita income still being a small fraction of that of its rooftop solar peers, India is currently attempting the world's largest clean energy transition among developing countries, using its own public funds and commercial borrowing. It is doing this while also pursuing the SDGs and developing home-grown clean-tech manufacturing capabilities in giga-factories. Pursuing the manufacturing of clean technology is relatively recent. Up to around 2020, most solar technology, including panels, inverters, controllers etc., were imported, mostly from China. Indian solar developers were taking advantage of falling hardware prices in China and submitting aggressive bids offering low tariffs in public tenders. Now, since 2021, India is seeking to boost the domestic manufacturing of a wide range of clean technologies (including battery energy storage) through elaborate fiscal incentives known as production-linked incentives or PLIs. These are offered to domestic and foreign investors as part of its

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<sup>1</sup> This paper refers only to grid-connected rooftop solar. By 2019, India had connected 99.8 per cent of households to the grid. Off-grid, stand-alone solar home systems are used only in very limited settings to provide electricity to remote communities where grid extension is not possible. An interesting development is that commercially operated, privately owned solar mini grids are appearing alongside the grid in some rural areas. Their target market (because unit costs per kWh are many multiples of the public grid tariff) consists of mainly rural business/commercial customers who prefer the greater reliability offered by private providers. In other words, they are prepared to pay a hefty premium for reliability. Some rural shops and businesses subscribe both to the public grid and a private solar mini-grid, and essentially use it as a backup. Others have invested in a bank of lead acid batteries which they keep fully charged with (cheap) public grid electricity when available and use it as an essential backup power supply when the grid has outages, which are frequent in rural areas. For the Ministry of New and Renewable Energy, the terminology 'rooftop solar' means a grid-connected, and not off-grid, rooftop solar system.



updated industrial policy. Achievement of the 60 GW target for ground-mounted, utility-scale solar is progressing ahead of schedule. The 40 GW target for rooftop solar is far behind; rooftop solar achievement stands at only 25 per cent of the target.

The objective of this paper is to attempt a deeper dive into the Indian rooftop sector, and to understand why the national target of 40 GW is lagging, with only 10 GW installed so far. What are the emerging lessons from the first few years of the government's grid-connected rooftop solar programme? The paper will also ask what is being done to improve rooftop solar adoption performance based on these learnings, and what are the prospects of making satisfactory progress in achieving the national rooftop target of 40 GW even at a delayed date.

Section 2 will discuss the historical background and summarize the lessons learned in terms of the two distinct phases that characterize India's rooftop journey of the last five years, 2017–2022. Subsequent sections of the paper will examine the two principal barriers that have emerged to slow down the sector's growth and will present the different business models that deal with each. Section 3 will discuss details of the affordability barriers and how they are being addressed. Section 4 will discuss details of why some state-owned distribution companies (discoms) have sought to 'block' or delay the growth of the Indian rooftop solar sector since 2019. It will also review the new policies and schemes introduced by the central government specifically to deal with the concerns of discoms about rooftop solar. Section 5 presents conclusions and thoughts on the way forward to reach the 40 GW target, even though it will be delayed by several years.

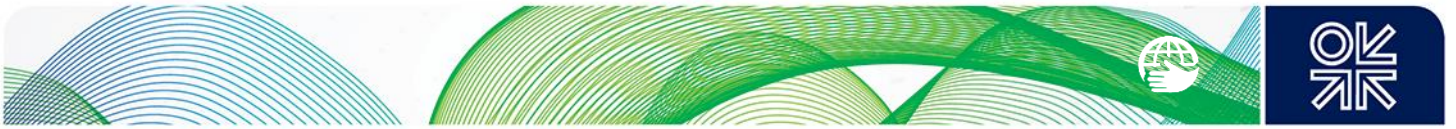
## **2. Historical background: two distinct phases in India's rooftop solar story from 2017 to 2022, and the arrival of the residential consumer on policymakers' radar**

Two distinct phases are noted in the Indian Government's rooftop solar support strategy so far. The first phase of the grid-connected rooftop PV programme was focused on promoting rooftop PV adoption by commercial and industrial (C&I) customers, who are considered the most creditworthy and profitable market segment by the commercially oriented, private rooftop suppliers and ecosystem players. The second phase (from mid-2019 to present) shifted away from C&I and focused heavily on residential consumers.

### **Phase 1: 2017–2020**

Phase I sensitized the market and raised overall awareness of rooftop solar, allowing potential adopters to decide whether it was a sound and credible investment or not in the Indian context. It also succeeded in building a competitive solar rooftop ecosystem in terms of installers, investors, lenders, and vendors, who all saw a commercial role and business opportunity for themselves. Phase I also demonstrated the third-party ownership or Renewable Energy Service Company (RESCO) model, also known as the operating expenditure (OPEX) model or 'rooftop solar as a service'. Details on this are provided in Part 3, which covers business models that have spontaneously arisen to cater to India's unique customer segments.

Indian policymakers found that in 2015 no commercial bank was willing to lend for this grid-connected clean technology, as it was still unproven in India. Bankers openly stated that it was far easier and faster for them to approve a large loan for a coal plant at that time, than to grapple with small, 'troublesome' loans for a rooftop solar plant for which there was 'nothing to go by'. Therefore, shortly after the Paris Agreement in December 2015, the Indian Government borrowed US\$1 billion with a sovereign guarantee from the World Bank and the Asian Development Bank for its rooftop solar programme. It designated two large Indian public-sector commercial banks to channel these internationally sourced funds to the market to be used exclusively for the installation of rooftop solar capacity. The rooftop programme would be designed and supported with grant-funded technical assistance support from the Global Environment Facility, which was channelled through the World Bank.



The Ministry of New and Renewable Energy (*MNRE*) policymakers' intention was to see how the rooftop market would develop with the injection of the government's dedicated multilateral funds that the market had been unwilling to provide. Money would be accessible to qualified private sector stakeholders, channelled through two designated banks, to buy/import the rooftop technology hardware. The Ministry's role consisted of ensuring that the usual grid-related regulations and incentives (in this case net metering) were in place in most of India's states.

The market development programme was a great success, and rooftop installations exceeded the World Bank-supported rooftop programme's targets ahead of schedule. But policymakers became alarmed after just two years, when only the richest commercial and industrial (C&I) consumers were found to have access to rooftop solar under the newly started market development programme. This was a direct result of the market-led arrangement for Phase 1, in which only designated commercial banks had been entrusted to decide which applicants would qualify for loans. Naturally due to risk aversion, they restricted their loan approvals to the strongest credits and largest C&I names.

As a direct result of the techno-economic approach that was being followed, to encourage participation of the commercial lenders, there was probably no entry point for 'equity considerations' in the early rooftop programme. This applied even to mid-level C&I or middle-income residential consumers who were all excluded by the commercial lenders' credit committees, not to mention the vast majority of the low-income population of 800 million people, or even small and medium enterprises. The commercial stakeholders running the programme on the ecosystem side (rooftop installers, equipment vendors, system integrators), as well as the commercial bank that was allocating the government's borrowed money, together all cherry-picked the highest rated C&I credits and facilitated only their access to the preferential funding.

The Indian electricity sector has built-in income redistribution objectives. This sector consists mostly of state-owned distribution utilities and an electricity regulator for each state. C&I customers are charged more than it costs to serve them, and residential and agricultural customers are charged much less. C&I customers effectively cross-subsidize the other categories. As a result of higher retail tariffs that they must pay for grid electricity, C&I customers throughout the country always have the highest potential savings from any number of units of avoided discom grid purchases. Therefore, this group has the strongest commercial justification to invest in rooftop solar due to the relatively short payback period for the investment.

In a lifetime 'cost of ownership' calculation, the electricity tariffs avoided by leaving the grid are the highest for C&I. Hence the number of years in which they will recover their initial investment outlay is the shortest. However, the actual savings from avoided grid purchases will depend on the rooftop system's size and solar generation as a percentage of the total load. The available rooftop space, and the state's policy and regulation in terms of what percentage of the rooftop solar system capacity is allowed relative to the customer's connected load, will have an impact on the savings made from the grid. Figure 1 illustrates sample C&I rooftops in India for a factory (industrial customer) which has covered every inch of available space and a hotel (commercial customer) which has not.

The first two years of experience with rooftop solar in India revealed that the situation in the residential market was not promising. Rooftop solar service providers (from the ecosystem) in some cases had refused to do business with residential customers, citing high transaction costs and low creditworthiness, while commercial lenders were not willing to offer rooftop solar loans to residential customers. Lenders considered such loans too risky and claimed that they had insufficient information on residential borrowers and rooftop systems. This is a major factor in why residential rooftop solar systems were crowded out in Phase 1. The nascent rooftop sector players flocked to the "low hanging fruit" of attractive C&I customers first.

In addition to barriers from lenders due to their risk-aversion (because rooftop solar was a new introduction and therefore lending track records in India were not available), the resistance to rooftop PV from electricity distribution companies (discoms, which is how distribution utilities are commonly referred to in India) also became clear during Phase 1; this can be thought of as 'the C&I phase' from





the start of 2017 to late 2019.

**Figure 1: Examples of C&I rooftops: factory (industrial) on the left and hotel (commercial) on the right<sup>2,3</sup>**



After the first two years of rooftop PV implementation experience, and witnessing the steady outflow of their best C&I customers (the strongest credits), a rebellion started inside many of the discoms. Their prized customers were migrating towards rooftop PV investments that cut into electricity purchases from the discoms. On top of this discom pain, net metering systems allowed by state regulators deprived discoms of precious revenues even for the units that C&I customers did buy. By 2020, discoms succeeded in changing the initial set of rooftop policies and regulations that had been announced under Phase I and which had previously been generous to all customers including C&I.

These were the two most unwelcome ‘eye-openers’ for MNRE, signalling time for a change:

- The reluctance of commercial lenders to deal with residential (and other non-C&I) customers, and hence the lenders’ de facto ability largely to determine and influence the composition of who would have access to the rooftop market.
- The behaviour of discoms, to ‘kill off’ the rooftop programme.

The market-led, hands-off approach was ending, as MNRE officials and policymakers realized that rooftop PV was never going to go mainstream and reach small consumers, or the 40 GW target, without their active intervention and direction.

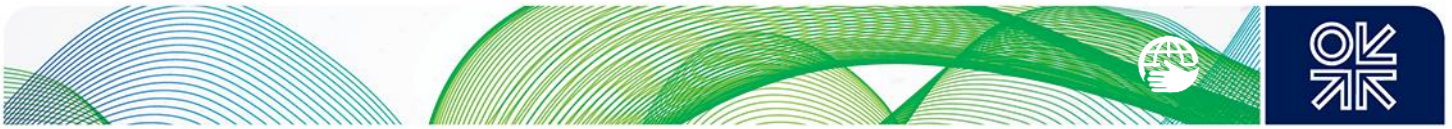
Another lesson was that even a 40 per cent upfront capital subsidy was not enough to ensure affordability and remove the need for most consumers to take out loans. Mainstreaming looked very far away until Phase II was formulated. Only the strongest C&I companies were enjoying large savings on their electricity bills from rooftop solar, and everyone else appeared to be locked out in Phase I.

MNRE policymakers had started to realize that apart from taking away ‘un-needed’ subsidies and incentives from the high-end C&I companies (who would probably have invested without a penny of government money from around 2018 onwards), the Indian rooftop programme also required active and enthusiastic cooperation from discoms.

MNRE had to find some value-adding role that discoms could play, instead of being opposed to rooftop PV in principle. The electricity customers who were rejected by commercial lenders were exactly the ones that MNRE wanted to reach for equity reasons (small, low consumption low income, or LCLI, in the residential category). These were also exactly the cross section of electricity consumers that discoms had already dealt with for years. Not only that, but discoms were also sitting on a wealth of financial information about them (who pays electricity bills on time, how much are their bills, who pays in full, who pays in advance etc.). The banks may have been lamenting that these consumers had very

<sup>2</sup> <https://www.pv-magazine.com/2021/07/28/commercial-and-industrial-rooftops-in-india-could-deploy-1875-mw-of-solar-in-2021/>

<sup>3</sup> <https://mercomindia.com/top-states-rooftop-solar-installations-infographics/>



high transaction costs, had no credit ratings and were therefore unacceptably risky, but the discoms' years and years of monthly granular data on payment history could in fact be better than credit ratings.

## Phase 2: 2019 to the present – government shifts the focus to residential rooftops

The second phase of India's grid-connected rooftop journey (mid-2019–present) was specifically designed by the MNRE to shift away from C&I and focus heavily on residential consumers. This group had been largely left out in the first phase (except for a handful of very high-income, separate houses).

Phase II was defined by a set of sharp regulatory and policy changes by government authorities seeking to move beyond the market 'elites' (C&I) and attempting to mainstream rooftop solar, above all to create space for tens of millions of residential customers. As it turned out, this was easier said than done because discoms were also demanding to be heard.

With this in mind, and a determination to form a win-win alliance, MNRE actively engaged with discoms to try and address their concerns and see how to alleviate them. This was the core of Phase II, developed in full consultation with a selection of state discoms. In March 2019, the government announced the soft launch<sup>4</sup> of Phase II of its Grid Connected Rooftop PV Program,<sup>5</sup> which contains specific financial and other incentives for discoms.

Phase II is strongly geared towards residential consumers, who require much smaller rooftop systems than C&I consumers. The capital subsidy which had previously been open-ended in terms of system size, was fine-tuned and eligibility was restricted:

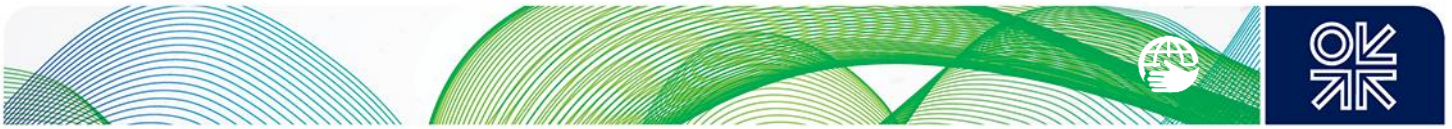
- In Phase II, the 40 per cent capital subsidy would only apply to the cost of a 1–3 kW system. For the remainder of the rooftop system, the subsidy would be 20 per cent, with a cut-off point at 10 kW. Any system larger than 10 kW would not be eligible for the capital subsidy.
- This low limit effectively excluded the entire C&I target market so favoured by the lenders, and it directed the government-funded subsidies mainly to small residential customers.
- In recognition of the commercial lenders' complaint that there was no information about the creditworthiness of residential customers, as well as extremely high transaction costs, governments created a central role for discoms to partner with lenders and provide some of the missing information as discoms did in fact have large amounts of data on residential customers.
- MNRE realized that discoms also interacted with customers every month to receive their electricity bill payments and could easily and with little effort—for a fee—perform that administrative service (loan instalment collection) for a commercial lender, simply by including the loan repayment amount as an additional line item on the monthly electricity bill. This would remove the argument of very high transaction costs and the banks' reluctance to deal with residential consumers on a solar energy asset.

Phase II of the central government's rooftop PV programme effectively put discoms in charge of facilitating rooftop PV for their customers, especially the smaller customers who had previously been locked out. Discoms could also provide guidance on which geographical areas of their cities to pursue as the most suitable for rooftop PV, based on the discoms' knowledge of their own network conditions. Knowing how cash-strapped many state discoms are, the government also created another financial incentive for discoms to cooperate in growing the rooftop sector. This was done by letting discoms earn a transaction fee for each administrative task, as well as an overall commission based on rooftop project size, if discoms were also conducting competitive rooftop PV tenders on behalf of their price sensitive residential customers.

This was a win-win approach as it also benefited rooftop developers and installers. By taking part in a discom-operated tender for consumers in a geographical urban cluster, developers could compete on price to install rooftop solar systems for thousands of customers at once. This was much better than

<sup>4</sup> <https://mnre.gov.in/img/documents/uploads/7ccd3b4b3bb94a51af516e2ee4fdede3.pdf>

<sup>5</sup> <https://solarrooftop.gov.in/>

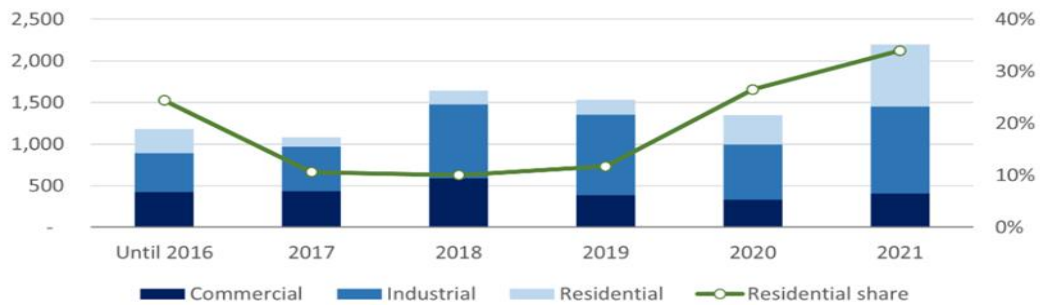


having to undertake slow and expensive customer acquisition one customer at a time. Discoms also realised that the larger the rooftop programs they would allow to connect to their networks, the higher the transaction fees they stood to gain.

The pandemic has slowed down the implementation of Phase II, which is only now gaining momentum at the end of 2022. State discoms have to “opt into” this Phase II of the MNRE grid-connected rooftop programme, since their commissions, incentives, and tender-management fees are all funded by the central government. A few of them have already done so. More discoms are expected to join.

Figure 2 below shows that there has been somewhat of a pivot to residential customers, even if it is slower than expected.

**Figure 2: New rooftop installations by consumer segment in MW, and indication of growth in residential share<sup>6</sup>**



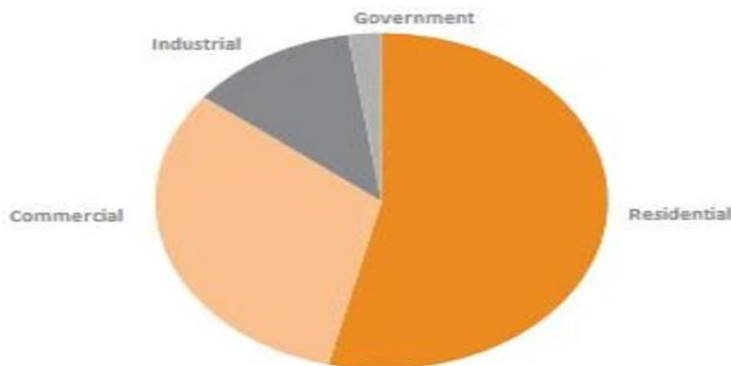
Source: BRIDGE TO INDIA research

Note: The unit on the left vertical axis is MW and the right vertical axis is the percentage of total customers)

Figure 3 further confirms the trend by highlighting Q3 2021 and showing that the residential sector attracted a large share of rooftop installations after the government’s policy change. This would have been unthinkable in Phase I (2017–2020), and it seems to indicate that the market is maturing, the ecosystem has expanded, more banks are participating and, most importantly, residential customers have gained a new status and attractiveness thanks to the policy changes introduced in Phase II.

**Figure 3: Indian residential customers are gaining a greater market share in Q3 2021<sup>7</sup>**

**Q3 2021 Rooftop Solar Installations Breakdown**

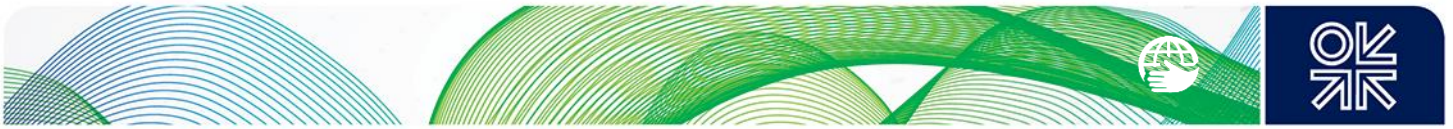


Source: Mercom India Research (Sep 2021)

<sup>6</sup> <https://bridgetoindia.com/residential-segment-perks-up-rooftop-solar/>

<sup>7</sup> <https://mercomindia.com/india-installed-rooftop-solar-9m-2021/q3-2021-rooftop-solar-installations-breakdown/>





### 3. What was the affordability barrier and what happened in terms of business models in the C&I rooftop market?

As noted earlier, in recognition of the banks' reluctance to lend for an unfamiliar technology, and in order to lower the cost of entry for a rooftop solar system, the central government offered a 40 per cent capital subsidy for all rooftop solar investors acquiring 'Made in India' solar panels. Despite this reduction in the acquisition cost of rooftop solar, most individual consumers—possibly due to low per capita incomes—were not able to purchase rooftop solar systems even at 60 per cent of the market price without an accompanying low-interest loan.<sup>8</sup>

For the first few years, rooftop PV systems thus remained unaffordable to most Indian consumers except for highly rated C&I borrowers. One of the most striking 'key takeaways' is the lesson that in low-income countries it is imperative to have affordable credit in place at the start of any clean technology programme. This is required for all the intended target groups, whenever any consumer-led clean technology is proposed to be mainstreamed as part of the energy transition.

The other side of the affordability barrier for rooftop solar is related to the low grid tariff rates paid by residential customers in states with long-unchanged tariff structures. Most of them were commercially better off just continuing to pay low tariff rates to the grid and not investing in rooftop PV—even if they had hypothetically qualified for a loan to invest in a rooftop solar system. Rooftop PV would be more expensive for heavily subsidized residential consumers, in terms of the net present value of their hypothetical debt service costs. This observation was particularly applicable to a customer group called Low Consumption Low Income, or LCLI.

Since the regulated tariff structure and built-in subsidies and social tariffs allowed subsidized categories of consumers to pay rates that were far below the discoms' cost to supply them, small LCLI customers were in fact 'saving money' by remaining with the grid.

At the same time however, the discom was 'losing money' by having such customers on its books. The discom had to purchase bulk thermal power, incur high transmission and distribution (T&D) losses and deliver electricity at a relatively high cost to itself, but would recover only a fraction of that in revenues earned from these small customers due to their low tariffs. In fact, it would be beneficial to the discoms if such loss-creating customers could be supported to switch over to rooftop solar at least for their daytime requirements. Even if they only purchased subsidized electricity from the discom for their night-time requirements, it would measurably cut the losses of the discom, provided this could be done at scale for millions of small and subsidized customers.

In the last six years, there has been much engagement by the government on discom finances in the country, specifically the very high financial deficits and many discoms' need for large and growing operating subsidies from state coffers.

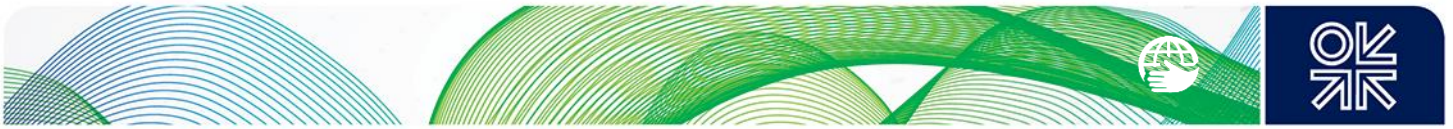
As a part of this intense focus, and two very large bail-out programmes funded by the central government,<sup>9</sup> many state politicians have reluctantly agreed to update their discoms' tariffs (although usually not to full cost recovery levels) to reduce the state's subsidy burden. This in turn has resulted in residential grid-electricity tariffs also being increased. The coronavirus pandemic has stretched state finances and diverted subsidies to many other areas.

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<sup>8</sup> The loan would allow them to make a 30 per cent down payment on the residual 60 per cent of the market price after the subsidy and borrow the rest. In effect this meant that the cost of entry was lowered to 18 per cent of the overall sticker price of the rooftop system if the customer could obtain a loan. Without the loan, the customer would be out of pocket for 60 per cent of the cost, with the government picking up the remaining 40 per cent. In practice, the government's 40 per cent capital subsidy was administered on a reimbursable basis, available only on concrete proof of rooftop solar installation. This was done to prevent abuse and promote transparency and governance. The result was that consumers would have to pay in full at first, either from their own or borrowed funds, in order to claim the subsidy which would arrive in their bank account after a gap of around six to nine months.

<sup>9</sup> The two centrally funded bailout programmes are known as UDAY and RDSS.





Because of rising electricity bills everywhere, even for previously cross-subsidized groups, (who are residential but are not included in LCLI because they do not receive the same amount of subsidy, in other words, e.g 200 kWh free per month), rooftop solar is now becoming more attractive to other consumer categories apart from C&I.<sup>10</sup>

Third-party business models had spontaneously emerged for C&I consumers in Phase I. The question is whether they can be extended to Phase II for residential consumers.

Some C&I customers purchased their rooftop systems with a single upfront payment in full. This was the CAPEX or Capital Expenditure model. The asset was reflected in their balance sheet along with their machinery and other hardware. Some CAPEX customers took a loan and some paid in cash up front, but if the C&I customer was willing to own the rooftop system outright, this was the CAPEX model. It was in fact the only business model before the government tried to introduce others, as discussed below.

It turned out that not all creditworthy C&I customers who were in search of rooftop solar were keen to take on a loan, or to own rooftop solar systems outright, even if they met the stringent creditworthiness criteria laid out by the designated bank for running the World Bank-supported program, which was the State Bank of India (SBI). This subset of C&I customers instead wanted to preserve their financial resources and borrowing power for the working capital needs of their business and were hence keener to use their credit facilities to finance their core business. They wanted to 'use' a rooftop solar system and take the services, but not to clutter their balance sheet with outright ownership of a non-core asset. Third-party rooftop specialists and investors looking for new opportunities started to take notice. Thus, the third-party financing model emerged in response to customer needs (also known as the OPEX model, or 'rooftop solar as a service'). The OPEX model and the multiple business models that are derived from it, have been a hallmark of India's rooftop solar sector.

The details of these business models are provided in the appendix.

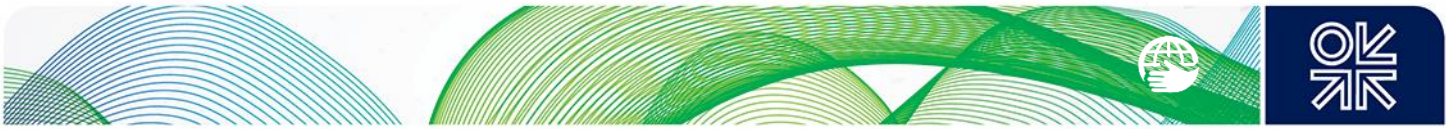
#### 4. The role of discoms in India's rooftop solar sector

The setting in which India's rooftop sector launch and growth activities are being implemented is important and helps to explain the two distinct phases of the rooftop journey so far. India has 28 states (like the 27 members of the European Union or the 50 states of the US). Each state also has its own electricity distribution company (and its own transmission company for transmission inside the state boundaries) as well as its separate electricity regulator. Under the 'One Nation, One Grid' policy in India, there is a central government owned interstate national high voltage transmission grid owner and operator (Power Grid Corporation of India Ltd, or PGCIL). PGCIL operates the interstate transmission system which delivers electricity from surplus to deficit areas of the country. Essentially there are 28 electricity markets in the country.

The governance of the Indian electricity sector is carried out jointly by the central government and the state governments. Each Indian state has its own electricity policy, incentives, and rooftop regulations, which is also like the EU and US.

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<sup>10</sup> There is a parallel between rooftop solar and EVs, both having attracted mainstream attention in India due to the pandemic, which caused pricing realignments that raised the popularity and speed of adoption of these two clean technologies. First, for rooftop solar: after the pandemic, some states were forced to increase electricity tariffs due to the unaffordability of the legacy levels of high electricity subsidies the state governments had been funding for certain categories of consumers. Rising grid electricity prices in turn are making rooftop solar systems more attractive for consumer categories who were previously not in the target market because they were heavily subsidized and grid prices were cheaper for them. Secondly, for electric vehicles: also as a result of the pandemic, India sharply raised petrol and diesel prices, and this in turn started to raise consumer awareness about the growing attractiveness of electric vehicles. In both areas, it is probably fair to say that the unexpected outcomes of the coronavirus pandemic played a role in waking up large new groups of customers to the pros and cons of clean technologies. It probably happened much more effectively and speedily than the government's previous efforts at promoting clean technologies. The pandemic caused faster price realignments than the usual consensus-seeking systems that are slow, political, and give a voice to all groups in India.



The central government (Ministry of Power, MoP, and Ministry of New and Renewable Energy, MNRE) can only recommend activities to states, and it can also design a set of national reform or investment programmes with financial incentives for which all states are eligible. However, the respective state government ultimately decides whether it wishes to join the programme (opt-in), undertake the supported reforms, meet the requirements, and choose to access the incentive or investment money from MoP or MNRE. For any reform, or any national initiative adopted by the central government (such as energy conservation or rooftop solar), the policy is ‘communicated top-down (in other words, from the central ministry), but implemented bottom-up’ (at state level, one by one).

Basically, for energy sector activities which occur entirely within the geographic boundaries of a particular state, the central government mostly takes a back seat. It operates through dialogue and persuasion, in training workshops by issuing memos and calling consultative meetings with discoms and state power ministry officials. Another recent example of this is the Energy Conservation Act that was updated in 2022 to specify a carbon credit trading scheme, for which states now need to engage and participate since they will generate the carbon credits.

The electricity sector is very politically sensitive in India. State officials who must frequently seek re-election from the voters of their state will often exercise indirect pressure on their State Electricity Regulatory Commissions (SERCs) not to agree to the full extent of tariff hikes petitioned for by the state distribution companies (discoms). State leaders are particularly reluctant to raise tariffs for residential customers and farmers (the latter are large and electorally important voting blocs).<sup>11</sup>

State officials can do this because their state-level ministries own and control and, from time to time, also pay subsidies to the state-owned discom (though these promised subsidies often arrive late and incomplete). Understandably, as previously mentioned, there is very limited appetite in state power ministries to run the discom on entirely commercial principles (except in one or two states) or to subject the discom to retail competition, unbundling, or privatization.

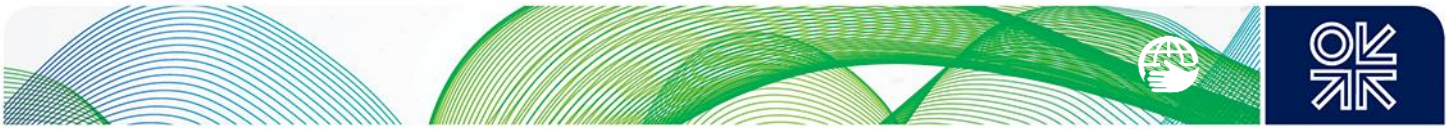
Discom privatization is not on the electricity sector reform agenda in any Indian state at present. Fewer than ten out of around seventy discoms in the country have some private ownership and private management. The rest are all state-owned and, with very few exceptions, they are loss-making and financially struggling, dependent on taxpayer-funded subsidies, and in arrears on their payments to generation companies and transmission companies.

#### 4.1 The effect of the net metering scheme

Net metering, where every surplus rooftop solar generated unit is purchased back by the discom at the customer’s own retail electricity tariff rate, is the most attractive and lucrative incentive system, shortening as much as possible the investor’s payback period for a rooftop solar system. In other words, net metering offers the highest rate that any consumer can expect to be paid by the discom for each surplus rooftop unit that a customer generates but cannot use, and therefore sells back to the discom. Under net metering, the discom does not actually pay cash for the units it buys at the customer’s own retail tariff rate. Instead, the number of surplus rooftop solar energy units purchased by the discom from a customer are offset against the number of units purchased by the same customer on a future bill, and those purchased units are ‘cancelled out’ through bill credits. So those with access to rooftop solar have a major advantage in terms of a reduction in amounts they owe to the discom on future bills. Each unit of extra self-generation is valued at the same rate as the grid tariff, so it creates a bill credit. These surplus units will then be set aside to “offset” the customer’s cost of future grid purchases.

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<sup>11</sup> In many Indian states, the tariff structure has remained in place for several years and is outdated, while upstream energy costs have been soaring. This means that the gap has widened between the average cost to supply a customer, and the average revenue earned from that customer. The resultant discom operating deficits have also been soaring. The state government, as the owner of the discom, is supposed to pay for the operating subsidy that the discom requires to balance its books, since the requested tariff hike is frequently not approved, and the extra costs cannot be recovered from electricity customers. This is one of the main reasons for state-owned discoms’ financial distress and growing losses.



Not all net metering is created equal in the rooftop solar regulations of Indian states. Even in net metering states, there are subtle differences in terms of the financial value of the incentive.

- Some states offer (i) net metering where bill credits are not carried forward. In other words, if a rooftop PV customer is unable to use the net metering bill credits in the month immediately following the one in which they are earned, the credits expire and are lost. This could happen because the customer is physically absent and has no consumption in the following month, or because the shop/factory is closed and hence there is no electricity bill against which to offset the previous credit.
- Other states allow (ii) net metering credits earned by a customer to remain valid for a full year. This means that the benefits from excess generation that are earned in the very sunny season can be enjoyed some months later, maybe in the cloudy or rainy season. This is to the consumer's advantage and the discom's disadvantage—discom revenues are already low in the cloudy season due to system-wide less use of air-conditioners etc. In a net metering scenario, revenues can become even lower because some customers are paying with earlier credits from large surpluses earned in the sunny season, instead of with new revenues. Some customers are even able to achieve zero bills, despite positive consumption amounts, thanks to net metering bill credits.
- Some states (iii) settle the cumulative net metering bill credit only once a year, meaning that the customer does not receive continuous cash flow benefits (in other words, electricity bill savings) from net metering throughout the year, but only once a year in a 'big bang'. Consumers continue to pay for their discom consumption every month, which is whatever amount they require over and above their self-consumption from the rooftop (e.g. night-time power). No bill credits are calculated during the year. Then, at the end of the year, the total annual export to the grid over the preceding twelve months is compared to the total annual paid consumption. The net surplus is then either deducted from the final bill paid out to the consumer in case more has been sent to the grid than consumed from it.

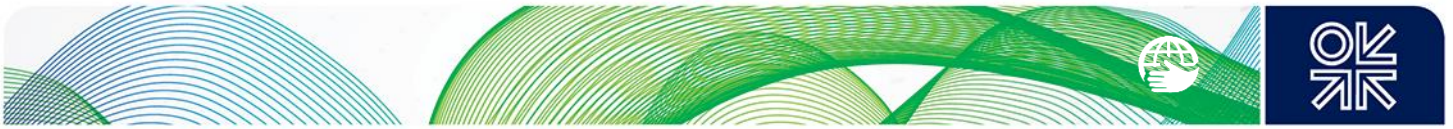
In all three examples above, despite a similar-sounding policy of 'states offering net metering', there will be differences across states in terms of the customer's payback period on a rooftop solar investment and the net monthly amount to be paid for electricity purchased from the grid. In practical terms, it means that the states with the shortest payback or breakeven period are the most attractive for a rooftop investor, or a 'third-party' investor, which is part of the Indian rooftop story.

However, net metering is controversial among energy economists, and some say it is an inefficient and inequitable support scheme for rooftop solar PV because it confers large advantages (energy bill savings) onto the few consumers who can afford the cost of rooftop solar, while shifting higher distribution network costs onto those who cannot afford rooftop solar.

The problem is even worse in India because these less well-off consumers are subsidized by C&I customers. Just two years after net metering was introduced for all consumers in 2017, it became controversial as discoms were especially hard-hit because the commercial and industrial (C&I) group of customers who pay the highest tariffs were the earliest adopters of rooftop solar. This meant the discoms' source of cross-subsidy, the C&I customers, were buying substantially less from discoms due to their new-found rooftop solar option and net metering benefits. Hence the discoms' source of funding to pay for the subsidized electricity to other categories was also drying up due to the enthusiasm with which C&I customers were chasing net metering benefits.

The discoms only recourse was to go to their political masters/legal owners (represented by state officials) and ask for even higher operating subsidies, claiming that their financial gap was growing at an alarming rate and presenting their political masters with the 'bill for rooftop solar'. Predictably, there were strong pressures from state authorities on state electricity regulators in mid to late 2019, to eliminate net metering. The idea for providing government support targeted at small residential consumers came in two phases. In Phase II the plan was likely to make rooftop solar investments less lucrative for C&I customers and thereby discourage at least some of them from investing.





The rooftop ecosystem members (consisting of rooftop installers, system integrators, and others) strongly opposed what the discoms were asking for—the scrapping of net metering incentives. Installers were aggrieved with discoms anyway for the long delays and foot-dragging in granting them approvals to commission their clients' rooftop installations.

The ecosystem members pleaded with state politicians and regulators to retain policy support and net metering incentives, which they said were needed to keep their own businesses afloat and, importantly, also to meet the central government's national rooftop targets.

State officials had initially gone along with the ambitious national rooftop solar targets, until they discovered (as conveyed in a private, off-the-record conversation) that due to net metering regulations favouring rooftop customers, the cost of meeting their state's share of the national 40 GW targets was somehow falling directly on their discom. This was resulting in higher subsidy requirements from their state coffers. The whole rooftop solar initiative and strategy of the central government, publicised in numerous fora, therefore appeared in a new light to states, and it was not as attractive as initially thought.

State officials did not entirely disavow rooftop solar, but they announced that the net metering incentives had to be sharply cut back for everyone and had to be removed completely for the highest-paying customers who did not need them, in other words C&I customers. If these customers still wished to invest in rooftop solar, even without receiving their earlier subsidies and incentives, obviously the state could not stop them from doing so. However, the state was not going to hasten its own financial pain by offering attractive incentives to C&I in its own regulations.

By late 2019, the priorities of states and the central government in terms of rooftop solar thus begun to diverge slightly. States wanted less of it, to protect their discoms, while the central government (and the rooftop ecosystem players) wanted more and faster rooftop coverage everywhere to be on track with ambitious national decarbonization targets.

In the end a compromise was struck. The government agreed to maintain the old net metering benefits, as petitioned by the ecosystem members, but it made them applicable to only a very restricted group of electricity consumers who were installing the smallest systems (500 kW and below). Eligibility for the capital subsidy was similarly restricted to an even tinier rooftop customer size: those installing 10 kW and below. The original 40 per cent capital subsidy was available for the very smallest systems (up to only 3 kW). For capacity of more than 3 kW and up to 10 kW, the subsidy was slashed to 20 per cent. This sent a very strong message about the government's shifting priorities.

Most of the attractive rooftop solar installation incentives that had been offered to C&I customers at the start of the programme were removed with a stroke of the regulator's pen, and were gone in nearly all states by late 2019—early 2020. A clear and sharp shift had taken place.

So, what kind of metering has now replaced net metering for all those who are no longer eligible?

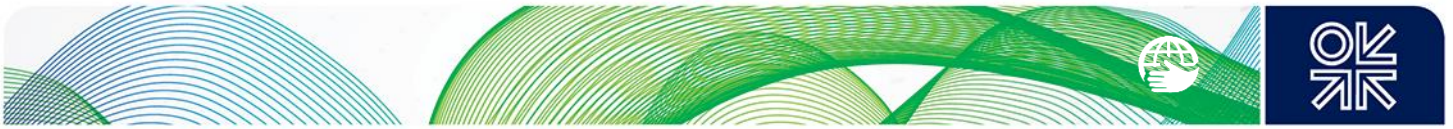
- Today, some states no longer offer net metering at all, but instead have proposed a low feed-in tariff<sup>12</sup> for any surplus generation that is sent to the grid.
- These states have drastically reduced the amount paid for surplus power from what was initially the customer's retail tariff (for example, INR 8/kWh) under the previous net metering policy. The new amount paid could have been lowered to the discom's average pooled power cost (APPC).

Implication 1: States that have removed net metering and are now operating their rooftop solar programmes under a revised feed-in tariff policy, set at APPC, are likely to see a sharp drop in the adoption of rooftop PV. This is because the payback period for a rooftop investor is much longer—it

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<sup>12</sup> This low feed-in tariff could for example be the so-called Average Pooled Power Cost, or APPC, of the discom. This is a weighted average of the price the discom pays for all its power purchases from large thermal plants (coal, gas), nuclear, solar, wind. In other words, the discom will not pay a higher price (such as the retail tariff equivalent) for a unit of surplus power it purchases from a rooftop, and thereby it avoids increasing its power procurement cost by allowing export of surplus rooftop power to the distribution network.





can now be reached in seven or eight years instead of in four or five years under the previous net metering regime.

Implication 2: In future, when battery costs in India fall by another 50 per cent, these states with the least generous feed-in tariff policies are likely to 'indirectly incentivize' their customers to invest quickly in batteries and avoid sending any surplus to the grid, or at least limit sales to the grid as much as possible due to the small amount received for such sales. Once batteries become widespread, customers will prefer to store their surplus electricity in the battery and use it to avoid evening purchases from the grid. By using stored power and avoiding purchases at their retail tariff rate, customers will once again be able to value every unit of stored power 1:1 effectively at their own tariff rate.

When, in future, batteries are available at Indian prices, then it is to be expected that high-end C&I customers will again be the early adopters, as they have been with rooftop systems. The economics of investing in batteries are the most compelling for the highest-rate payers, which are C&I in India. However, it is expected that widespread battery adoption by most consumer groups will not happen any time soon, even after prices fall. The only exceptions could be the largest domestic and international C&I companies. Today, most Indian customers are still barely able to afford a rooftop solar system, let alone buy it together with a battery, or even afford the financing to do so.

For the moment, exporting the surplus to the grid, and taking whatever price the regulator says the customer will receive from the discom (even the low APPC rate), seems to be the only option for an average rooftop investor. Financial calculations and breakeven points/number of years of payback, must be made on those considerations. Systems for new rooftop adopters are also likely to be sized more conservatively since surplus generation receives a low reward from the discom.

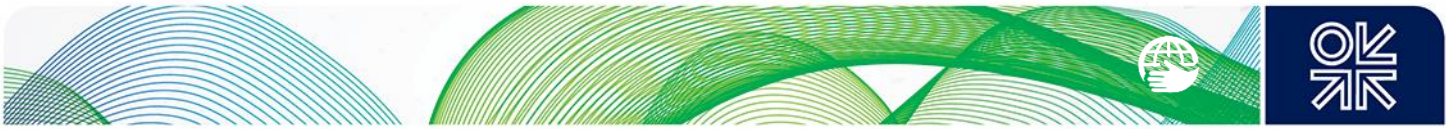
Discoms are still not satisfied because they must find resources to invest in some new network equipment to accommodate rooftop solar, even though net metering has gone. Both the original net metering system and the updated net metering system using APPC of course place an administrative burden on the discom. Both incentive systems require the discom to buy more complicated bidirectional metering hardware. In addition, the discom must invest in software and training for its billing department to process automated bill adjustments unique to each customer based on multiple meter readings—in other words, measuring amounts of grid electricity purchased by the customer versus amounts of surplus solar generation exported from the rooftop to the grid.

In Indian rooftop solar terminology, 'net billing' refers to an updated net metering scenario in which there is a difference between the rate at which the customer purchases kWhs from the discom and the rate at which the customer sells kWhs to the discom. As with net metering, net billing also places a burden on the discom in the form of a requirement for specialist billing software and staff training, as well as automation to generate accurate bills. Bills are based on bidirectional meter readings of what was purchased by the consumer and what was purchased by the discom, valuing them appropriately at the tariff rate and the APPC rate respectively.

Some states permit neither net metering nor net billing. These are 'gross-metering' states. One or two states even give their electricity customers a choice of gross metering or net billing.

Gross metering is where 100 per cent of the electricity generated on the rooftop is purchased by the discom for a (usually low) price like the APPC or a bit higher—in other words gross metering is 100 per cent fed into the grid, without the customer consuming anything that is generated on the rooftop. No netting out is required of any amounts of consumption or sale. Instead, the discom procures the customer's full rooftop generation to fulfil its own Renewable Purchase Obligation (RPO). The discom then distributes the electricity purchased from the rooftop solar investor to its other non-solar customers on the last mile grid.

The discom avoids transmission and distribution losses by procuring part of its RPO this way, rather than from utility-scale projects located many hundreds of kilometres away, for example. Due to transmission losses when purchasing bulk power from remote generation sites, the discom has to buy and pay for a higher amount of bulk power than it will actually receive at the sub transmission station



near the load centre; this wasteful loss does not occur when the discom meets part of its RPO from nearby decentralized generation that takes place within the last mile distribution network.

What is the attraction of gross metering to the customer and why would they decide to invest in rooftop solar in a gross-metering state? Gross-metering customers are told that they can operate a 'passive business' to earn an income stream from their idle roof space. They do so by investing in a mini-power plant (their rooftop solar system) and selling all of their output to the discom. Their existing electricity purchasing arrangements from the discom do not change. They are likely to see an adjustment on their bill where the discom has reimbursed them for the amount it purchased.

A crucial difference between net billing and gross metering is as follows: in a gross-metering consumer's bill from the discom, there is no netting off in terms of kilowatt hours; it is done only in terms of income (rupees) earned from the rooftop electricity sale/purchase. This method requires much less investment by the discom in terms of upgrading its billing system, nor is there much need for investment in staff training and administrative expenses. Under gross metering, all electricity used by the consumer continues to be purchased from the discom at a price determined by the regulated tariff schedule. There is no offset relationship for self-consumption (the two streams are metered separately).

Discoms have been far less hostile to rooftop solar when gross metering is applied. They do not lose revenue because all customers continue all purchases as before, and discoms are able to fulfil their RPO at a lower cost, in other words, they pay APPC whereas if they had to buy from a solar generator through a power purchase agreement (PPA) it could be slightly higher.

## 4.2 The reform of discoms

A key question is whether rooftop solar should wait for discom reforms to be completed?

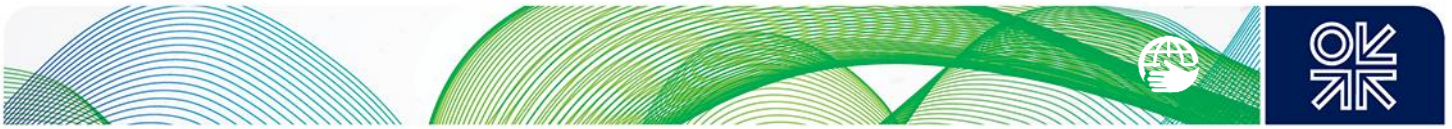
Developing countries are unlikely to sequence their clean energy transition by first completing the electricity distribution sector reform agenda and then introducing renewables. Instead, they will have to find their own script for the clean energy transition, even as the reform agenda is being implemented in parallel, either slowly or quickly (it is mostly likely to be very slow).

The challenge of managing both distribution sector reforms and the simultaneous introduction of decentralized, grid-connected renewable technologies is very large. There has been no consensus on state discom reforms which were debated for two decades before clean technologies came along. The sudden presence of clean technologies has not proved sufficient to bring about the required consensus for discom reforms. Therefore, the energy transition in developing countries is bound to be somewhat messy and imperfect given the multiple agendas that are in play.

The required reform of the distribution system is more than just privatization. This is evidenced in areas of India with privatized and very efficient, cutting-edge distribution companies, such as the National Capital Territory (NCT), which covers New Delhi and its surrounding areas, where only a small fraction of rooftop potential has been achieved in the residential sector.

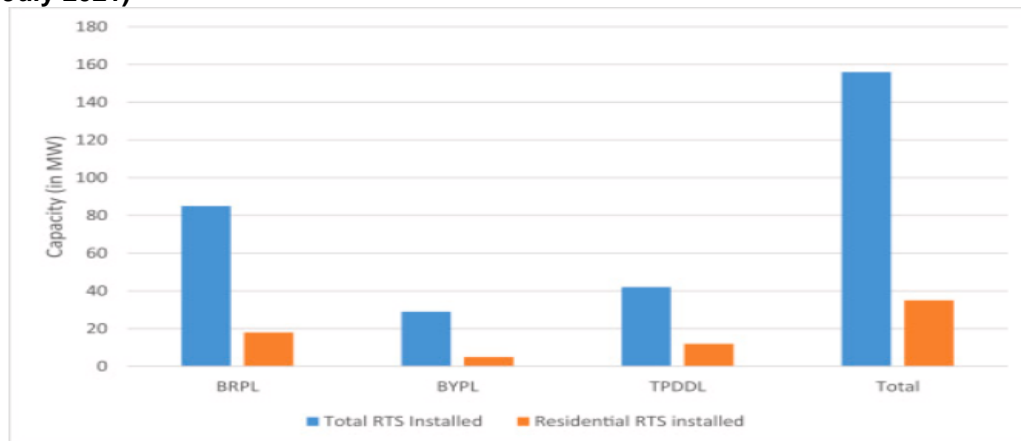
NCT has three private discoms, a modernized and updated, digitized distribution network with supervisory control and data acquisition (SCADA), and automation, as well as better rates of per capita income and awareness among the customer base. Figure 4 below shows the relative, very small share of residential rooftops for the three private discoms in Delhi (known as BRPL, BYPL, and TPDDL), which are among the best and most advanced in India. These three discoms had collectively installed less than 150 MW of rooftop solar on middle-income and high-income residential roofs by mid-2021.

However, private discoms are likely to be better equipped to utilize the services of distributed energy resources, including solar PV. Many of the state-owned, financially struggling discoms have not digitized their operations, other than in pilot parts of their network. This means that unlike the privatized discoms, which have invested in advanced information systems and grid modernization, loss-making, struggling state discoms cannot generate enough granular data to 'see' the 'avoided costs' from encouraging rooftop solar. They do not see the transmission and distribution losses occurring on their network in real



time and therefore they cannot grasp the positive impact on their finances from avoiding such losses in the feeders with on-site (rooftop) generation.

**Figure 4: Total and residential rooftop solar (RTS) installations for main discoms in Delhi (as on 31 July 2021)<sup>13</sup>**



Source: Energy Efficiency & Renewable Energy Management Centre website.

Private discoms have also worked out that certain residential customers (LCLI consumers) will always be loss-making for them (LCLI cost more to serve than they will earn in revenues). All discoms have this group of customers, but the non-digitized discoms are unable to track and analyse the impact of LCLI customers on their bottom line. Hence, non-digitized discoms are slower to be convinced that rooftop solar may be a cheaper way to supply LCLI, and thereby lower their own losses. The revenue is going to be low as a matter of policy, which the discom has to take as a given. The discom's strategy should therefore be to bring down the cost closer to the revenue level and thereby limit the gap between the two which is the loss. Serving the LCLI customers with on-site rooftop solar, rather than buying distant thermal power for them, is one way to lower the cost.

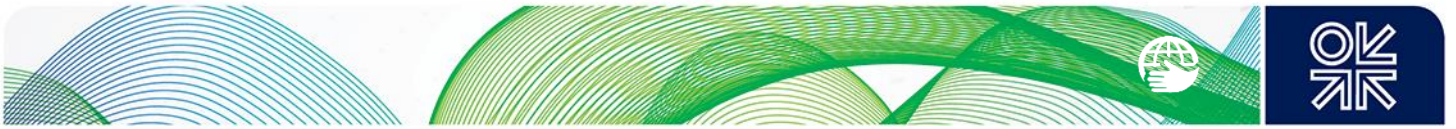
Therefore, private discoms are in some cases embracing rooftop solar (to be owned by themselves, as the discom, or by a RESCO on their behalf) as a way of lowering their own cost of supply to these loss-making customer categories.

### 4.3 Technical challenges to the penetration of rooftop solar PV

Technical challenges in the network arise from the high penetration of rooftop solar, and require discoms (including their non-solar customers, through tariff hikes) to fund certain network upgrades. The network stability issue may be simplified as follows: intermittent and two-way power flow from rooftop systems on a network which was built for one-way power flow, usually creates impacts on discom power quality. Stabilizing the voltage and power factor and mitigating harmonics requires additional network investments and technical staffing expertise to be adequately managed. Harmonic filters are expensive and not necessarily in the priority list of hardware purchases, but items such as these and tap changers may be urgently required after a certain level of rooftop penetration on a feeder. Non-solar customers, who may have been waiting a long time for other upgrades, will be overtaken. Their tariffs are likely to go up due to these additional expenses, and if their maintenance needs are bumped down to a lower priority, then non-solar customers face a double disadvantage from their rooftop solar investor neighbours. They have to pay more and also wait longer for their own (non-solar related) maintenance needs to be met.

<sup>13</sup> Dutt, D. and Ranjan, A. Towards a just energy transition in Delhi: Addressing the bias in the rooftop solar market (Jan 2022) <https://www.sciencedirect.com/science/article/pii/S0301421521005322>





Most state-owned, cash-strapped discoms in India are unable to make the required investments in such network strengthening and localized automation hardware, sensors, and switches as well as the associated capacity building of their staff. Yet, when network disturbances arise, it becomes urgent for a rooftop solar feeder once the penetration of rooftop PV reaches a certain level in the catchment area of a distribution transformer. So far, the penetration is still low in most of the network, but discom engineers can see where it is headed based on their experiences with the first few feeders that are starting to have high numbers of prosumers.

All these 'frictions' are likely explanations for why the achievement of rooftop PV targets lags far behind the achievement of ground-mounted PV targets. Only 25 per cent of the rooftop target is achieved in the same period, even as nearly 85 per cent of the utility-scale target has been reached. Discom barriers to the growth of rooftop PV, and counteracting them, are a work in progress in India. A handful of private discoms in the country are leading the way in removing barriers by experimenting with rooftop solar innovations. They are even carrying out small learning pilots and demonstrations of peer-to-peer trading of rooftop solar electricity in one or two states with progressive regulators who are allowing 'regulatory sandboxes' to pilot new arrangements for the demonstration and assessment of impacts in a ring-fenced setting.

Some observers have commented that the 'unbundling of Indian discoms and removing price distortions through competition, is key to resolving misaligned incentives at discoms'. This is of course correct, in a first-best world. In fact, the central Ministry of Power agrees, and is repeatedly trying to pass an update to amend the Electricity Act that would, among other measures, also 'de-license' electricity distribution to introduce retail competition with incumbent legacy discoms. Predictably, states are very opposed to this plan and have so far ensured that the Electricity Amendment Bill does not make it onto the parliamentary agenda, but instead remains in the 'consultative process' stage for the foreseeable future.

The main fear of opponents to all previous versions of proposed distribution reform is that private distribution companies will siphon off all the good customers who are able to pay for service and reliability. So, despite a commentator's correct observation that removal of misaligned incentives is the way to proceed, the real-life situation and political economy considerations in India mean that in a second-best world, policymakers either need to (i) find ways to navigate most of the obstacles created by the misaligned incentives, which they are doing, and which has received an unexpected push from the pandemic; or (ii) the clean energy transition and introduction of clean technologies has to wait until the misaligned incentives are straightened out, however long that takes.

Indian policymakers have opted for the former approach. In other words, muddle through the misaligned incentives, navigate the obstacles, and learn by observing who needs support in order to grow the rooftop sector (for example, discoms and residential customers). They then put together a package of the required incentives and interventions, and declare a new phase, Phase II, and continue the experimentation and learning by doing to find the right script for India's energy transition, which incidentally will have its own variations in each of the states.

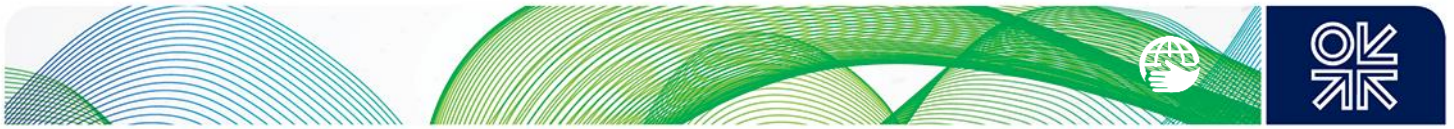
## 5. Conclusion and way forward

Energy transition in developing countries typically faces complex and unanticipated social and economic barriers, particularly for consumer-led clean technologies such as rooftop solar panels or light electric vehicles. The key value proposition for these technologies, of a high upfront cost followed by large future energy savings (by avoiding grid-electricity bills and petrol/diesel purchases) does not resonate with large numbers of low-income and even middle-income consumers<sup>14</sup> in the developing world.

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<sup>14</sup> In a developing country context such as India, middle income consumers earn from US\$7 to \$18 per day, according to the government's definition. The average annual per capita GDP is around US\$2,100 or US\$5.8 per day, which comes to US\$175 per month. In this context, upfront costs are difficult to afford, commercial loans for new technologies are limited (the same





It is tempting to think of clean technologies as ‘cheaper’ than traditional non-renewable ones, and therefore to conclude that they must be an obvious and easy solution for poor people in developing countries. In addition, developing countries often enjoy abundant year-round sunshine that can be turned into ‘fuel-free’ electricity generation. However, this only happens in the presence of the right hardware such as a rooftop solar PV system, which is not affordable to many people if they must pay for the hardware upfront in the absence of low-cost financing.

In practice, therefore, referring to rooftop solar as ‘very cheap and ideally suited’ to developing countries, is a gross over-simplification. There are multiple obstacles to the mainstreaming of clean technologies in low-income populations in developing countries that must be overcome through the design of appropriate economic solutions and business models, which have been the subject of this paper. It is fair to say that the development of the right business models will be the key to unlocking widespread use of renewable energy technologies in the developing world—not the mere existence of the ‘mature technologies’ themselves.

Large volumes of concessional funding for risk mitigation and for lowering the cost of capital to the end-borrower will be required to establish workable business models. The simple fact is this: whether the clean technology is rooftop solar or a swappable battery for an electric vehicle, it will not be the 800+ million low-income customers who will ever qualify to take loans and directly own these assets. Instead, a financially qualified third-party entrepreneur (such as a Renewable Energy Service Company, or RESCO, or a battery swapping investor called an Energy Operator, EO), will need to take out the loan, buy and own the asset and sell the services of that asset to end users in affordable increments. These affordable increments, which are only possible if the interest rate is concessional, will be aggregated and used by the third-party entrepreneur to repay the loan.

Higher interest rates charged to the intermediary RESCO mean that charges to end-customers will be higher and there will be fewer takers who can afford rooftop solar as a service. This will of necessity slow down the speed at which the mainstreaming of solar rooftops takes place. These are the hidden drivers of the energy transition in developing countries, and they are directly related to the cost of funding for the clean technologies.

In summary, despite a decade-long fall in the costs of solar panels, it turns out that they are still too expensive for an outright purchase by large numbers of consumers in the 100 or so countries where the average annual per capita incomes are around \$7 per day or less.

In the absence of the ability to afford an outright purchase, alternative third-party methods of providing access to rooftop solar PV must be found that do not involve the end user’s ownership of the rooftop system, but only the use of it. Third parties will require de-risking support and highly concessional credit lines if they are to take on loans to buy equipment and sell solar services to low-income customers who cannot afford large monthly payments to RESCOs.

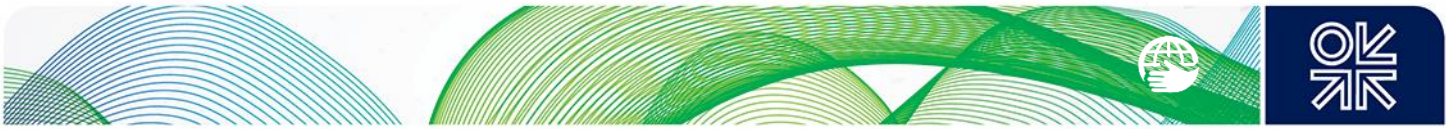
Developing countries are regularly urged to raise their climate ambition without any indication of the pricing and other terms and conditions under which clean technologies will be transferred or made available to their populations.<sup>15</sup> Pressure on developing countries to decarbonize or ‘leapfrog’ to renewable energy, without offering any financing solutions, does not sufficiently take into account the connection between a country’s per capita income and its prospects for mainstreaming consumer adoption of clean technologies.

India is experimenting with several rooftop PV business models and sequencing of target market segments, to address market and ecosystem development, as well as affordability and accessibility

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person may be able to obtain a car loan or a motorcycle loan but not a rooftop solar loan), and the addition of battery energy storage with rooftop solar is prohibitive, unaffordable, and unrealistic even for most large C&I customers, let alone individual households or small businesses.

<sup>15</sup> This applies both to mature technologies such as rooftop PV, as well as cutting-edge renewable energy technologies currently under development.

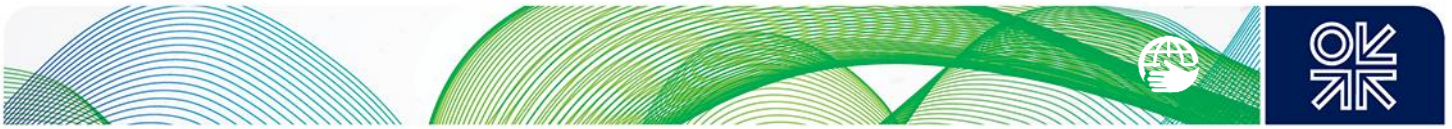


barriers. Its lessons of experience will undoubtedly be of interest to other countries with similar challenges.

A new set of business models, built on insights that are relevant for low-income developing country populations, is urgently needed. The chicken and egg problem is that for the new business models to materialize at scale, there is a need for adequate volumes of risk mitigation and concessional capital.

India is one of the leaders among developing countries in exploring workable solutions that allow third parties to sell rooftop solar as a service. It may be a few years behind on its rooftop solar targets, but it will certainly reach it, with some zigzags on the way as new lessons emerge and new policies are designed to overcome them.

It is possible that the 40 GW rooftop target may be reached five to six years later than planned, but there is little doubt that it will be reached and that rooftop solar will be mainstreamed in India as the country continues its path to net zero in 2070.



## Appendix: Business Models for Financing Rooftop Solar

### **BUSINESS MODEL ONE: The third-party financing model (also known as the OPEX model, or 'rooftop solar as a service')**

This has been the hallmark of India's rooftop solar sector. It emerged in 2016 during consultations on rooftop market development which revealed that some C&I customers were looking for an alternative to the outright ownership model (Capital Expenditure, or CAPEX model). This was the genesis of the 'third-party model' or 'rooftop solar as a service'—and the so-called Operating Expenditure (OPEX) model. A subset of C&I companies was looking to acquire rooftop solar systems for which small and regular payments would appear only as an Operating Expenditure on their income statements.

These small and regular operating expenditures should ideally appear in the form of solar electricity purchases from a third party, instead of as debt service payments.

The third-party solar electricity seller would then use these electricity payments received from their customer as the source of their own debt service payments to repay the project finance loan they would take from the State Bank of India (SBI), the designated bank to pioneer the commercially funded rooftop solar sector using the government's loan from the World Bank. The third-party electricity seller was responsible for placing the rooftop solar system on the customer's roof. This way the third-party investor took the loan and took ownership, and the C&I customer remained debt-free, not because they were unqualified to borrow, but only because it did not match their business strategy and the balance sheet requirements of their investors.

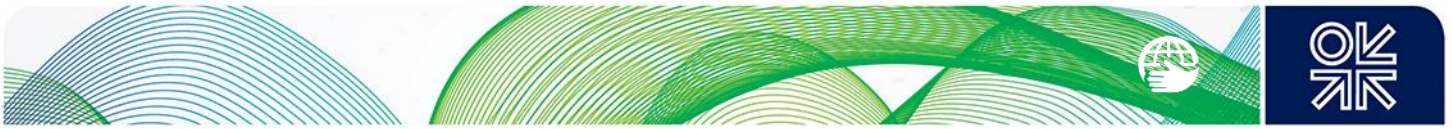
The C&I customer's preference not to be the owner of the rooftop system, but just to use it as a service, could only work if 'someone else' (a third party) were to become the borrower and take the SBI loan and then use this loan to invest in procuring and owning the rooftop solar system. This business model envisaged that a third party would have to be the borrower and use the funds to purchase the rooftop system, install it on the customer's roof, and then sell the system's solar kWhs to the C&I customer whose owns the roof at an agreed price. This agreed price of solar energy would have to be lower than the grid tariff to make it worthwhile for the C&I customer to sign a contract with a third-party rooftop service provider.

Responsibility for maintaining the rooftop asset and ensuring maximum generation would rest entirely with the third-party owner, who was frequently referred to as a Renewable Energy Service Company, or RESCO, or simply a 'rooftop developer'. All this would be reflected in a power purchase agreement between the C&I customer and the RESCO for, say, a period of ten, twelve, or fourteen years, or however long the RESCO's loan term was (for the loan taken to purchase the rooftop system hardware on behalf of the C&I customer). In other words, the RESCO would take on, say, a ten-year loan to repay the cost of the rooftop solar system. This meant that the RESCO would require a PPA with its customer for at least those ten years, showing that a cash flow stream from rooftop solar electricity sales to a reliable customer was expected to be an income stream for the RESCO over the life of the loan. Furthermore, this income stream would be used to repay the RESCO's loan to SBI.

Most PPAs would indicate that at the end of the power purchase agreement the RESCO would have received enough revenues from its customer to have repaid all instalments of the SBI rooftop loan in full. In addition, the RESCO would also have recovered its required return on its own equity or the down payment it had to make in order to secure the loan.

Therefore, at the end of the PPA term, when the entire loan was repaid and the return on equity had been earned as expected, the RESCO would then symbolically transfer ownership of the rooftop solar system to its customer at a token price of, for example, US\$1 equivalent, and would then leave.

The hardware/asset would not move from its original location on the customer's rooftop where it had been installed at the start of the ten-year PPA. However, after the RESCO had left, the rooftop system would now belong to the rooftop owner and would stay in place for its remaining expected physical life of another 12 or 13 years.



The rooftop owner would not have to make any more payments after an orderly PPA expiry, since they would now be the full owner of the rooftop system. All energy generated from the rooftop solar hardware would be 'free of charge' to the customer after the RESCO completed the loan repayments to the bank. This would have been done by the RESCO over the previous ten years, using money earned from energy sales (rooftop as a service) to the customer. The concept is like paying off the last instalment of a mortgage and owning a property 'free and clear' once the bank has exited the picture upon collecting the last loan repayment.

The RESCO or OPEX model was a Build-Own-Operate-Transfer (BOOT) business model which meant that any C&I customer who was fortunate enough to qualify, was able to acquire a rooftop solar system when it was 'Transferred' to them at the end of the PPA, say after ten years. This was achieved by them without any upfront payment, and they had no debt service obligations for the rooftop system; their only obligation was to purchase the electricity from the third party, which was sold at a cheaper rate than their current grid tariff. Everything else was done by the RESCO.

There is one small variation to the BOOT model, which is also a third-party model and is practised in India. It is Build-Own-Operate-Maintain, or BOOM. This is a 'purer' form of 'rooftop solar as a service' because, in this business model, the customer does not want ownership of the rooftop system during the lifetime of the system; not at the start, not in the middle, after ten years, and not at the end.

The customer simply decides that they will never own the item and only wants to buy solar energy from the RESCO as long as they are running the business, so possibly for the next 25 or even 50 years.

BOOM customers are typically driven by concern about technology change in solar panels, inverters, etc. They do not want to take any responsibility for managing these aspects. If the rooftop system technology becomes obsolete, it is the RESCO's responsibility to replace it so that the energy purchase contract continues. If there is no generation due to prolonged bad weather, it is the RESCO's problem and not the client's as the client will buy from the discom. In some contracts, the client could possibly also collect some compensation from the RESCO if they are forced to buy from the discom because the solar panels are not able to deliver. This compensation would be to offset the price differential between the solar cost and the discom cost. The client bears absolutely no performance risk in the BOOM third-party model.

Aggregator RESCOs are free to sign up hundreds of customers, buy hardware in bulk, and then sign BOOM or BOOT contracts with them, depending on the latter's preference. (Energy sector observers who are familiar with the swappable electric vehicle battery business model in India will recognize a similarity here. The battery swap client also never wants to own the renewable energy technology/battery. They prefer someone else to be in charge of managing, repairing, and replacing it every three years. The client only wants to pay for the service, have access to a charged battery when needed, and no more). In BOOM rooftop as a service, the client will have the RESCO's panels on their roof and will be consuming the energy but taking no responsibility for operations or ownership of the asset at any time.

In the BOOM model, like the BOOT model, the rooftop client has no upfront entry cost and makes no payments. This is a great privilege, available only to the best credits. Two parties have taken a risk on the customer in order to have this model: the RESCO, which may lose its equity if the debt goes bad, and the Lender to the RESCO, which will have to write off the loan if the underlying client stops paying for electricity purchases from the RESCO.

Essentially, as mentioned, the solar rooftop tariff charged by the RESCO must cover the RESCO's debt service obligations and return on equity expectation, and still has to remain below the grid tariff. This applies in both the BOOT and the BOOM case. If it is more expensive than the grid, the client has no incentive to enter the arrangement.

This was possible with the SBI-World Bank credit line because the loan maturity was long, and the blended interest rate (World Bank interest rate plus concessional climate funds, plus a grant) was low. This meant that the debt service burden for the RESCO was lower than it would have been at market rates.





This debt service burden was to be recovered only through sales of rooftop energy to the customer, so the customer benefited from the fact that its RESCO had managed to secure a low-cost loan. Specifically, the benefit came in the form of a lower solar tariff.

This is a crucial lesson for developing countries. They must secure low-cost or concessional debt to keep solar tariffs affordable for most of their low-income consumers.

Once the RESCO's loan, taken from SBI under the World Bank-funded rooftop line of credit, was fully repaid and the RESCO had earned back its required return on equity,<sup>16</sup> there was no need for the arrangement with that particular rooftop customer to continue. The RESCO would leave the rooftop solar panels and other components in situ, transfer ownership since it had recovered all that it required and would move on to repeat the transaction with new customers. If the customer had a BOOM arrangement, then the RESCO arrangement would have to continue but at a lower per kWh rate, after the RESCO had repaid its hardware loan out of the first round (for example, 15 years) of electricity sales to the customer. When the panels are renewed at the end of life, and a new loan is taken for the new panels, rates will adjust again. In the BOOM model, the RESCO remains the owner at all times.

This type of third party-owned, 'as a service' OPEX model was available only to qualified C&I customers and it became an important addition to India's nascent rooftop solar ecosystem in 2017.

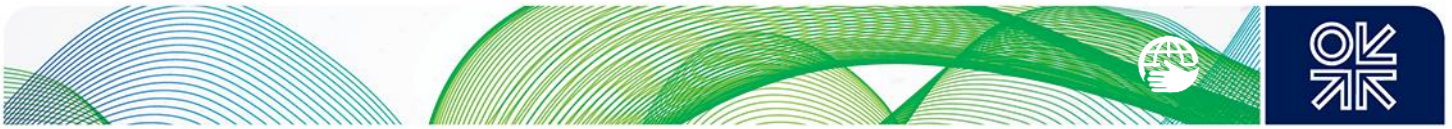
The arrangement involved some complexity and several stakeholders had to 'accept each other' for the arrangement to work. Specifically:

- the C&I customers had to be judged 'non-risky' by both the RESCO and the lender (SBI);
- the RESCO's loan application to SBI for concessional funds to buy the rooftop system had to indicate where the cash flows would come from to repay the loan and possibly also attach the draft PPA initialled by the C&I customer;
- since it was a project finance loan, SBI had no recourse to the RESCO's other assets outside of the rooftop solar system; SBI had to depend on its loan to be repaid from the earnings that would be related to this asset that SBI had financed;
- all repayments to SBI were only to be made from this rooftop project's cash flows originating from rooftop solar electricity generation and sales of that electricity to the customer on whose roof the asset was placed; the primary use would be self-consumption of rooftop solar generation by the customer;
- as mentioned, these cash flows that the rooftop loan rested upon were basically the C&I customer's electricity payments to the RESCO. They had to be sufficient to cover the agreed, low, and affordable debt service as well as the RESCO's own return on equity.<sup>17</sup>

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<sup>16</sup> The RESCO's equity in this case refers to the down payment that the RESCO had to make to SBI to secure the debt portion of the rooftop loan. Typically, the down payment was 20 per cent, and SBI would provide a loan of 80 per cent if the RESCO itself was a credible enough borrower and if its proposed customer (C&I) was also seen as a good risk who would pay on time and in full. So, while the RESCO has put down an equity payment in order to unlock the loan, this equity payment has an opportunity cost—what could that equity have earned if it were not used for this purpose? Most required returns on equity for solar projects in India are in the neighbourhood of 15 per cent. That means the ten-year stream of payments for rooftop solar generation had to cover the rooftop hardware loan repayment as well as a 15 per cent return on the equity portion contributed by the RESCO, in other words, 20 per cent of the total project cost.

<sup>17</sup> For a hypothetical rooftop system cost of US\$100, the RESCO would have funded it with 30 per cent equity and a 70 per cent loan from SBI. There was a fixed debt service on the \$70 (possibly at a below-market interest rate due to the blending of multilateral funds, the concessional climate funds, and the sovereign guarantee). The low interest rate that the RESCO can borrow at also lowers the amount the RESCO must collect from its customer to repay the RESCO's lender. This low interest rate therefore immediately allows the RESCO to charge a competitive price for the solar electricity. It is an important insight that when there is no fuel cost, as in a solar project, the cost at which clean electricity is sold depends largely on the interest rate that is charged for the hardware which produces the clean electricity. Apart from the low fixed debt service, in the ongoing example, the RESCO also needed to offer a market rate of return—at least 15 per cent—to the providers of the 30 per cent equity portion. Both payment streams (debt service to SBI and return to RESCO shareholders) would have to come from the monthly revenue stream arising from the sale of rooftop PV electricity to the customer. Naturally, this revenue stream would have to be absolutely reliably paid on time so that the RESCO could repay its loan on time using this money. This implies that the RESCO's target market would be restricted to a very limited group of C&I customers who would be considered qualified. This is the story of Phase 1 and why the programme was initially 'the opposite of mainstreamed', in other words, it was very restrictive in terms of who was eligible.



Since these were early days, the project risks were all unknown: would the customer default or would the rooftop system instead fail to work as expected? What if, in the Indian context, rooftop solar electricity generation was very low due to pollution or dust or any other reason, and what if the projected revenues from the RESCO's solar electricity sales to the customer never materialized? How would SBI recover its loan in that scenario if the RESCO was not being paid enough by the C&I customer because the rooftop generation fell short?

No one was sure what the actual risks would be or how to price them. Naturally all stakeholders became extremely conservative and risk-averse and only the very strongest credit risks among C&I customers were accepted, as underlying OPEX customers.

The government watched with some concern as SBI conservatively decided who could be in and who would not be in the country's rooftop sector, based on the first blended finance loan that the government had arranged with the World Bank to kick-start the sector.

On the other hand, the government was also pleased to observe the rapid development of the very high-calibre rooftop ecosystem, made up of strong players, which may not have happened if less creditworthy parties were to be helped to muscle their way into the first phase. SBI performed its role well of ensuring that only good credit risks were part of the programme.

Who were the RESCOs in this OPEX business model? Some of them were solar developers who had recently been burned in the extremely competitive ground-mounted solar auctions under way at the time. Bid prices were exhibiting near-irrationality. Winning bids were far below cost on the bidders' stated assumption that in six months' time, when the hardware procurement would start, global equipment prices of Chinese solar panels, inverters, and locally procured cables and mounting racks, would have all have fallen further to match their aggressively low, quoted levels.

Large solar developers in search of better margins wanted to exit the ground-mounted sector and explore the rooftop sector where unit prices and margins were considerably higher.

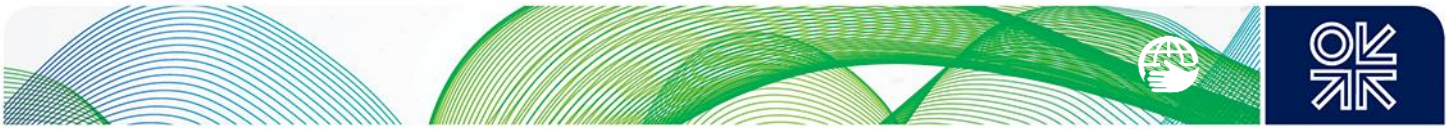
Other RESCOs did not come to rooftops from the ground-mounted sector. Instead, they started and remained in the rooftop space as rooftop specialists; some were also able to attract international private equity investment. All were drawn in by the government's SBI line of credit, which was affordably priced and dedicated to the rooftop PV sector.

## **BUSINESS MODEL TWO: The OPEX business model evolves: RESCOs become aggregators**

Before long, during project preparation discussions between SBI, the Ministry of New and Renewable Energy, and the World Bank, the decision was made that RESCOs should also have the possibility to become aggregators. In other words, willing RESCOs should bundle or aggregate their rooftop PV loan applications to SBI in minimum units of 1 MW or greater, representing the demand of multiple C&I customers instead of funding one C&I rooftop client at a time.

From the RESCO standpoint, becoming an aggregator would allow them to procure bulk hardware for hundreds of rooftop solar systems and thus secure better pricing and volume discounts from suppliers. This would allow them to be more competitive and make better offers to win market share. From the commercial lender SBI's standpoint, aggregation to offer rooftop solar as a service to hundreds or thousands of customers 'at a time' would reduce the transaction costs of loan applications from RESCOs. It would also allow SBI's Credit Committee to approve larger loans (minimum 1 MW instead of perhaps 200 kW at a time) to qualified RESCOs.

From the Ministry and World Bank's standpoint, aggregation would scale up the programme and allow for faster geographical coverage if RESCOs were incentivized to speed up customer acquisition among C&I customers. The embrace of the aggregation concept was an early indication of slightly improving confidence on the part of SBI, although the World Bank loan to the Government of India was still under preparation and there were no grid-connected rooftop installations in place yet in India to learn from.



The decision to encourage RESCOs to become aggregators and bring minimum deals of 1 MW to SBI had several side effects.

- First, it unfortunately knocked out all the smaller RESCOs who had been planning on borrowing funds from SBI one customer at a time.
- Second, it brought in a 'pan-India' focus to the remaining, large RESCOs. They were told by the government that the pool of concessional funds for rooftop solar that India would apply for from the World Bank was limited.
- Once this sovereign loan to reward the first movers in the rooftop sector was fully allocated, future loans would be at market rates and they would not have a sovereign guarantee to lower interest rates. In 2017, India was interested in offering one-time help and not continuous help to the rooftop sector.
- Each of the remaining RESCOs was therefore keen to 'lock in' as soon as possible as much of the SBI's concessional funding and sign contracts with the most attractive C&I customers.
- Finally, scaling up happened quickly and somewhat unexpectedly as the large RESCOs started actively making subcontracting and partnership arrangements with anonymous rooftop installers in multiple cities around the country, to give themselves more of a national presence. They did so in anticipation of putting in applications for funding of more than the minimum of 1 MW at a time, to secure large amounts of this one-time concessional funding for rooftop solar.

At this point, the nascent rooftop ecosystem was supporting around 8–10 large RESCOs. As mentioned, they went on an ambitious customer acquisition effort to set up a portfolio of rooftops throughout the country and, in the process, they discovered the finer details on what, hitherto untested, rooftop policies were prevailing in the rule books of various states.

Not all states were equally attractive in terms of the business environment for doing rooftop PV projects. The Ministry of New and Renewable Energy, with the support of the technical assistance grant under the World Bank–SBI Rooftop Program, has created an elaborate Rooftop Attractiveness Index to rank various states and hopes to encourage them to strive to improve their rankings.<sup>18</sup>

### **BUSINESS MODEL THREE: The Lease business model**

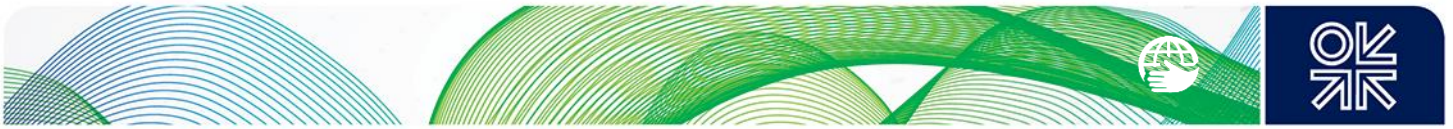
This is another third-party arrangement in the Indian rooftop sector. In this case, there could be an investor looking for a tax advantage (accelerated depreciation) from making an investment in rooftop solar systems. The investor (lessor, panel owner) knows nothing about the rooftop solar subject, unlike the RESCO.

- The lessor only wants ownership of solar panels for the tax advantage to be gained for other parts of their business. They seek to earn a flat lease payment every month in return for the customer's use of their rooftop solar asset. The lessor takes no risk in terms of rooftop system performance, solar generation, etc.
- As the owner of the system, they may partner with an installer to help find customers/counterparties. The lessor's rooftop systems will sit on the roofs of various customers who like this arrangement because they need only pay a flat amount in the form of a lease payment every month.
- The electricity generated on the roof under a lease arrangement is not metered. Unlike in the BOOT and BOOM cases, there is no RESCO who is explicitly selling kWh of solar electricity at a price. The rooftop owner (lessee/customer) consumes whatever they require and pays a flat rate of, for example, \$100 a month. If there are forty sunny days in a row, and there is a large amount of generation, the amount to be paid (\$100) remains the same. All those kilowatt hours will be enjoyed for the same hypothetical payment of \$100, no matter how many kWh they are. This implies that the effective cost per kWh of solar electricity will be very low because the flat payment buys a large amount of electricity.

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<sup>18</sup> <https://solarrooftop.gov.in/notification/Notification-30082019-161516.pdf>





- If, on the contrary, there are forty rainy days in a row and little or no rooftop generation happens, the customer or lessee must buy all their electricity needs from the discom AND they must also pay the lease fee to the lessor.
- Remember, in this business model the cost to be paid is independent of rooftop generation. This hypothetical scenario of no sunshine and very little generation, paid for by a flat lease fee, makes the notional cost of each kWh relatively high.
- Some customers are willing to bet on this as they particularly like not having to buy the metered solar electricity units from an active independent power producer (IPP). They would rather have a solar panel generating on the roof during daylight hours, and have full predictability over their payment obligations (the amount of the lease payment). If such a lessee can find a lessor who is looking for a tax investment and is willing to buy solar panels with or without a loan, there is a win-win business opportunity.

#### **BUSINESS MODEL FOUR: The Rooftop Rental business model**

This is another variation of the third-party arrangement for rooftop solar. In this case, a RESCO is looking for rental space in order to sell all the rooftop generation to the discom. The RESCO approaches ordinary electricity consumers who have well-situated roofs (south-facing, shade-free, easy to access, free of clutter). These consumers could be residential, or C&I, or institutional customers. There is no credit risk in terms of whose roof the RESCO uses since that rooftop owner is not buying any of the electricity generated from the RESCO. The RESCO sells it all to the discom, so is just looking for an optimal sunny location from which to generate the most electricity.

- A rental rate per square foot of roof space is offered. The idea is that the RESCO will locate its own rooftop system on the rented roof. None of it will be consumed by the rooftop owner, who will continue to buy from the grid as usual.
- The rental income from the roof could help the rooftop owner to offset their electricity bill or could be treated as any other income. There is no direct relationship with the electricity bill. This model was the earliest one in India, tried in the state of Gujarat in 2010–2011 when the current Prime Minister of India was Gujarat state's chief minister.
- Consumers with an attractively positioned roof (one that is receiving high solar irradiation, is south-facing and unshaded) are approached by the discom, or by a third-party agent on behalf of the discom, or by a RESCO. Rooftop owners are made the offer of a fixed monthly rental payment to allow the discom or RESCO to place its own rooftop solar system on the customer's roof.
- There is no connection between the discom or RESCO-owned equipment and the customer's meter, and no question of any consumption by the customer of the solar electricity being generated on their roof.
- The difference between rooftop rental and gross metering is that the rooftop rental payment by the discom is always constant, whereas the gross-metering payment depends on the metered amount of generation that has been exported from the roof to the grid and varies every month.
- An even more profound difference is ownership: in the gross-metering model, the customer is the investor and owner of the rooftop system. In the rooftop rental model, the discom or a RESCO is the investor and owner of the rooftop system. In gross metering, the rooftop owner makes their money from their own panels on the roof, whereas in rooftop rental, the rooftop owner makes their money from their floor-space on the roof.
- With ownership comes risk allocation and motivation: in gross metering, the burden is on the customer to keep the panels dust-free and generating at the maximum efficiency because their earnings will depend on how much metered energy the panels generate and send back into the discom grid.
- In the rooftop rental model, by contrast, the generation risk is borne by the discom or the RESCO, whoever is the owner of the rooftop system. The customer always receives a flat and constant payment for providing the space to place the panels, regardless of whether anything is generated from the panels or not. They do not have to worry about panel cleaning and maintenance. The discom or RESCO crew requires access to the roof at agreed intervals to



come and clean the panels and check that the inverters are working and so on; this will have to be part of the rooftop space rental agreement. The rooftop owner is not concerned with keeping an eye on the panels—their fixed payment is assured regardless of how much generation occurs. The discom or RESCO also do not necessarily have to measure how much is generated as they are not paying anyone per kWh. They pay only the flat rental fee and hope for the maximum amount of generation to occur. Generating for themselves on well-located rooftops will help discoms to meet their Renewable Purchasing Obligation at a lower cost. They also benefit from having clean energy generation injected into the last mile grid close to consumption centres, which allows them to avoid costly long-distance transmission losses.