Community Solar for Advancing Power Sector Reforms and the Net-Zero Goals

Bhawna Tyagi and Neeraj Kuldeep

Issue brief | November 2023

Image: Abbie Trayler Smith/DFID/ClimateVisuals

Executive summary

Decarbonising the power sector is critical to achieving India's net-zero goal by 2070. The electricity sector is the most carbon emission-intensive sector, contributing to ~40 per cent of total carbon emissions in India. However, to meet national climate and renewable energy goals, there is a need to infuse operational and financial efficiencies in the distribution sector. The discoms in India struggle with under-recovery of cost, billing and metering inefficiencies, high cross-subsidy burden, higher transmission and distribution (T&D) losses, legacy power purchase agreements (PPAs), and underinvestment in infrastructure. These inefficiencies in the distribution sector impact the financial health of the overall power sector.

Residential consumers are at the core of challenges faced by the distribution companies. More than 70 per cent of households consume less than 100 kWh a month (Agrawal et al. 2020a). These consumers receive electricity at highly subsidised rates that are non-cost reflective, thereby resulting in under-recovery of cost and impacting the financial health of discoms. **Distributed solar can play a catalytic role in the financial turnaround of the distribution sector by injecting low-cost solar to serve the subsidised consumers, which helps reduce the average cost of supply**. These consumer segments also have the highest share in terms of economic potential, with 80 per cent of the total economic potential lying between the 0–3 kW system size. However, the uptake of rooftop solar in the residential segment has been marginal over the years, particularly among the low-consumption consumers. Several perceived risks such as low payment security, smaller and fragmented demand, and higher operational costs, hinder its adoption in the residential sector.

A. Community solar models – Resolving the discom's challenges

Innovative business models such as community solar would be essential to overcome these risks and support accelerated rooftop solar deployment. Community solar models aggregate demand and propose installing a more extensive system on the community premises owned by the utility, developer or community. These units connect at the distribution level, providing more comprehensive and controllable power supplies than household units. Utility-driven community solar models are also an attractive proposition for discoms. It benefits discoms in avoiding power purchase costs, meeting renewable energy obligations, reducing transmission and distribution loss, and transmission and generation capacity procurement.

Community solar models driven by discoms also provide different grid services compared to utility-scale installations. Solar units sited at feeders and substations provide power where users locally consume power, and mitigate grid inefficiencies that are currently present in the traditional model of pushing power out from a centralised generation source. Community solar models offer the discoms greater operational control at the community level, to serve the local load. The distributed nature of these systems adds to grid reliability and system benefits. The locally situated and

> **Distributed solar can play a catalytic role in the financial turnaround of the Power distribution sector.**

load matched distributed resource reduces pressure on the grid by bringing down congestion and avoiding distribution system upgrades required to accommodate unidirectional power that larger resources might push. Community solar models also solve the grid stability challenges arising from rooftop solar's fragmented and haphazard penetration, such as reverse power flow, voltage fluctuations, and power loss (Uzum et al. 2020).

We present the case of utility-led community solar models in India and assesses the model's feasibility for the states of Bihar and Meghalaya. To estimate the benefits to discoms from community solar, we adopted a framework developed by Kuldeep et al. (2019), called Valuing Grid-Connected Rooftop Solar (VGRS) framework. The findings from the analysis show that at the system level, 100 kW installation by North Bihar Power Distribution Company Limited (NBPDCL) and Meghalaya Energy Corporation Limited (MePDCL) saves INR 2.7 crore (or USD 3.5 million[1]) and INR 2.8 crore (or USD 4 million) during the lifetime of the project, respectively. Among other benefits, savings were highest from the avoided power purchase cost. In terms of per kW, Bihar saves INR 2.7 lakh (or USD 3,558) per kW and Meghalaya INR 2.8 lakh (or USD 3690) as shown in ES 1. The scaling up of community solar installation under different scenarios increases the benefits multifold. A total of 500 MW community solar systems' installation in Bihar results in a projected system-level net benefit of INR 10,478 crore (or USD 1.4 billion) over 25 years. In the 500 MW installation scenario, the first-year benefits could reduce the subsidy requirement by 8 per cent (BERC 2022).

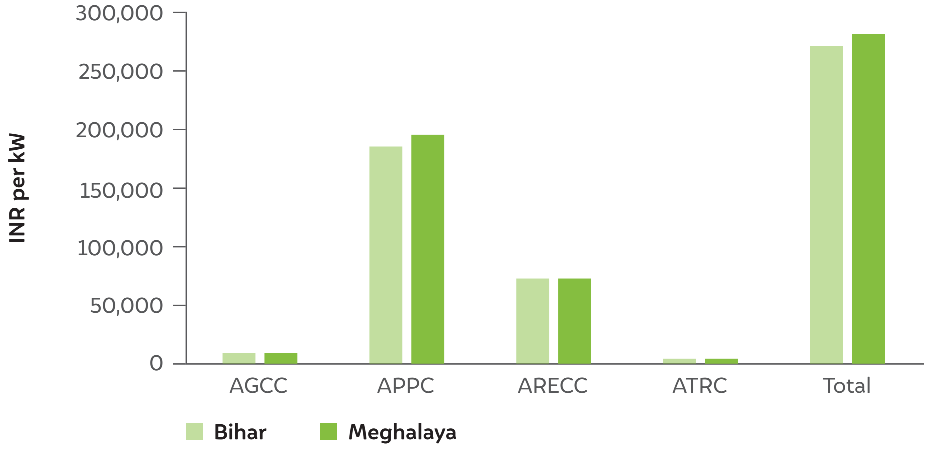
B. Recommendations

There are long-term benefits for discoms from scaled community solar installations. However, the current Indian ecosystem is not ready to adopt these models and is restricting their adoption. The key barriers include discom access to finance, absence of financial incentives, tedious tendering process, lack of interest among discoms, etc.[2]

1. USD to INR conversion rate considered INR 76.747 as on 8 May 2022 from Reserve Bank of India (RBI).

2. Based on stakeholder consultations

Figure ES1 System-level benefits if a 100 kW community solar system is installed by NBPDCL and MePDCL



Source: Authors' analysis using the VGRS framework developed by Kuldeep et al. (2019)

As these models have not been tested in India, a pilot of such a project will demonstrate the potential benefits to discoms with support from enabling policies. To support and scale up the community solar model in India, we propose the following recommendations:

- **The provisions of the Ministry of New and Renewable Energy (MNRE) Rooftop solar (RTS) Phase II scheme could be modified**, to incorporate community systems that are not installed on consumer premises but serve or benefit residential consumers. This would enable utilities to avail of the capital subsidy for aggregated community solar installations and help drive the market away from subsidies.
- **MNRE or states could propose a dedicated scheme for community solar** to keep a targeted focus on community solar in the long run. The focus of the scheme would be on low-paying consumers in rural and semi-urban areas receiving high electricity subsidies. The capital incentives from MNRE for community installation would also be covered under the scheme.
- **To finance the utility-led community solar model, the state electricity subsidy amount could be explored in two ways:** direct lending to utilities for installations or creating a payment security mechanism to raise cheap capital. Utilities could explore creating a special purpose entity (SPV) to seek finance. In addition, utilities could explore concessional loans through the existing line of credit from the World Bank and Asian Development Bank.
- **The Ministry of Power (MoP) could impose a criterion under the Revamped Distribution Sector Scheme (RDSS) by linking the incentive of improved power performance** by achieving x percentage of the sales through community solar in rural and semi-urban localities. This will encourage utilities to undertake community solar installation and improve system-wide benefits and potential future losses related to cross-subsidy burden, thereby impacting the performance of discoms.
- **A model tender document could be prepared by MNRE/Solar Energy Corporation of India Limited (SECI)** with key elements such as simplification of the process, rationalisation of the timeline, including buffers for external shocks, etc. to smoothen the process of implementation. This would encourage participation from solar companies in distributed solar tenders.
- **Introducing battery storage along with the community solar installation could increase discoms' benefits multifold.** The existing community solar sites become potential candidates for introducing storage at a later stage.
- **In the long run, the community solar model could be extended to include consumer subscriptions**, allowing them to be part of the energy transition. Incentives could be introduced at a later stage to encourage consumer participation.

1. Rethinking power sector reforms

The power sector in India has undergone a significant transformation, both at the central and state levels. Several efforts have been made in the last few decades to revamp the distribution sector, such as unbundling state electricity boards, allowing open access in distribution, and making regulatory bodies autonomous. However, the sector continues to face considerable challenges.

Distribution utilities (discoms) continue to struggle with challenges such as theft, billing and metering inefficiencies, high cross-subsidy burden, higher T&D losses, legacy PPAs, and underinvestment in infrastructure (Regy and Sarwal 2021). Ultimately, these challenges have led to a large number of discoms facing capital challenges and insolvency. The residential and agriculture consumers are at the heart of these financial challenges (Regy and Sarwal 2021). Under current conditions, electricity supplied to these consumers is highly subsidised across states, resulting in low revenues and leading to under-recovery of costs by discoms. The difference between cost and revenue is primarily compensated by imposing high tariff rates on commercial and industrial consumers, while the remaining revenue gap is supported through state subsidies and revenue grants under the *Ujwal DISCOM Assurance Yojana (UDAY)* scheme. In 2019–20, discoms recovered only 95 per cent of the total expenditure incurred on supplying electricity to consumers, after taking into account state subsidies, revenue grants, and other incomes (PFC 2021). Tariff subsidies constitute a significant portion of the total revenue, amounting to 17 per cent (PFC 2021). The cost of under-recovery by discoms impacts the overall financial health of the power sector (Garg and Shah 2020). This condition threatens the viability of the sector and handicaps the sector's ability to contribute to meeting national climate and renewable energy goals.

Operational performance of discoms across India lags behind performance of discoms in other modern countries. The T&D[3] losses at the national level stand at ~20.66 per cent, with distribution losses amounting to INR 31,672 crore (or USD 4.17 billion[4]) (CEA 2022; PFC 2021). The aggregate technical and commercial (AT&C) losses have been improving, down to ~22 per cent, but are still considerably high as compared with performance in other countries such as Japan (4 per cent), China (5 per cent), the United States (6 per cent) (Regy and Sarwal 2021). The billing and collection efficiency of discoms has also improved but remains far from achieving 100 per cent and currently stands at 85 per cent and 92 per cent, respectively. The profitability gap continues to be positive, as demonstrated by the average cost of supply (ACS) being higher than the aggregate revenue requirement (ARR)[5] and is currently at ~INR 0.6 per kWh (PFC 2021). The operational and financial performance varies considerably across states and between private and state discoms. The AT&C losses vary from more than 30 per cent in Madhya Pradesh, Jharkhand, and Bihar, to less than 15 per cent in Tamil Nadu, Kerala, Punjab, Gujarat, Andhra Pradesh, etc. (PFC 2021). A few states and union territories perform well and incur surplus instead of revenue losses per unit, such as Gujarat, Assam, Chandigarh, and Mizoram (PFC 2021). The inefficiencies in the distribution sector impact the financial health of discoms and result in massive overdue balances to generators. As of March 2022, the discoms' overdue balance to generation companies at the national level is INR 92,184 crore (or USD 12 billion) (Ministry of Power n.d.).

Several central schemes have been introduced to fastrack the upgradation of distribution infrastructure and improve operational efficiencies, such as UDAY, *Integrated Power Development Scheme* (IPDS), and *Deen Dayal Upadhyaya Gram Jyoti Yojana* (DDUGJY) (Regy and Sarwal 2021). However, the distribution sector continues to face clear barriers. Transitioning to distributed renewable energy (DRE) is emerging as an opportunity that can also contribute to meeting various objectives envisioned in the above-mentioned schemes, and this can lead to improved discom performance such as making the residential consumer self-sufficient, reducing billing and collection issues, and reducing losses by co-locating the systems at the point of consumption, among others.

> **Transitioning to distributed renewable energy (DRE) is emerging as an opportunity.**

---

3. The T&D losses refer to technical and commercial losses due to energy dissipation and pilferage. Another component of commercial losses is non-recovery of billed amount that refers to collection losses. Adding collection losses to T&D losses is called as AT&C losses.

4. USD to INR conversion rate considered INR 76.747 as on 8 May 2022 from RBI.

5. The ARR refers to the amount of revenue required to recover the cost pertaining to the licensed business, i.e. electricity supply.

1.1 Low-income households and the discom's challenges

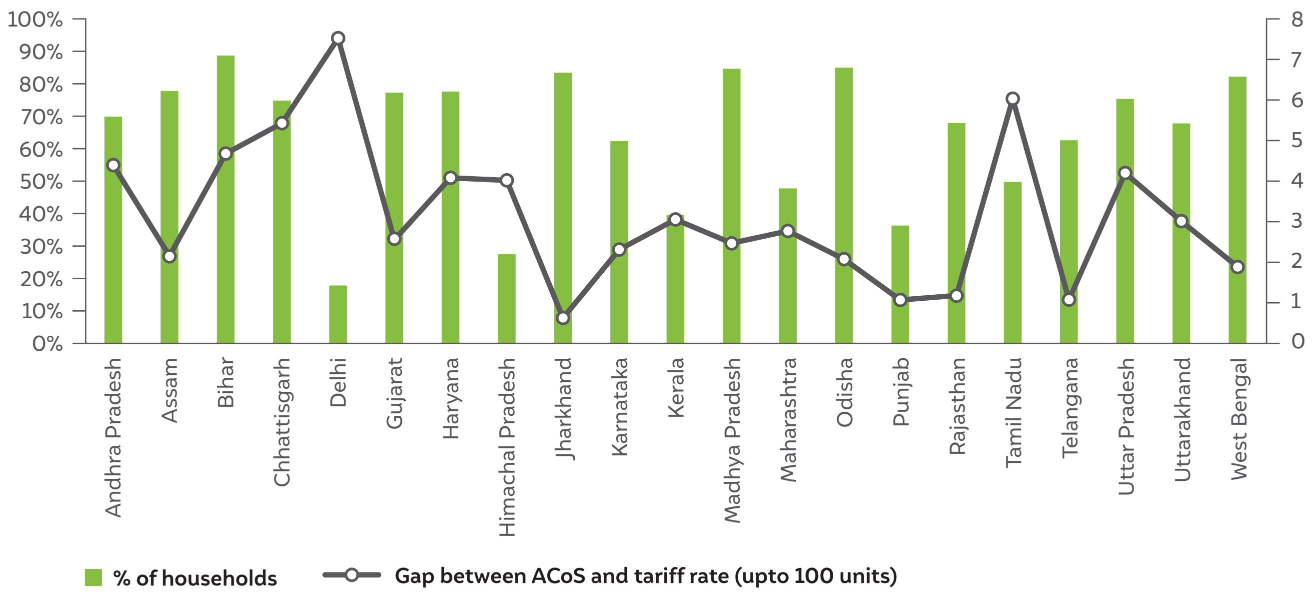
In most of the states in India, the **electricity consumption is positively skewed, with more than 70 per cent of households consuming less than 100 kWh a month** (Agrawal et al. 2020b). A large portion of these households resides in rural and semi-urban areas. These consumers' usage characteristics and payment habits contribute significantly to financial and operational challenges faced by discoms. The linkage between low-income households and discom challenges is explained in detail below.

- **Low paying capacity**: Due to low consumption and low paying capacity, these consumers receive electricity at highly cross-subsidised rates. The retail tariff rate paid by these consumers is not reflective of cost causation, which is evident from the significant gap between tariff rate and the average cost of supply across states, as shown in Figure 1. Therefore, their contribution to the discoms' overall revenue is not reflective of the costs for services they receive. Since it frequently costs discoms more to supply than they can collect from low-income consumers, they are disincentivised from serving these consumers, and billing and collection efficiency remain poor.

- **Low demand**: The low-income rural households reside in sparsely populated areas. Along with distance, overall low consumption and the propensity to use electricity at peak times make serving these consumers more expensive. The usage pattern of these customers and the lack of revenue they generate disincentivises discoms from upgrading the distribution infrastructure, further contributing to inefficiencies and higher power losses. This leads to a poor quality of service being supplied from the grid, with frequent power cuts and voltage fluctuations as a normal occurrence.

- **Universal access to electricity**: India has nearly electrified 100 per cent of its households with impetus from central schemes (such as *Rajiv Gandhi Grameen Vidyutikaran Yojana* (RGGVY), DDUGJY, and *Saubhagya*) (Saubhagya portal, n.d.). However, to achieve its objective of universal electricity access, there is also a need to improve the reliability and quality of the power supply. This requires investment to improve the distribution infrastructure. However, the discoms' poor financial health hinders the sector's transformation. The schemes focused on rural electrification are at odds with supporting the financial turnaround of the discoms because they do not address the challenges around tariff realisation (Regy and Sarwal 2021).

Figure 1 The difference between tariff rate and cost of supply is significant across states



Source: Agrawal et al. 2020b; PFC 2021

1.2 Community solar model – a viable pathway to the discom's fiscal health

Distributed solar can play a pivotal role in the financial turnaround of the distribution sector by injecting low-cost solar to serve the subsidised consumers, and it helps to reduce the average cost of supply. It can also be instrumental in the decarbonisation of the residential sector, critical to achieving India's renewable energy ambitions and net-zero goals. In addition, it offers several potential co-benefits such as job creation, better facilities for education and health, and improved power supply quality, among others (Purkayastha et al. 2021; Regy and Sarwal 2021; Tyagi et al. 2021). Distributed solar can come in many forms, from small modular rooftop units sited on consumers' homes, to medium-sized units that serve the entirety of a multi-household building, to large units (e.g., 100kw) sited at a feeder or substation which pushes power to the grid and provides a variety of power and grid services.

Community solar models are a popular business model in the United States for deploying distributed solar technology. The model aggregates demand and proposes installing a larger system on the community premises owned either by the utility, developer or community. These units connect at the distribution level, providing larger and more controllable power supplies than household units. The medium-sized community solar model offers opportunities to solarise rural and semi-urban areas where consumers lack adequate roof space, in shaded areas, or face difficulties getting access to solar (such as low-income households). However, India's discoms are not leveraging the benefits of distributed solar, and rather, many are opposing their adoption. Some discoms perceive the increased uptake of distributed solar as a disruption to their existing business model. The apprehensions among the discoms include the growing adoption of distributed solar by commercial and industrial consumers, further negatively impacting their revenues. Other key concerns include inequitable tariff mechanisms, the need to augment infrastructure, impact on the grid stability, increase in administrative responsibility, greater operations and maintenance, difficulty in recovery of fixed costs, etc. (Shakti and Deloitte 2016). The central government is pushing the deployment of rooftop solar through various schemes, such as a scheme for grid-connected rooftops and offering capital subsidies. However, the uptake of rooftop solar in the residential segment has been marginal over the years, particularly among low-consumption households in rural and semi-urban localities.

Within the residential segment, the early adopters so far are the high paying residential consumers and not rural and semi-urban households. **While the opportunity exists in rural and semi-urban areas, there is significant inertia to move to rooftop solar due to limited awareness, high upfront costs, lack of financing, low paying capacity, etc.** The consumer-centric challenges could be overcome through innovative models such as discom-owned community solar. This model also helps to overcome the discoms' concerns over revenue loss, and supports accelerated distributed solar deployment.

Utility-driven community solar models are an attractive proposition for discoms. They enable the discoms to financially allocate the cheap, fixed price solar to the highly subsidised customers. It thereby benefits discoms in avoiding power purchase costs, meeting

BOX 1 Success of the Community Solar Model in the US

Utilities across the United States have recognised the potential of community solar projects by deploying distributed solar technology, increasing energy independence, hedging against rising fuel costs, cutting carbon emissions, and creating jobs. As a result, as of 2020, 3.25 GW of community solar capacity has been installed across 39 states in the United States. To further support these installations, 22 states have also announced enabling policies and regulations (Heeter et al. 2021). Installations have grown rapidly at the rate of 121 per cent since 2010 with the highest installation of 1 GW in 2020 (Heeter et al. 2021).

These projects have resulted in significant reduction in energy burden for low-income consumers. For example, a community solar installation in Massachusetts reduced energy burden by ~3.2 per cent for the lowest income bracket. Another community solar installation in Washington reduced the energy burden for the lowest income households from 13.5 per cent to 8.8 per cent (Heeter et al. 2021).

Source: Heeter et al. 2021

renewable energy obligations, reducing transmission and distribution loss, and transmission and generation capacity procurement. This will improve the financial health of the discoms by closing the gap between the cost of supply and revenue generated, resulting in reduced tariff rates in the long run. Over time, improvement to the financial health of the discoms by virtue of closing the gap between the cost of supply and collections will translate into savings for these consumers in the long run. These units can also provide balancing services and other grid needs. In addition, it helps them to contribute to the state's solar energy goals through the accelerated deployment of distributed solar.

Community solar models are driven by discoms and also provide different grid services than utility-scale installations. Solar units sited at feeders and substations provide power where users locally consume power and mitigate grid inefficiencies that are currently present from the traditional model of pushing power out from a centralised generation source. It offers the discoms greater operational control at the community level, to serve the local load. The distributed nature of these systems adds to grid reliability and adds system benefits. The locally situated and load matched distributed resource reduces pressure on the grid by reducing congestion and avoiding distribution system upgrades, to accommodate unidirectional power that larger resources might push. It also solves the grid stability challenges arising from rooftop solar's fragmented and haphazard penetration, such as reverse power flow, voltage fluctuations, and power loss (Uzum, et al. 2020). Community solar systems are also opportune sites for introducing battery storage solutions, creating further opportunities for grid support and other services.

> **Utility-driven community solar models are an attractive proposition for discoms as they provide an opportunity to serve highly subsidised consumers with cheaper solar power.**

2. Distributed solar adoption in rural and semi-urban areas in India

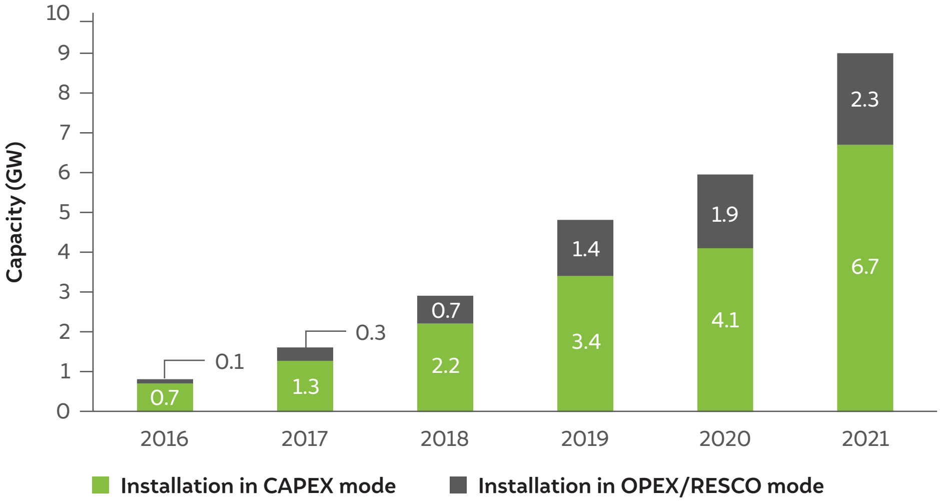
Distributed solar[6] holds an important place in India's renewable energy ambitions. A 40 GW target was allocated to RTS out of the 175 GW target by 2022, to recognise its technical potential. However, the distributed sector has struggled to keep pace with utility-scale solar deployments.

The **share of RTS is minuscule and stands at 7.7 GW compared to the 37.5 GW capacity installed through utility solar, as on January 2022**, as shown in Figure 2 (Bridge to India n.d.; MNRE n.d.).

The RTS installations are primarily concentrated in two segments within the DRE sector – commercial and industrial (C&I). The residential sector only contributes 20 per cent of the total capacity, as shown in Figure 3. The high grid electricity tariff rates faced by C&I consumers make RTS adoption a value proposition. The solar developers also favour consumer segments that are most attractive economically and offer scale, such as C&I consumers. The CAPEX model is the preferred mode of installation by the developer, as shown in Figure 2, because the owner invests the upfront capital, and the developer is paid to install the system. Therefore, the developer/installer is not exposed to the consumer's risk of default under the CAPEX model. For the OPEX/RESCO model, developers make the capital investment and mitigate their credit exposure to consumers by targeting high creditworthy consumers. The consumer credit exposure makes this model less preferred by developers. In addition, the RTS installations are primarily concentrated in industrial states such as Gujarat, Maharashtra, Haryana, and Rajasthan, which have become leaders in RTS for the C&I segment.

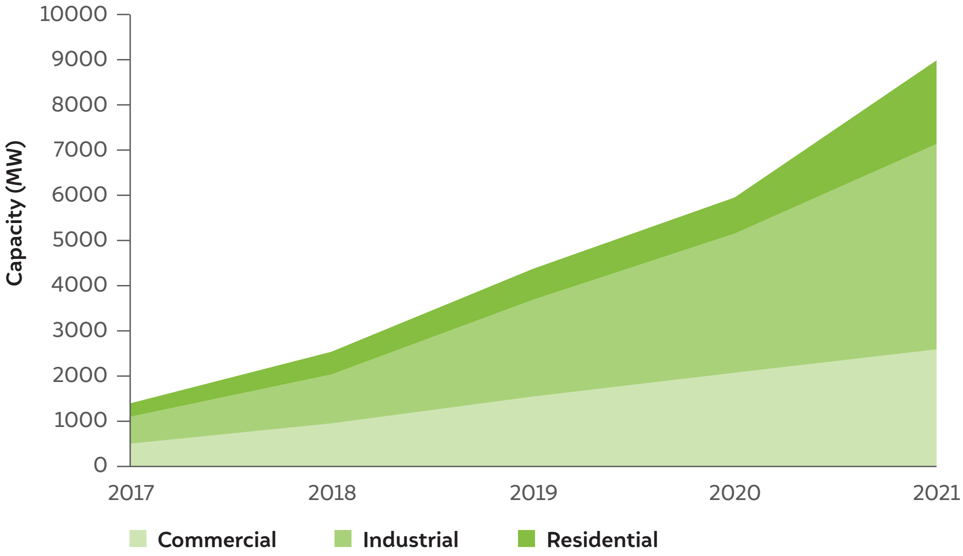
6. In the report, distributed solar is used to refer to the grid connected rooftop solar installations. We have not considered off-grid installations under this study.

Figure 2 7.7 GW of rooftop solar installed against 40 GW of utility solar till June 2021



Source: Bridge to India, n.d.; MNRE, n.d.

Figure 3 Rooftop solar installations are highest in the industrial sector



Source: Bridge to India n.d.

Similar trends can be observed within the residential sector, where urban consumers with higher incomes and awareness of the benefits of solar are the leading adopters. These consumers also exhibit higher consumption characteristics and benefit from the market and economic benefits of adoption. At the same time, the role of RTS in rural areas is minimal and, in some cases, has limited access to electricity. Limited adoption in the rural semi-urban locality is also due to the challenges described in detail in Section 2.3. Barriers, such as financial constraints, policy uncertainties, restrictions on capacity installation by states, lack of uniformity in statutory approvals, and lack of consumer awareness, contribute to its limited adoption.

2.1 Switching gears – Focus on semi-urban and rural consumers

Improving the financial health of discoms is essential in decarbonising the high cost of service to low-income households. National and state decarbonisation goals require their inclusion. In order to include these segments, discoms must find opportunities to cover these costs but must do so in a way that meets the consumers' and the utility's needs. Under the current state, opportunities for these segments to decarbonise their consumption are non-existent and have not been the focus areas of policymakers. There is a need to switch gears and shift the focus to semi-urban and rural areas for three primary reasons:

- **Untapped opportunity in rural and semi-urban areas**: About 80 per cent of the total economic potential (57 GW) for RTS systems lies in the 0–3 kW system size. This is in line with electricity consumption characteristics of less than 100 units[7] per household. This consumer segment offers potential when targeted for reducing the discom solvency challenges. Presently, the RTS potential in the 0-1kW category remains untapped due to unattractive economics and policy constraints. Only eight states allow RTS systems below 1 kW in their net-metering regulations, such as Haryana, Goa, Madhya Pradesh, and Maharashtra. The positive concentration of economic potential is consistent across states. Therefore, tapping into this segment requires innovative business models such as community solar.

- **Benefits to discoms in overcoming legacy issues**: Tapping into this opportunity shows the potential for discoms to improve their financial solvency. However, the current financial condition of the cash-strapped discoms is a significant barrier to achieving potential gains. There are several direct benefits to discoms deploying medium-sized distributed solar such as community solar installations, as discussed below:

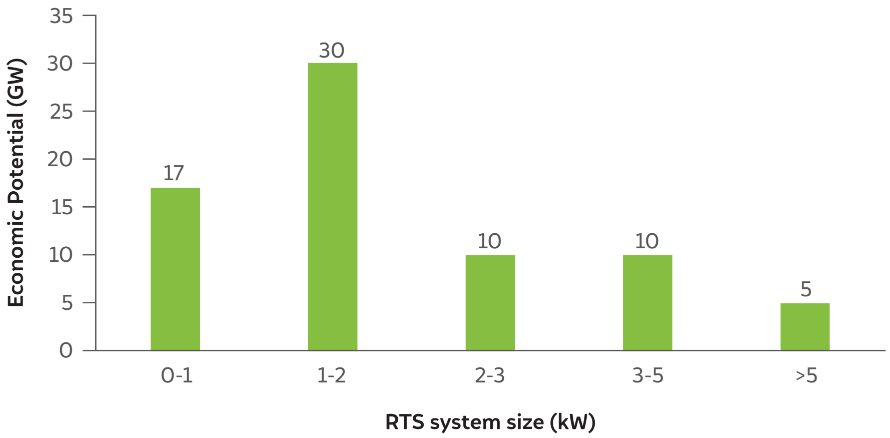
  » **Improved revenue realisation**: Community solar injects low-cost power at the feeder level and caters to the local load. It helps in reducing the variable part of the power purchase cost that the discom pays for the actual quantum of electricity procured from generators. Therefore, it offers a means to reduce the cost of servicing the residential consumers in rural geographies and the revenue gap.

  » **Reduced infrastructure investment**: Electricity generating stations are usually located far off, resulting in transmission and distribution losses, both inter-state and intra-state. This requires investment in upgrading infrastructure, to achieve universal electricity access. By co-locating the generation with a distribution feeder, community solar can reduce these losses and improve the overall efficiency. It also helps in reducing the investment in infrastructure upgradation.

  » **Reduced carbon footprint**: Discoms can cut down on their carbon footprint by using the solar electricity generated from these community installations, and it helps to contribute toward the discoms' renewable purchase obligations (RPOs).

- **Overall economic development of rural areas**: Integrating solar in the rural economy also offers several indirect benefits, such as improving the reliability and quality of power supply to the 'last mile'[9], boosting rural income, strengthening education and health services, and providing employment opportunities. The grid supply is

Figure 4 Rooftop solar economic potential is highest in the 1–2 kW category



Source: Authors' analysis based on IRES Survey data[8]

7. Unit refers to kWh.
8. The most preferred system size is in the 1–2 kW (30GW) category, followed by 0–1 kW (17 GW) and 2–3 kW (10 GW). Presently, the RTS potential in the 0–1kW category remains untapped due to unattractive economics and policy constraints.
9. Last mile refers to the consumers in rural areas or semi-urban areas facing power supply access and quality issues. This condition typically occurs with customers furthest from centralized generation. These customers often represent the highest incremental cost customers to serve.

available typically for less than 20 hours in many northern and eastern states (MoP 2019). Power outages continue to be a challenge in the states. Improvement in reliable supply to health centres will boost critical healthcare services in rural areas, including immunisation, labour and deliveries, and antenatal and neonatal care (Mani et al. 2019). Powering livelihood through decentralised clean energy provides an opportunity to boost rural income. There is an opportunity to create USD 50 billion markets for new livelihood appliances (CEEW n.d.). In terms of employment, distributed solar creates seven times more jobs than utility solar and has the potential to generate 2.8 lakh jobs by 2030 (Tyagi et al. 2021).

2.2 Challenges to distributed solar adoption in semi-urban and rural areas

The limited adoption of distributed solar in rural and semi-urban areas is due to several deterrents, both on the demand and supply sides. Some of the dominating factors are:

- **Awareness gap**: Despite the considerable push from the MNRE to educate consumers, there is a lack of awareness among residential consumers about potential benefits. According to data from India Residential Energy Survey (IRES), only 44 per cent of households have heard about rooftop solar, with 48 per cent in urban and 42 per cent in rural areas (Agarwal et al. 2020).

- **Affordability and access to finance**: The phase II scheme of MNRE offers a subsidy to systems over 1 kW and above in size in the residential sector (MNRE 2019). This limits the access to low-cost solar to a significant fraction of households. Access to low-cost financing is a challenge even for systems larger than 1 kW. Financing is needed to pay for the remaining system cost, which is still significant for these consumers even with central and state subsidies.

- **Policy asymmetry**: The solar policies vary from state to state in terms of minimum and maximum capacity, constraints on sanctioned load, distribution transformer capacity, etc. For most states, the system size limit varies from 1 kW to 1 MW and allows system capacity of up to 100 per cent of the sanctioned load (Jain et al. 2019). A few states and union territories have also placed restrictions, based on the sanctioned load, such as Jammu and Kashmir, which allows for the installation of up to 50 per cent of the sanctioned load. This restricts consumer ambitions and allows them to substitute only a portion of their demand, even though they can install larger systems. Furthermore, there are regulatory hurdles, such as delays in approving feed-in tariffs (FITs), installing net meters, and adopting virtual net metering regulations.

- **Lower participation rate**: The traditional CAPEX model will not work for these consumer segments as even a small upfront payment is a high cost for them (Saji et al. 2019). In the case of the OPEX/RESCO model, the size of these systems is too small for developers.

- **High cost of consumer servicing**: Vendors face several challenges in targeting these geographies, such as the high cost of servicing these consumers due to low and fragmented demand, maintenance of these distributed systems, highly subsidised electricity, and unreliable sources of income (predominantly agricultural income or income from petty jobs). Additionally, difficult terrains and road/network connectivity make developing infrastructure in rural areas much more challenging than in urban areas. The consumers in lower consumption slabs receive electricity at highly subsidised tariff rates, making rooftop solar unattractive. The additional costs of consumer acquisition and demand aggregation borne by developers discourage them from participating.

Traditional approaches to decarbonising these segments have not been successful so far. Therefore, we need to re-strategise and bring innovation in our approach to target the rural and semi-urban areas.

> **Adoption of rooftop solar is limited in semi-urban and rural areas due to several constraints such as limited awareness, lack of financing options, and policy uncertainty.**

3. Leveraging the utility-owned community solar model

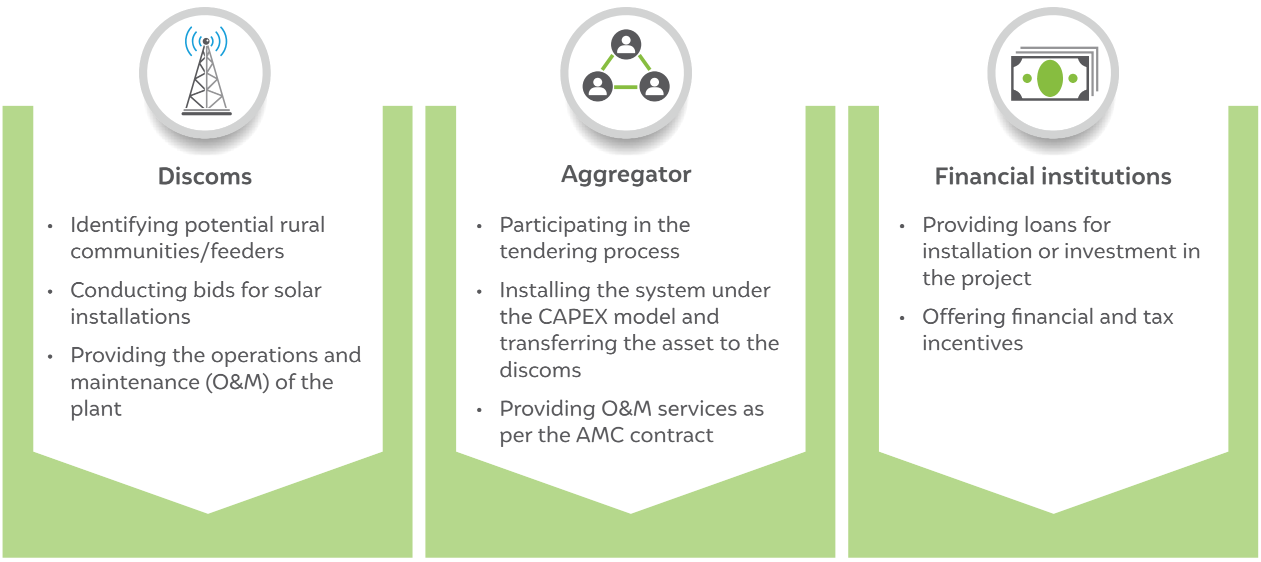
Community solar as a concept helps overcome market barriers in serving residential households in rural and semi-urban localities, such as lack of awareness, access to finance, and inadequate roof space. It provides an opportunity to community members to be part of the energy transition by sharing the benefit of solar power. The deployment of community solar models in the United States has been done primarily in three ways – utility-owned-and-operated, developer-owned-and-operated, and community-owned-and-operated (Coughlin et al. 2010). However, each ownership mode presents its own set of challenges. In the case of the community-owned-and operated model, major barriers are the need to sensitise consumers about the potential benefits, lack of access to upfront capital by consumers, and the need for bringing about regulatory changes to facilitate such a model (such as introducing virtual net metering regulations, updating billing and metering mechanisms, etc.).

Considering the low success of RESCO models in India for RTS, developers will have similar apprehension for RESCO-based community solar models, such as the risk of consumer default, policy uncertainty, and burden of maintaining the system for 25 years, etc. **Therefore, in the case of India, utility-led community solar models are more promising**. This is because discoms are best placed to overcome these challenges (operations and maintenance, upfront cost, billing and metering, virtual net-metering, etc.) and could also achieve scale.

Under the discom-owned-and-operated model, the discom deploys a medium-sized solar PV system (100–150 kW). The installation is carried out either on the discom's substation land or on community land, in close proximity to a residential feeder. In the case of non-segregated feeders, the feeder serving predominantly residential consumers is targeted. The energy generated by these systems is directly fed into the feeder supplying the residential load. The system will be set up by a solar developer/EPC company selected through a tendering process. The responsibility of operating and maintaining the system lies with the discoms.

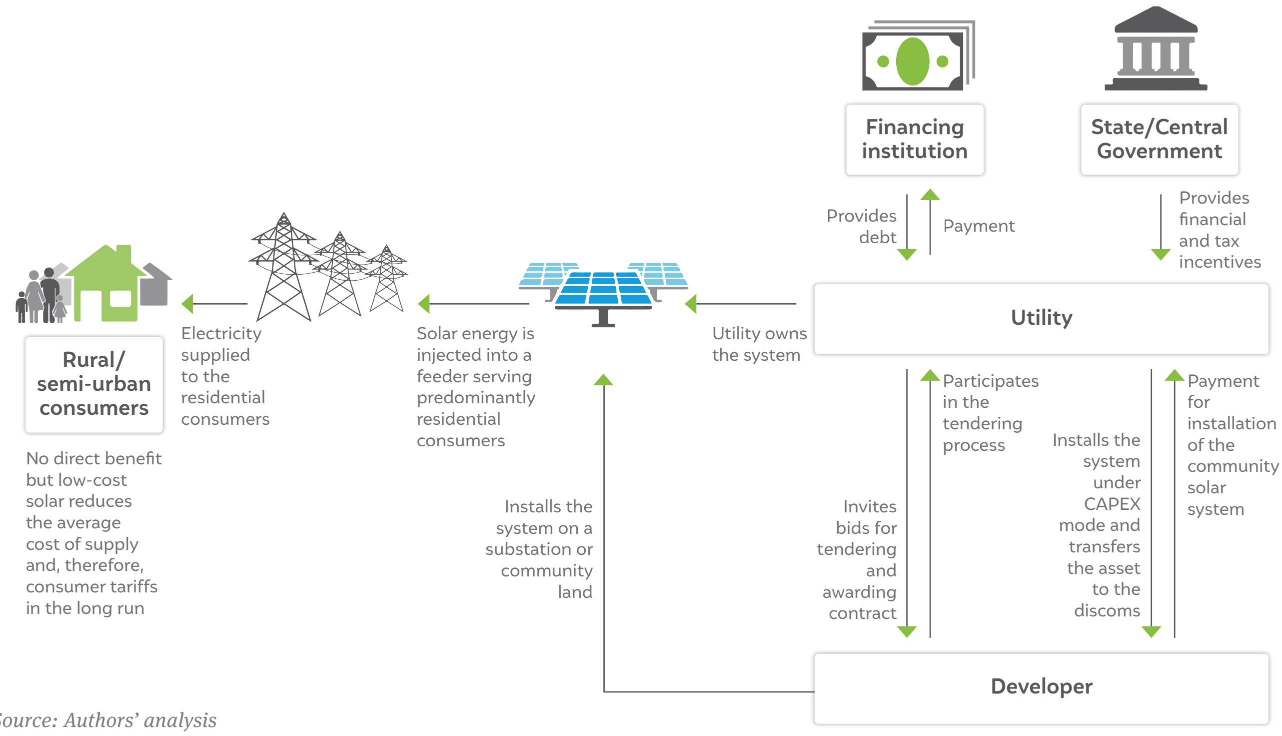
In this model, discoms benefit from the reduced cost of providing electricity to sparsely distributed rural consumers. This model involves no direct community engagement but provides indirect benefits to consumers. That is, the overall savings under this model improve the discoms' financial health and reduce supply costs. This translates into a reduction in tariff rates in the long run for consumers. In addition, the quality of power supply also improves for consumers with the co-location of the generating station closer to the feeder. The responsibilities of different stakeholders are described as follows, and shown in Figure 6:

Figure 5 **Responsibilities of different stakeholders under the community solar model**



Source: Authors' analysis

Figure 6 Schematic of a utility-owned community solar model



Source: Authors' analysis

BOX 2 Sol Partners Cooperative Solar Farm, Colorado

A case study of the utility-sponsored model

United Power is an electric cooperative, serving areas in Northern Colorado. The utility initiated a project in 2009, where they installed a solar farm on their land and allowed its consumers to participate in the programme. The project was financed by United Power, with a grant of USD 50,000 from the State Governor's office and also received tax credit. The programme allowed for participation from both, its residential and commercial consumers. Under the programme, consumers subscribe to capacity generated from a panel for a period of 25 years by paying a one-time fee. Energy generated from their panel's production gets credited in the customers' monthly bill at a solar rate (11 cents/kWh) marginally higher than the retail rate (10.5 cents/kWh). Phase I of the programme was subscribed by 25 consumers. The RECs generated from the project were retained by the utility. The programme had a vision of 'grow as you go' where it was envisioned that new consumers would fund the expansion of the project. Overall, the project anticipated USD 900 worth of electricity credit over a period of 25 years. After the success of phase I, United Power rolled out more programmes. (Coughlin et al. 2010)

Source: Coughlin et al. 2010

3.1 Business case for utility-owned community solar in Bihar and Meghalaya

The project is supported by the US-India Clean Energy Finance (USICEF) task force which is a coalition between the Ministry of New and Renewable Energy and the US Department of State. Bihar and Meghalaya were selected as the potential states under the project, to assess the utility-led community solar model's feasibility in targeting residential communities. Both states are predominantly comprised of rural households, with more than 80 per cent of households living in rural areas (Census 2011). In Bihar, more than 60 per cent of energy is sold to domestic consumers, whereas their share in the revenue is 31 per cent, resulting in a revenue gap (BERC, 2022; PFC 2021). A similar trend is observed in the case of Meghalaya, with a share of about 26 per cent in energy sold and about 24 per cent in revenue (MSERC 2021; PFC 2021). To compensate for the revenue gap, Bihar and Meghalaya discoms received a subsidy of INR 5,193 crore (or USD 0.7 billion) and INR 10 crore (or USD 1 million), respectively (PFC 2021).

BOX 3 Implementing learnings from the US experience to India

India's MNRE and the US Department of State (DOS) signed a statement of intent on 15 November 2018, on the utility-led, community-based demand aggregation business model collaboration under the USICEF task force. The task force seeks to tailor successful US models to the local context in order to scale India's clean energy sector.

Under this task force initiative, three states have been identified, to study and tailor a distributed solar business model to its context – Delhi, Bihar and Meghalaya. Delhi is ideal for rolling out utility-led, community-driven demand aggregation campaigns called 'Solarise Campaigns'. These urban campaigns have been successfully launched in collaboration with Delhi discoms.

For community solar models, Bihar and Meghalaya have been considered, for studying the feasibility of implementing utility-led models as dominated by rural and semi-urban consumers.

Source: Authors' analysis

In terms of per-unit basis, Bihar received a tariff subsidy of INR 1.63/kWh and Meghalaya INR 0.04/kWh, to cover up for the revenue gap of more than INR 4/kWh (PFC 2021). Therefore, both states became suitable candidates for the installation of utility-owned community solar models to improve the discoms' financial health.

For the feasibility assessment, we adopted the approach developed by Kuldeep et al. (2019) to estimate the value of a grid-connected rooftop solar system, the VGRS framework. The approach estimates the direct benefits to discoms of installing distributed solar such as savings in terms of the average power purchase cost (APPC), avoided generation capacity costs (AGCC), avoided transmission charges cost (ATRC) and avoided renewable energy certificate cost (ARECC). These benefits are compared with overall capital investment to estimate the return on investment. The detailed methodology of the VGRS framework and assumptions are discussed in the annexures. APPC savings refers to the discoms savings in terms of the variable component of the power purchase cost. AGCC captures the saving in terms of avoiding fixed expenses of signing a new PPA as generation from the solar plant can decrease the contracted capacity for a new PPA. An increase in distributed solar capacity within a discom's distribution network reduces its overall energy requirement. This reduces the need for additional transmission capacity, and these savings constitutes the ATRC benefit. The ARECC refers to the cost of avoiding the purchase of renewable energy certificates by discoms to meet their renewable purchase obligations. The findings from the benefit analysis are presented here:

- **System-level analysis**[10]: If NBPDCL installs a 100kW community solar system at the cost of INR 39,08,000 (or USD 51,503), it saves INR 2.7 crore (or USD 3.5 million) during the lifetime of the project. In the case of Meghalaya, the MePDCL saves INR 2.8 crore (or USD 4 million) during the project lifetime for an installation of 100 kW. The reduction in power purchase costs largely contributes to the savings for both states. In terms of per kW, Bihar saves INR 2.7 lakh (or USD 3,558) per kW and Meghalaya INR 2.8 lakh (or USD 3,690). As discussed in Figure 1, more than 80 per cent of consumers in Bihar are consuming less than 100 units and facing low tariff rates, which is non-cost reflective. This translates into significant savings in terms of avoided power purchase costs if these consumers are served by low-cost solar, as shown in Figure 7. The consumer benefits indirectly from the improved financial health of discoms, resulting in reduced cost of power and improvement in the quality of supply in the long run.

Overall, the return on investment is positive for discoms if they own and operate the model with net benefits[11] of INR 62 lakh (or USD 81,709) in the case of Bihar. For Meghalaya, the net benefits of a 100 kW community installation are INR 61 lakh (or USD 80,391). Therefore, there is a significant role utility-owned community solar could play in improving the financial health of discoms.

- **Impact on system-level benefits from scaling up**: A significant scale-up of the utility-owned community solar model could also provide increased benefits to discoms. We conducted the state-level analysis for

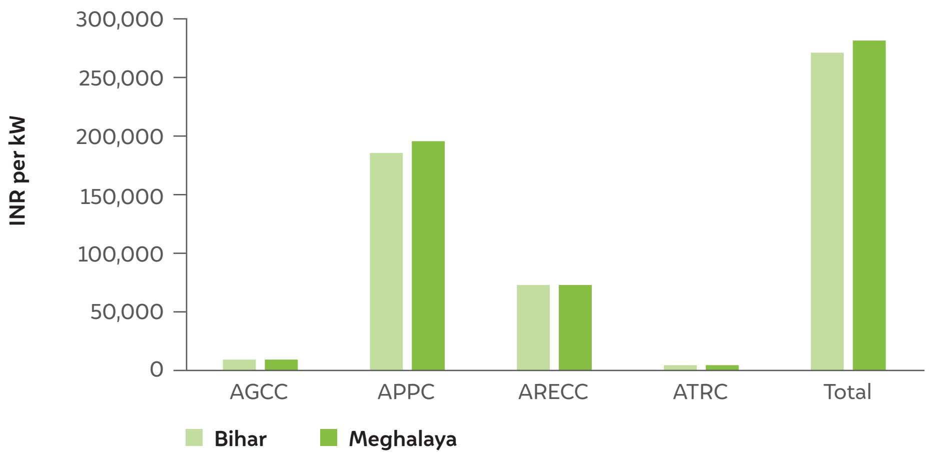
10. The details on assumptions and cost considered for the analysis are discussed in detail in the annexures.

11. Net benefit refers to difference between total benefits accrued and total cost incurred for community solar installation.

Bihar to identify the potential benefits of scaling up. The analysis presented three scenarios – a moderate scenario with a target of 500 MW, an ambitious scenario with a target of 1000 MW, and a highly ambitious scenario with a target of 2000 MW. Under the moderate scenario, **if 500 MW of community solar systems are installed, the net system-level benefit (including AGCC, APPC, ARECC and ATRC) for discoms over 25 years could be projected up to INR 10,478 crore** (or USD 1.4 billion), as shown in Figure 8. In this scenario, the first-year benefits could reduce the subsidy requirement by 8 per cent for Bihar (BERC, 2022). As we increase the target installations, the net benefits increase significantly. Under ambitious and highly ambitious scenarios, the net benefits stand at INR 20,956 crore (or USD 2.7 billion) and INR 41,913 crore (or USD 5.6 billion), respectively. The return on investment is positive under all three scenarios for discoms in Bihar.

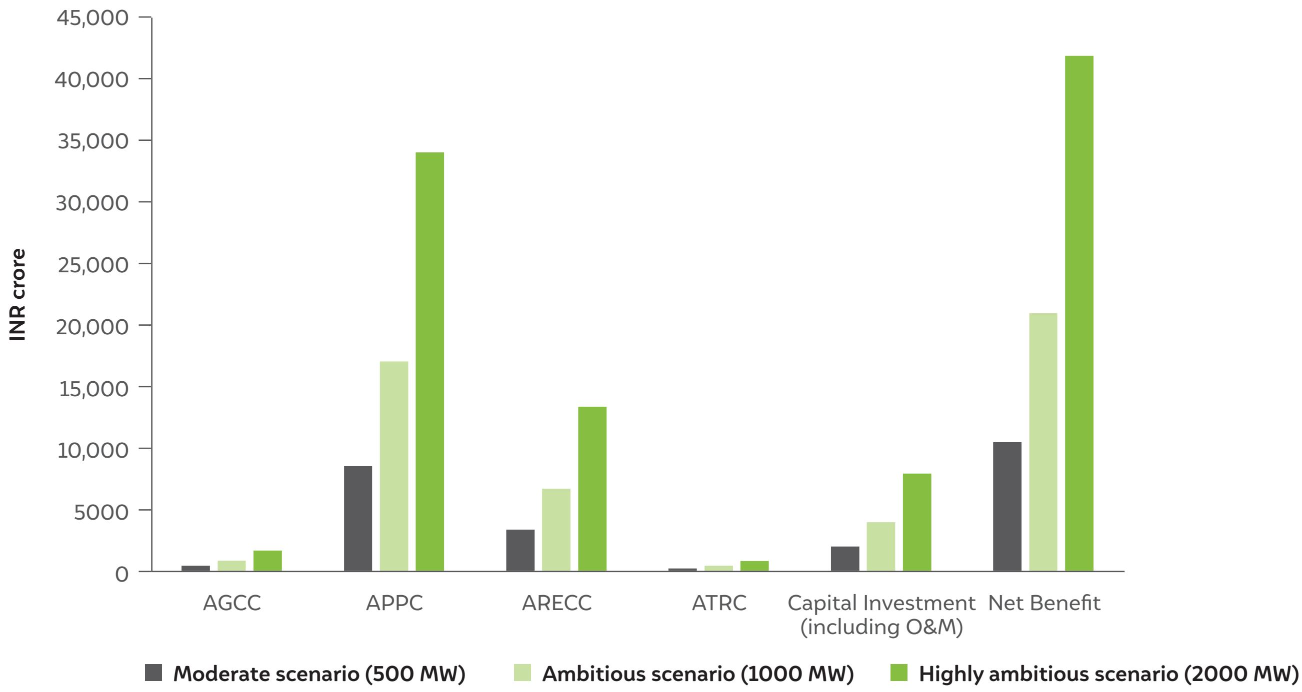
- **Trajectory of system benefits**: If we analyse the benefits over a 10-year trajectory for NBPDCL, the number of units purchased from conventional sources declines by 2 per cent under a moderate scenario, compared to the business-as-usual (BAU) scenario. The decline increases further to 4 and

Figure 7 Significant system-level benefits if a 100 kW community solar system is installed by NBPDCL and MePDCL



Source: Authors' analysis using the VGRS framework developed by Kuldeep et al. (2019)

Figure 8 System-level benefits of community solar system installation in Bihar are positive under three scenarios

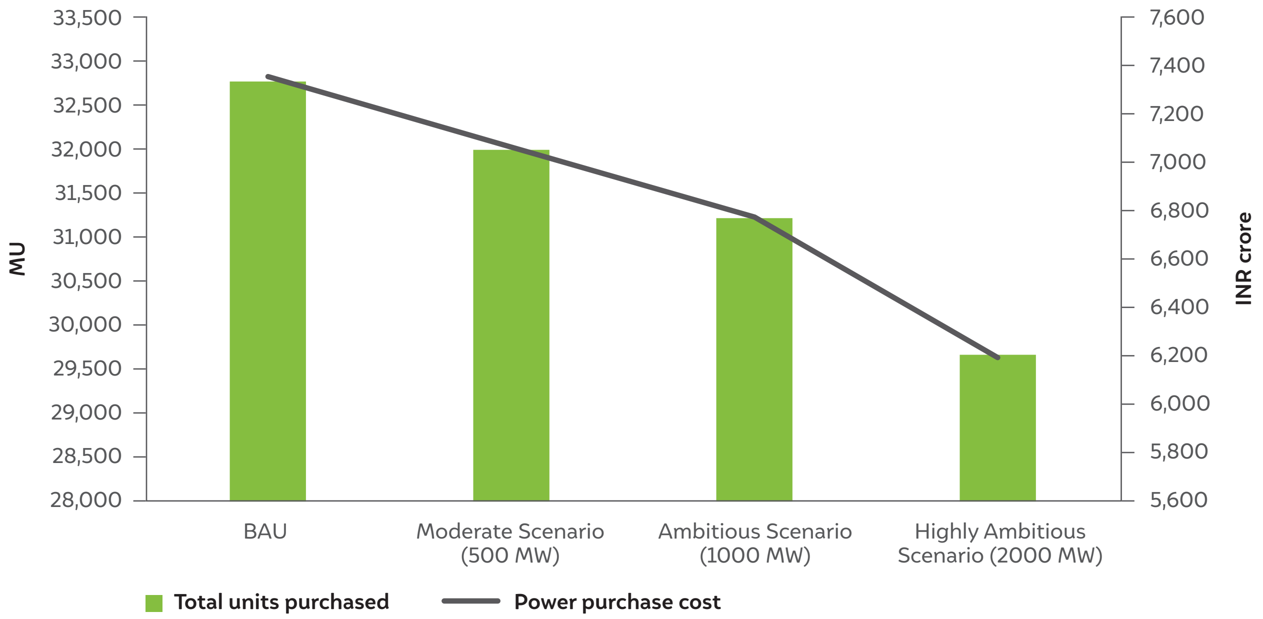


Source: Authors' analysis using the VGRS framework developed by Kuldeep et al. (2019)

7.9 per cent under ambitious and highly ambitious scenarios, respectively. A similar trend is observed in the case of power purchase cost with a decline of 2.4 per cent, 4.8 per cent and 9.5 per cent under three different scenarios, compared to the BAU. The utility-owned community solar installation also accelerates the rate of decline in AT&C losses over a 10-year trajectory, following a decline in the energy requirement.

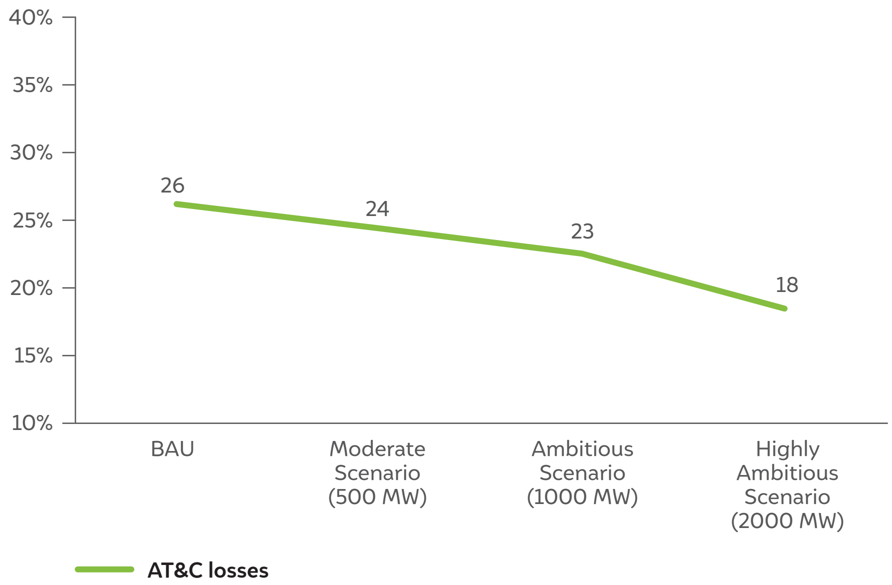
Figures 9 and 10 represent the benefits of the first year under three different scenarios. There is a significant reduction in the power purchase cost and units required from year 1. The benefits increase with scaling up. This helps to reduce the revenue gap that discoms face and improves their overall financial health.

Figure 9 Significant decline in power purchase requirement and cost under three scenarios for NBPDCL



Source: Authors' analysis using the VGRS framework developed by Kuldeep et al. (2019)

Figure 10 Scaled community solar installation increases the pace of decline of AT&C losses



Source: Authors' analysis using the VGRS framework developed by Kuldeep et al. (2019)

3.2 Comparative assessment of different ownership modes of the community solar model

Parameter	Utility	Developer	Community
Description	Medium-sized solar set-up by the utility on their own premises and injecting the electricity directly into the residential feeder or a feeder predominantly serving residential consumers	Medium-sized solar set-up by a third party vendor closer to the feeder, and developers sign a power purchase agreement with the discom for solar electricity generated at an agreed rate	Medium-sized solar set-up by the discom, and solar electricity is offered by subscription to residential consumers. Metering and billing are carried out through virtual energy accounting
Owner	Utility	Developer	Community
Financed by	Utility, financing institution, incentives, grants	Developer, financing institution	Ratepayer subscription, incentives
Consumer subscription	No	No	Yes
Benefits to discoms	Avoided power purchase costs, avoided transmission charges, avoided cost of procuring renewable energy certificates, avoided generation cost, reduction in AT&C losses *Example: Net benefits for discoms of 100 kW installation in Bihar is INR 62,34,401*	Avoided power purchase costs, avoided transmission charges, avoided cost of procuring renewable energy certificates, avoided generation cost, reduction in AT&C losses. *Example: Net benefit for discoms in Bihar reduces to INR 49,50,865 if a third-party vendor installs the solar set-up.*	Same benefits as the other two models. However, the quantum of benefits to the discom declines further as savings are shared with subsidised consumers.
Benefits to consumers	Indirect benefits in terms of the reduced power purchase cost and improved power quality	*Indirect benefits in terms of the reduced power purchase cost and improved power quality*	Participating consumers benefit from reduced electricity bills and improved power supply
Advantages	• Easier to implement and maintain the system on discom property • No changes are needed within the current regulatory framework • Discom benefits are highest under this model	• Lesser responsibility of the burden of O&M on discoms	• Maximum community engagement • Creates momentum in the solar market (including rooftop) • Habituating a class of consumers to pay for better quality power
Barriers in adoption	• Minimum community engagement • Reluctance from discoms to participate owing to the need for upfront capital cost • Difficulty in arranging finance due to the discoms' poor financial health	• Net benefits of discoms reduce as discoms pay more if they procure power from the vendor, rather than providing the upfront Capex cost • Difficulty in getting finance • No community engagement • Need for payment security for developers against consumer defaults would be more clear • Low interest from developers due to O&M responsibility for 25 years	• Decline in a net benefits for discoms due to sharing in savings with consumers • Difficulty in getting consumers to participate, lack of awareness about potential benefits of rooftop solar, challenges with financing, etc. • Need for payment security for developers against consumer defaults • Requires changes in regulations such as approval of virtual net metering to credit benefit for consumers • Difficulty in securing O&M in remote areas

Source: Coughlin et al. 2010; Heeter et al. 2021

Discom financial benefits are highest in the utility-owned community solar model, with no sharing of direct savings either with consumers or developers. Considering the operational challenges, it is easier to implement the utility-led model as it is a new concept for India. Other ownership models could be tested later on, as the utility-owned installation proves the validity of its concept and scales.

3.3 Is the Indian ecosystem ready to adopt the utility-owned community solar model?

Despite the significant potential to scale up, the Indian ecosystem faces real barriers to adopting community solar in the described context. There are several challenges faced by discoms, restricting its adoption in India.

- **Lack of access to finance**: One of the critical concerns for discoms is access to capital for financing such projects. Due to their poor financial health, discoms receive poor credit ratings, restricting their access to cheap capital. Given their limited access to capital, distributed solar is not prioritised over other system investments.
- **Tedious tendering process and low participation rates**: Discoms are required to issue tenders for installing these projects under the CAPEX model. In general, low participation is observed from solar companies for distributed solar tenders. This is largely driven by multiple challenges such as different tendering guidelines across states, higher earnest money deposit (EMD) requirements, variation in qualification criteria, unreasonable timelines, certification requirements, and restrictive benchmark rates.[12] Tendering for community solar projects might also encounter similar challenges. In addition, the process of seeking approvals by discoms may face procedural delays and impact the progress of these installations.
- **Lack of discom appreciation of the benefits**: Similar to community solar, the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana (PM-KUSUM)* scheme targets the agriculture feeder for solarisation. The scheme has seen a low participation rate from discoms as they prefer to procure low-cost power from utility-scale projects rather than undertaking efforts to install distributed solar projects (Rahman, Aggarwal, and Jain 2021). Community solar projects could also witness such competition and trade-offs, and initially, it would be difficult to get discoms on board.
- **Underdeveloped internal capacity for control of distributed energy resources**: Discom grid operators and executives have expressed their ongoing challenges with balancing the grid due to the growth and expansion of distributed rooftop solar systems. These concerns have also been articulated in relation to the application of community solar. The ability to manage a dynamic grid is essential as more intermittent generation resources join the grid to meet decarbonisation goals. Grid management could improve with the potential integration of battery systems which, however, would increase the cost of the system.
- **Absence of financial incentives**: Presently, there are no financial incentives that could nudge the discoms into undertaking community installation. The incentive available through the MNRE rooftop solar scheme also limits the subsidy to consumers who install systems within their premises and are direct beneficiaries. However, **under the utility-led community solar projects, community engagement is limited, but the consumer benefits indirectly in the long run**. Therefore, these incentives could not be leveraged for community solar installations due to the larger system sizes. These incentives would have enabled faster uptake of distributed renewables and the achievement of India's ambitious clean energy targets.

As Section 3.2 shows, there are long-term benefits for discoms from scaled community solar installations. However, these models have not been tested so far in India. A pilot of such a project will demonstrate the potential benefits to discoms, as supported by enabling policies. Community solar installations in the United States have been supported by enabling regulations and policies, which contributed significantly to scale-up (Heeter et al. 2021). Therefore, there is a need to create a supportive ecosystem that would require persistent efforts to nudge the discoms into undertaking community solar installations.

12. Based on stakeholder consultations

4. Recommendations

This section suggests key recommendations to support and scale up the community solar model in India. Each recommendation highlights the key beneficiaries, main actors, and the proposed intervention's envisioned impact.

Modify provisions to claim capital subsidy under RTS Phase II schemes

The MNRE Phase II scheme provides a capital subsidy for RTS installation in the residential sector and encourages discoms to play a pivotal role in the process (MNRE 2019). However, the progress has been limited so far with minimal utilisation of funds. Utility-led community solar serves both these purposes, with discoms cost-effectively undertaking the charge to solarise the residential feeders. There is a need to modify the existing provisions under component A of the MNRE phase II scheme to incorporate community systems that are not installed on consumer premises but nonetheless serve or benefit residential consumers. The current financial assistance is available to the system installed within the consumer premises, with residential consumers being the direct beneficiaries. Further, delinking the subsidy from consumers' contract account (CA) numbers (meter/consumer identification code) would enable utilities to avail of the capital subsidy for aggregated community solar installations. In addition, the utility-led community solar model benefits from economy of scale and requires lower subsidies compared to residential consumers. Therefore, they would help to drive the market away from subsidies quickly, while continuing to replace residential electricity with solar.

Key beneficiaries
Residential consumers, discoms

Main actors
MNRE

Envisioned impact
Encouraging the participation of discoms in undertaking community solar installation which improves discoms' fiscal health

Roll out a dedicated community solar scheme

Utilising capital subsidy under the existing MNRE scheme would help to initiate the deployment of community solar installation. However, to keep a targeted focus on community solar in the long run, a dedicated scheme for community solar could be proposed by MNRE or the states. The focus of the scheme would be low-paying consumers in rural and semi-urban areas. The scheme could target residential feeders if segregated, or feeders serving predominantly residential consumers, and the system would be installed closer to the feeder. The scheme could include provision for capital subsidy for community installations with a share from both central and state governments. Discoms would be encouraged to select the feeder with high T&D losses or theft issues and lower bill payments to help them minimise the cost to serve these consumers and improve their financial health. Siting within communities may increase the local community's sense of ownership in the system, improve the project's visibility, or allow local communities' engagement through voluntary labour and/or job trainees.

Key beneficiaries
Residential consumers, discoms

Main actors
MNRE and state government

Envisioned impact
Increasing the share of clean energy in the utility power procurement mix, improving the discoms' financial health

Finance mechanism for the utility-led community solar model

Getting finance is a challenge for debt-laden utilities due to their poor credit rating, and discoms would face a similar challenge for community solar installations. In the present scenario, state governments bear a large portion of the cross-subsidy burden to provide electricity to residential consumers at a lower rate. The state subsidy amount from the state government could be utilised in two ways. First, the state government could extend such funds directly to utilities to set up community solar installations. Second, such funds could be allocated to create a payment security mechanism to help discoms raise cheap capital in local currency. This is the most preferred route that would help drive the market away from subsidies in the long run. This will also ring-fence the returns to investors by providing security against payment defaults. Utilities could explore seeking finance directly or creating an off-balance sheet special purpose entity (SPV) with no recourse to the utility's balance sheet. Creating such an SPV would enable utilities to secure finance at lower interest rates. However, separation in the cash flows of SPV and the utility is necessary to ensure transparency. Community solar could also be presented as a green network investment by utilities for network optimisation and can thereby secure finance at a lower rate. In addition, utilities could also explore concessional loans through the existing line of credit under the clean technology fund from the World Bank and Asian Development Bank for community solar installation.

Key beneficiaries
Discoms

Main actors
Central and state governments, financial institutions

Envisioned impact
Reducing the financial burden on the discoms and state government

Link the performance incentive with community solar installation under RDSS

The RDSS aims at improving the quality, reliability and affordability of power supply and improving the financial performance of the discoms by reducing the AT&C losses and reducing the ACS-ARR gap (MoP 2021). Community solar installation driven by utilities can potentially be used for network optimisation and could contribute significantly to the objective of the RDSS scheme by reducing the cross-subsidy savings, habituating bill payment, reducing T&D losses, and lowering investment in infrastructure, thereby improving the utilities' financial health. A 100 kW system saves INR 2.7 lakh per kW during the lifetime of the project for a discom, with a significant reduction in the power purchase cost. Therefore, to encourage utilities to undertake community solar installation, the MoP could impose a criterion under the RDSS by linking the incentive of improved power performance by achieving x percentage of sales through community solar in rural and semi-urban localities. This could be potentially linked with component II, 'Distribution Infrastructure Works', of the scheme, focusing on loss reduction. This will improve system-wide benefits and potential future losses related to cross-subsidy burden, which could significantly impact the performance of discoms.

Key beneficiaries
Discoms

Main actors
MoP

Envisioned impact
Reducing the cross-subsidy burden on the discoms and state government, improving the quality of supply for consumers

Simplify the tendering process

Discoms, in general, face low participation from solar companies for distributed solar tenders. This is largely driven by multiple challenges and tendering for community solar might encounter similar challenges. To smoothen the process of implementation, a model tender document could be prepared by MNRE/SECI with key elements, such as simplification of the process, rationalisation of the timeline, including buffers for external shocks, standardisation of performance ratios, detailed information on benchmark rate (scope of work, their use as an indicative cost rather than ceiling rate, adjusting for external shocks, creating rationalisation of tiers), revisiting the amount of EMD and performance security to facilitate ease in deployment, linking performance bank guarantee with performance evaluation criteria, among others.

Key beneficiaries
Developers

Main actors
MNRE/SECI

Envisioned impact
Encouraging participation by developers for community solar, hastening the process of installation

Introduce battery storage along with community solar

Introducing battery storage will have additional benefits for discoms, such as peak shaving with a subsequent impact on the cost of supply. A battery storage component could be introduced later on, as the community solar installation picks up. Therefore, existing community solar sites would become potential candidates for introducing storage, increasing the manifold benefits of community solar. However, a cost-benefit analysis needs to be carried out to identify net benefits to the discom by introducing storage. To finance battery storage for community solar, incentives available under the battery storage scheme could be explored.

Key beneficiaries
Discoms

Main actors
MNRE

Envisioned impact
Captialising on the opportunity to reduce the cost of supply for discoms to the fullest extent

Consumer participation incentives for low-income households

The community solar model could be extended further in the long run to encourage consumer subscription. Community solar provides an opportunity for consumers to participate in the energy transition process and offers multiple benefits such as improved quality of supply even in the remotest of places, increased livelihood opportunities, and improved access to other facilities such as health and education. Presently, there are several challenges to the consumer subscription model, such as lack of awareness, subsidised electricity tariffs, restrictive metering provisions, and lack of finance. However, after the communities become accustomed to the concept of community solar, incentives could be introduced, such as rebates for timely payment in the form of energy credits, to encourage consumer participation, similar to what has been offered in the United States.

Key beneficiaries
Consumers

Main actors
Central and state government, discoms

Envisioned impact
Increasing the participation of consumers in energy transition, reducing the cross-subsidy burden on the discoms and state government

Annexure

Methodology and assumptions for estimating benefits for discoms and consumers

Table A1 Assumptions for levelised cost of energy (LCoE) calculations

Parameter	Unit	Bihar	Meghalaya
Installed Power Generation Capacity	kWp	100	100
Capacity utilisation factor	%	17	17
Useful Life	Years	25	25
Power Plant Cost	INR	39,08,000	42,98,000
Debt	%	70	70
Equity	%	30	30
Repayment Period (Including Moratorium)	Years	10	10
Interest Rate	%	9	8.50
Discount Rate	%	8.64	8.36
Return on Equity (ROE)		14	16
Depreciation Rate for First 10/12 Years	%	7.00	5.83
Depreciation Rate 11/13th Year Onwards	%	1.33	1.54
O&M Charges	Months	1	1
Maintenance Spare (%age of O&M Expenses)	%	15	15
Receivables from Debtors	Months	2	2
Operation & Maintenance	%	1% of Capital cost	1% of Capital cost
O&M Expense Escalation	%	3	3

Source: (BERC, 2017, 2022; MNRE, 2021; MSERC, 2014, 2021)

Table A2 Assumptions for cost-benefit analysis

Parameter	Unit	Bihar	Meghalaya
Generation capacity cost	INR/kW	6901	6901
Transmission Capacity cost	INR/kW	2816	2816
Variable power purchase	INR/kWh	3.05	3.3
REC purchase cost	INR/kWh	2.1	2.1
Transmission losses	%	3.92	4.8
Distribution losses	%	15	12
System coincidence factor	%	5.6	5.6

Source: (BERC, 2017, 2022; MNRE, 2021; MSERC, 2014, 2021)

The methodology to calculate cost and benefit are derived from Valuing grid-connected rooftop solar study (Neeraj et. al, 2019).

Table A3 Formulas for estimation of different benefits

Benefit	Formula
APPC	$APPC = \sum \frac{\text{Solar Energy}}{(1\text{-}TL\%)(1\text{-}DL\%)} \times \text{Variable Power Purchase Cost}$
AGCC	$AGCC = \sum \frac{\text{Solar plant capacity}}{(1\text{-}TL\%)} \times \text{System Coincidence Factor} \times \text{Degradation Factor} \times \text{Capacity Cost}$
ARECC	$ARECC = \sum \text{RTS Energy} \times \text{REC Cost}$
ATRC	$ATRC = \sum \frac{\text{RTS output}}{(1\text{-}TL\%)(1\text{-}DL\%)} \times \text{Transmission coincidence factor} \times \text{Degradation factor} \times \text{Transmission} \times \text{Capacity Cost}$

Source: (Kuldeep et al., 2019)

Table A4 Assumptions for state-level analysis

Parameter	Unit	Bihar
Annual power purchased escalation rate (MU)	%	3%
Annual power purchase cost escalation rate	%	3%
AT&C loss annual reduction rate	%	0.5

Source: Author's analysis

References

Agrawal, S., Mani, S., Jain, A., Ganesan, K., & Urpelainen, J. (2020a). *India Residential Energy Survey (IRES) 2020 Design and data quality*. New Delhi: Council on Energy, Environment and Water.

Agrawal, S., Mani, S., Jain, A., Ganesan, K., & Urpelainen, J. (2020b). *India Residential Energy Survey (IRES) 2020 Design and data quality*. New Delhi: Council on Energy, Environment and Water.

BERC. (2017). *The Bihar Gazette - RE regulation*.

BERC. (2022). *Tariff Order for FY 2021-22*. www.berc.co.in.

Bridge to India. (n.d.). INDIA SOLAR ROOFTOP MAP. Retrieved March 31, 2022, from https://bridgetoindia.com/report/india-solar-rooftop-map-march-2017-edition/.

CEA. (2022). *Executive Summary on Power Sector Government of India*.

CEEW. (n.d.). *Clean Energy Research in India | Powering Rural Livelihoods* | Retrieved March 31, 2022, from https://www.ceew.in/powering-livelihoods.

Census. (2011). *Primary Census Abstracts*. Registrar General of India, Ministry of Home Affairs, Government of India. Available at: www.censusindia.gov.in.

Coughlin, J., Grove, J., Irvine, L., Jacobs, J. F., Phillips, S. J., Sawyer, A., & Wiedman, J. (2010). *A guide to community shared solar*. www.osti.gov/bridge.

Garg, V., & Shah, K. (2020). *The Curious Case of India's Discoms: How renewable energy could reduce their financial distress*.

Heeter, J., Xu, K., & Chan, G. (2021). *Sharing the Sun: Community Solar Deployment, Subscription Savings, and Energy Burden Reduction*.

IEX. (2021). *Renewable Energy Certificate*. Indian Energy Exchange Ltd. https://www.iexindia.com/marketdata/recdata.aspx.

Jain, S., Garg, T., Jain, R., & Kuldeep, N. (2019). *Demystifying India's rooftop solar policies*. New Delhi: Council on Energy, Environment and Water.

Kuldeep, N., Ramesh, K., Tyagi, A., & Saji, S. (2019). *Valuing Grid-connected Rooftop Solar A Framework to Assess Costs and Benefits to Discoms*. New Delhi: Council on Energy, Environment and Water.

Mani, S., Patnaik, S., & Dholakia, H. H. (2019). *The State of Electricity Access for Primary Health Centres in India Insights from the District Level Household and Facility Survey (DLHS-3 and DLHS-4) Issue Brief* | New Delhi: Council on Energy, Environment and Water.

Ministry of Power. (n.d.). *PRAAPTI - Payment Ratification And Analysis in Power procurement for bringing Transparency in Invoicing of generators*. Retrieved March 31, 2022, from https://www.praapti.in/.

MNRE. (n.d.). *Physical Progress*. Retrieved March 31, 2022, from https://mnre.gov.in/the-ministry/physical-progress.

MNRE. (2019). *Grid Connected Solar Rooftop Programme*. https://mnre.gov.in/solar/schemes.

MNRE. (2021). *Benchmark costs for Grid-connected Rooftop Solar*.

MoP. (2019). *Press Information Bureau*. https://pib.gov.in/PressReleseDetailm.aspx?PRID=1592833.

MoP. (2021). *Guidelines for Revamped Distribution Sector Scheme Reforms-based and results linked*.

MSERC. (2014). *Meghalaya State Electricity Regulatory Commission (Terms and Conditions for determination of Tariff for Generation from Renewable Energy Sources) Regulations, 2014*.

MSERC. (2021). Tariff Order: Aggregate Revenue Requirement for the Control period FY 2021-22 to FY 2023-24 & Distribution Tariff for FY 2021-22.

PFC. (2021). *Performance of power utilities*.

Purkayastha, D., Gavarraju, V. N., & Gautam, K. (2021). *Going beyond the grid: The future of DRE in India*. CPI. https://www.climatepolicyinitiative.org/going-beyond-the-grid-the-future-of-dre-in-india/.

Rahman, A., Agrawal, S., & Jain, A. (2021). *Powering Agriculture in India Strategies to Boost Components A and C Under PM-KUSUM Scheme*. New Delhi: Council on Energy, Environment and Water.

Regy, P., & Sarwal, R. (2021). *Turning around the power distribution sector: learnings and best practices from reforms*.

Saji, S., Kuldeep, N., & Chawla, K. (2019). *Scaling Rooftop Solar Understanding Consumer Perspectives in East Delhi*. New Delhi: Council on Energy, Environment and Water.

Shakti, & Deliotte. (2016). *Rooftop Solar-Garnering Support from Distribution Utilities*.

Tyagi, A., Lata, C., Korsh, J., Nagarwal, A., Rai, D., Kwatra, S., Kuldeep, N., & Saxena, P. (2021). *India's Expanding Clean Energy Workforce*. In CEEW. https://www.ceew.in/publications/indias-expanding-clean-energy-workforce.

Uzum, B., Onen, A., Hasanien, H. M., & Muyeen, S. M. (2020). *Rooftop Solar PV Penetration Impacts on Distribution Network and Further Growth Factors-A Comprehensive Review*. Electronics, 10, MDPI. Doi: https://doi.org/10.3390/electronics10010055.

The authors

Bhawna Tyagi
bhawna.tyagi@ceew.in | @bhawnatyagi17

Bhawna is a Programme Associate at The Council and focuses on accelerating rooftop solar adoption in India through research on consumer perception, undertaking techno-economic feasibility assessment, developing innovative business models, and supporting new policy and regulatory developments. She holds a post-graduate degree in economics from Ambedkar University, Delhi, and a graduate degree in economics (Hons) from the University of Delhi.

Neeraj Kuldeep
neeraj.kuldeep@ceew.in | @neerajkuldeepp

Neeraj Kuldeep has worked and published extensively on renewable energy markets. He is currently co-leading the renewable energy team at CEEW. His research at The Council revolves around solar and wind markets and the socio-economic benefits of renewables, including jobs and skilling in the renewable energy sector. Neeraj holds an undergraduate degree in energy science and engineering and an MTech in energy systems from the Indian Institute of Technology (IIT), Bombay.

Suggested citation: Tyagi, Bhawna, and Neeraj Kuldeep. 2023. *Community Solar for Advancing Power Sector Reforms and the Net-Zero Goals*. New Delhi: Council on Energy, Environment and Water.

Peer reviewers: Harsha Meenawat, Senior Programme Manager, World Resources Institute (WRI); Lanvin Concessao, Program Associate, WRI; Nidhi Sarin, Program Head, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; and Vaibhav Pratap Singh, Programme Lead, CEEW.

Acknowledgment: We immensely thank Ruth Ku and the U.S. State Department's Bureau of Energy Resources (State/ENR) for initiating and managing this exciting project, as well as Moises Behar of State/ENR for his project support. We also thank Joseph Pereira, Deputy Director of the Colorado Department for Regulatory Affairs for sharing his expertise on community solar installation in the United States. We also want to acknowledge inputs from Abhishek Ranjan, ReNew Power; Abhinav Goyal, Consultant, World Bank; Sugata Mukherjee, Head - Operations, Tata Power; Mudit Jain, Head - Research, Tata Cleantech Capital Limited; Selna Saji, Head - Policy Advocacy and Market Strategy, SunEdison; Sishir Garemella, Head, PV Evolution Labs—who helped us in shaping the policy rerecommendations. Further, we are grateful to India's Ministry of New and Renewable Energy (MNRE) for constantly providing the governmental support required to implement the Solarise project.

Publication team: Kartikeya Jain (CEEW); Alina Sen (CEEW); Natasha Sarkar; Twig Designs; and FRIENDS Digital Colour Solutions.

Organisations: The **Council on Energy, Environment and Water** (CEEW) is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. CEEW has a footprint in over 20 Indian states and has repeatedly featured among the world's best managed and independent think tanks. Follow us on X (formerly Twitter) @CEEWIndia for the latest updates.

The **U.S. Department of State, Bureau of Energy Resources** leads the Department's efforts to develop and execute international energy policy to promote: energy security for the United States and its partners and allies; U.S. economic growth that benefits American business and people; and global political stability and prosperity through energy development.

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

ISID Campus, 4 Vasant Kunj Institutional Area
New Delhi - 110070, India
T: +91 (0) 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewindia

Scan to download the study