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ACCELERATING SOLAR ROOFTOP
FOR RESIDENTIAL CUSTOMERS

WHITE PAPER

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ACCELERATING SOLAR ROOFTOP FOR RESIDENTIAL CUSTOMERS

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ABBREVIATIONS

AERC	Assam Electricity Regulatory Commission
APDCL	Assam Power Distribution Company Limited
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Limited
ARR	Aggregate Revenue Requirement
AT&C	Aggregate Technical and Commercial losses
BERC	Bihar State Electricity Regulatory Commission
CEA	Central Electricity Authority
C&I	Commercial and Industrial
CAPEX	Capital Expenditure
DGVCL	Dakshin Gujarat Vij Company Limited
DHBVNL	Dakshin Haryana Bijli Vitran Nigam Limited
DISCOMs	Distribution Companies
DPV	Distributed Solar Photo Voltaic Rooftop
EESL	Energy Efficiency Services Limited
EPC	Engineering, Procurement and Construction
FIT	Feed-in Tariff
GERC	Gujarat Electricity Regulatory Commission
GoI	Government of India
GW	Gigawatts
HERC	Haryana State Electricity Regulatory Commission
INR	Indian Rupees
INR Cr	Indian Rupees Crore (10 million rupees)
JBVNL	Jharkhand Bijli Vitran Nigam Limited
JSERC	Jharkhand State Electricity Regulatory Commissions
KSEB	Kerala State Electricity Board Limited
kWh	Kilowatt hour or one Unit
kWp	Kilowatt peak
LED	Light Emitting Diode
LPC	Low-Paying Customer
LT	Low Tension
MGVCL	Madhya Gujarat Vij Company Limited
MUs	Million Units

MW	Mega Watt
NBPDCL	North Bihar Power Distribution Company Limited
NSM	National Solar Mission
PACE-D	Partnership to Advance Clean Energy – Deployment
PACE-D 2.0 RE	Partnership to Advance Clean Energy – Deployment, Second phase
PFC	Power Finance Corporation
PGVCL	Paschim Gujarat Vij Company Limited
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photo Voltaic
RE	Renewable Energy
RECs	Renewable Energy Certificates
RESCOs	Renewable Energy Service Companies
RPO	Renewable Power Purchase Obligation
SBPDCL	South Bihar Power Distribution Company Limited
SERCs	State Electricity Regulatory Commissions
SOURA	SOURA Natural Energy Solutions India
SPVRT	Solar Photo Voltic Rooftop
T&C	Technical and Commercial
T&D	Transmission and Distribution
TPL	Torrent Power Limited
UGVCL	Uttar Gujarat Vij Company Limited
UHBVNL	Uttar Haryana Bijli Vitran Nigam
UJALA	Unnat Jyoti by Affordable LEDs for All
USAID	United States International Development Agency
WBERC	West Bengal Electricity Regulatory Commission
WBSEDCL	West Bengal State Electricity Distribution Company Limited

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EXECUTIVE SUMMARY

The Government of India (GoI) has set a target of 100 gigawatts (GW) of solar deployment by 2022, including 40 GW of solar photovoltaic rooftop (SPVRT) deployment. However, as of November 2020, only 3.4 GW of the SPVRT target had been achieved. Several interventions from the Ministry of New and Renewable Energy (MNRE), such as a 40 percent subsidy, incentives for distribution companies (DISCOMs), modified metering regulations, streamlined demand aggregation process, and financial and technical assistance mobilized through international partners and Indian public sector banks, have not provided the desired results. Major remaining challenges include lack of awareness on solar rooftop systems, DISCOMs' and low-paying customers' fear that SPVRT will be more expensive, and a lack of public information about the approval process. COVID-19 has further affected SPVRT deployment. The objective of this paper is to examine the challenges and make recommendations for accelerating the deployment of SPVRT among residential customers, where the greatest potential for rooftop solar expansion lies.

The commercial and industrial (C&I) customers are investing in SPVRT more than residential customers and are benefitting from greater savings (as their tariffs are higher than the cost of supply). Losing these C&I customers has resulted in a loss of revenue for DISCOMs, who essentially have become passive facilitators for SPVRT. For residential customers, tariffs are lower than the cost of supply, so the value of SPVRT deployment is less immediate.

However, the value of solar rooftop systems is the highest for dispersed low-paying customers (LPC) located in semi-urban and rural areas. Since these customers are situated in more remote areas, connected to the tail ends of distribution lines and vulnerable to infrastructure constraints and poor maintenance, the transmission and distribution (T&D) losses are comparatively much higher than the average T&D losses of DISCOMs. In the partner states Assam and Jharkhand, we found that there are many 11 kilovolt (kV) feeders where T&D losses are above 40 percent. Power to such customers is generally subsidized, necessitating yearly budgetary support of between 600 and 4,000 Indian rupees crore (INR Cr) from state governments to the DISCOMs. The subsidy varies from state to state depending on the size of the state and the cost of supply.

The USAID PACE-D 2.0 RE team studied the prevailing self-owned, third party–owned, and DISCOM-owned business models and used the international experience of California, Australia, and Japan to innovate the Super Renewable Energy Service Company (RESCO) model to overcome the various challenges faced by LPC, RESCOs, and DISCOMs in large-scale solar rooftop adoption in the residential sector. In this model, the DISCOM acts as a Super RESCO to (a) aggregate RESCOs for the deployment of solar PV rooftop installations on the roofs of low-paying customers; (b) facilitate deployment of these systems by the RESCOs; and (c) buy power generated from these systems against the power purchase agreements (PPAs) with RESCOs as in the gross-metering system.

The DISCOMs will identify RESCOs based on the lowest tariffs quoted through a competitive bidding process. The selected RESCOs will install rooftop systems on customers' rooftops, own these systems, and enter into PPAs with the DISCOM to supply power at a fixed rate for 25 years. The entire amount of electricity generated from the project will be fed into the grid through gross metering. The DISCOMs will pay the RESCOs for the amount of solar energy fed into the grid at a price agreed upon in the PPA. DISCOMs/RESCOs will provide rent or electricity credit to the customers for providing their roofs to the RESCO for installation of the SPVRT.

The financial and economic analysis at the 5, 10, and 15 percent levels of SPVRT penetration at three different levels of T&D losses was carried out for six states (Assam, Jharkhand, Bihar, Gujarat, Haryana, and West Bengal) and at the national level. We found that at the level of 22 percent T&D losses and 15 percent penetration of SPVRT, DISCOMs, investors, and state governments, across India will receive the benefits described in Table 1. Residential customers will receive financial compensation for rooftop use and improved quality and reliability in their power supply.

Table 1. Benefits expected at 15 percent penetration and 22 percent T&D losses

Parameters	Unit	Value
SPVRT capacity addition	GW	27
Annual savings to DISCOMs	Indian Rupee Crore (INR Cr)	5,837
Investment	INR Cr	1,21,500
Gain to investor	INR Cr	4,376
Employment generation	No. of jobs	1,34,099
Reduction in CO_2 emissions	Million tons/year	37,494

The Table 1 benefits are calculated without any subsidy from MNRE for deployment of SPVRT. The subsidy by MNRE would make SPVRT financially more beneficial to DISCOMs and customers. The paper identifies the challenges in implementation of the Super RESCO model and makes eight recommendations to accelerate deployment of SPVRT in the residential sector. The key recommendation is converting DISCOMs, which are at the heart of the SPVRT program, from passive facilitators to active facilitators, generators, and investors.

INTRODUCTION

The Indian power sector is undergoing a significant change to provide 24/7 power to all citizens in a sustainable manner and from clean energy sources. The Government of India has set a target to reach 175 GW of installed renewable energy (RE) capacity by the end of 2022 against the present installed capacity of 375 GW from all sources. Of this 175 GW capacity, 40 GW is targeted to come from solar PV rooftops (SPVRT). However, as of November 2020, only 3.4 GW had been achieved. About 70 percent of this capacity is from commercial and industrial (C&I) customers, with residential customers accounting for less than 20 percent of the total installed capacity. This is in contrast to most developed economies, which targeted residential customers when starting their solar programs. These economies now have a sizable share of installations in the residential sector. China and India, on the other hand, have used large-scale solar installations in an effort to quickly achieve scale and simultaneously push down costs. With costs now significantly lower, it is time to accelerate SPVRT for residential customers who hold the largest potential.

It is important to take a closer look at the multiple reasons for the slow rate of deployment. Both the customers and the DISCOMs have their own reasons for lack of interest. The customer faces several challenges in deploying SPVRT, including upfront investment, limited knowledge, uncertainty about getting the subsidy, lack of awareness about the procedure, subsidized tariffs, etc. The cost to the DISCOM of supplying electricity to most residential customers is higher than the revenue collected. The gap is much higher for customers at the tail end of the network. The average gap between power purchase cost and revenue recovery from domestic customers is INR 0.26/kilowatt hour (kWh) [6]. Therefore, for this paper, we define low-paying customers (LPC) as those for whom the gap between power purchase and revenue recovery is more than INR 0.26/kWh. We can also define LPC as those customers for whom transmission and distribution (T&D) losses are higher than the average customer T&D loss experienced by DISCOMs. This white paper focuses on residential customers within the low-paying customer category. However, the recommendations and way forward developed for residential customers in this report can also be applied to other categories of low-paying customers such as those in the agricultural sector.

CHALLENGES IN DEPLOYMENT OF SOLAR ROOFTOP FOR LOW-PAYING CONSUMERS

While improved performance of solar panels, convenient funding options, and promising policy and regulatory frameworks have spurred growth in the industry, residential rooftop solar PV deployment is yet to gain momentum. Meeting rooftop solar targets requires the active participation of the consumer; therefore, it is important to look at the sector from the consumer's perspective. This section describes the key barriers to the deployment of rooftop solar PV for low-paying consumers.

Consumers lack awareness about the use of solar PV technology to yield better quality, more reliable electricity and the financial benefits of roof utilization. These consumers tend to rely on sources of information that lack objectivity and clarity. Key obstacles include the absence of clear information about the product, processes, and approvals required for installing the system. This lack of reliable information creates a strong dependence on vendors for know-how.

Accessibility to finance is another key obstacle. Low-paying customers do not have the money to pay the upfront costs required for deployment of SPVRT. Even if LPC are aware of financing options, financing through banks, as promoted by the government, is a complex process.

The **electricity consumption pattern of LPC is a bottleneck**. Most LPC use and require electricity during off-solar hours and find it difficult to comprehend how they will benefit from SPVRT.

They feel recovery of their investment will be slow. The policy and regulatory framework, with respect to tariffs and subsidies, plays a significant role in determining how a low-paying customer considers financing the installation of rooftop PV systems. Moreover, LPC generally have lower demand for daytime electricity, unlike other consumer segments. As a result, the recovery of their investments in solar PV is tied to the terms of their export of electricity. These differences call for financial offerings that are flexible enough to adapt to the requirements.

Consumers also at times experience **confusion over procedures and delays in approvals** due to institutional discrepancies and lack of appropriate management. Mandates designed to eliminate chaos and confusion for consumers are inadequately enforced by DISCOMs, who sometimes view rooftop solar PV as conflicting with the regular grid-based power supply. In addition, customers face delays in the solar rooftop installation process, which lead to higher transaction costs for the individual customer, because they must attain permission from multiple departments at the DISCOM. Although the processes are clearly delineated, customers report challenges on the ground.

The low electricity tariff for LPC is also an important barrier. In most states, the electricity tariff for LPC is highly subsidized by the state government and cross-subsidized by commercial and industrial customers. The subsidy makes the retail tariff for LPC lower than the DISCOM's cost of supply and lower than the per-unit generation cost of SPVRT. Consequently, many LPC customers feel that SPVRT will not be financially beneficial to them.

PERCEPTION OF DISCOMS

In 2019, to achieve the target of 100 GW of solar by 2022, the Ministry of New and Renewable Energy (MNRE) envisioned the following roles for DISCOMs:

- Simplify the application process for customers;
- Facilitate the transition for SPVRT customers, instead of viewing them as competitors;
- Set annual targets and work with MNRE and the Solar Energy Corporation of India (SECI);
- Form a dedicated team for coordinating with various entities (both internal and external agencies);
- Create a customer helpline for resolving queries related to grid connectivity;
- Publish a list of permissible meters with costs and vendors on their website; and
- Update respective billing mechanisms.

The USAID PACE-D 2.0 RE team conducted analyses for partner states Assam and Jharkhand and found that deploying SPVRT on the premises of LPC provides financial gains for the DISCOM. The analysis was conducted with data from four more states, and the results were consistent with the earlier findings. To address the challenges faced by customers and support the growth of residential rooftop systems, the Super RESCO business model was developed. Please see chapter 2 for a detailed description of the model.

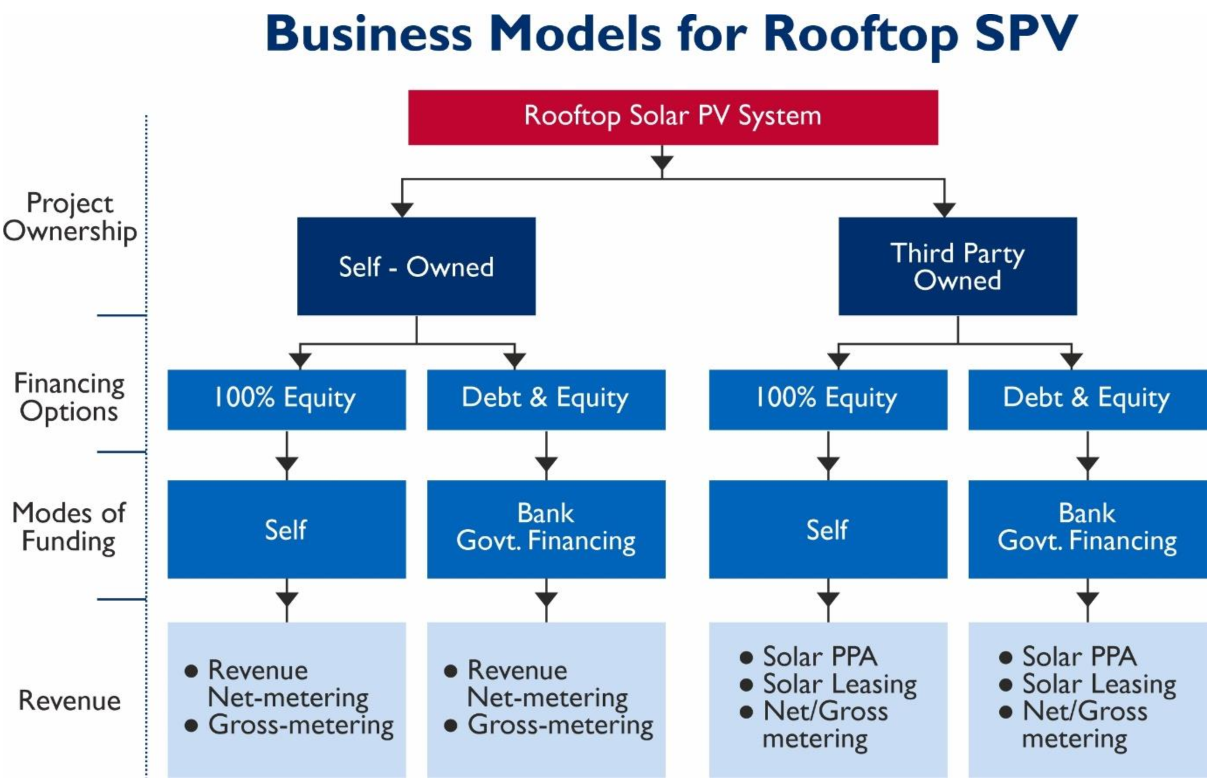
Chapter 3 presents the analysis and benefits generated by this new model, which is seen as a win-win situation for customers, DISCOMs, investors, RESCOs, and state governments. Customers get gainful utilization of their vacant roof and higher quality, more reliable power since the generation is near the load. This proximity of generation and consumption also means that DISCOMs are able to reduce their T&C losses among low-paying consumers. Through the SPVRT systems, DISCOMs get low-cost power close to their load centers, compared with centrally generated thermal power. In addition, greater deployment of SPVRT will result in the release of network capacity. The state governments get economic benefits and better health for their citizens due to the increased use of green power, new investment in the respective states, and the creation of jobs.

The analysis and the proposed business model were discussed and refined in several workshops conducted by the PACE-D 2.0 RE team with multiple stakeholders, including DISCOMs, state electricity regulatory commissions, developers, financiers, state governments, etc. This paper is the outcome of those workshops and provides guidance for DISCOMs on implementing the Super RESCO model for deployment of SPVRT on the premises of low-paying customers. The paper provides important documents such as a power purchase agreement and a tripartite agreement among DISCOMs, developers, and customers, as well as information on compensation for the rooftop; capacity for installation versus contracted load; customer engagement; and tender design. Jharkhand has decided to test this approach by conducting a pilot for 25 MW. The tender for this was released in April 202.1

DESIGNING APPROPRIATE BUSINESS MODELS FOR SOLAR ROOFTOP SYSTEMS

Deployment of solar rooftop systems on the premises of low-paying customers hinges on the design and adoption of an appropriate business model that addresses all the challenges that come with these projects for customers who pay very little for grid-based electricity, avoid interaction with DISCOMs, and have limited to no credit history and little knowledge of the financial benefits of SPVRT. The business model would have to ensure that no upfront investments are required from either the DISCOMs or the LPC and that the return on investment is protected through appropriate long-term contract arrangements.

Solar PV rooftop installations for low-paying customers can be deployed using a variety of models. These can be classified into two main categories: self-owned and third party–owned. Each category can be further divided as presented in Figure 1, based on financing options, modes of funding, and revenue (net metering/gross metering). Some of the popular models are described below.



Source: MNRE Presentation on Target Setting for 100 GW solar.

Figure 1. Business models for solar rooftop

SELF (CUSTOMER)-OWNED BUSINESS MODELS

The customers invest in solar rooftop systems either to generate electricity for self-consumption or to supply to the grid. For most of the self-owned business models, the rooftop owner invests in the equity component of the rooftop system, while the debt component is usually financed through a financial institution. Customer-owned business models can be one of the three following types:

- Captive or off-grid model: In this business model, the customer sets up the solar rooftop system with the intention of utilizing all the power generated by the system. These are prevalent in places where the grid is either absent or has very poor reliability as in remote areas.

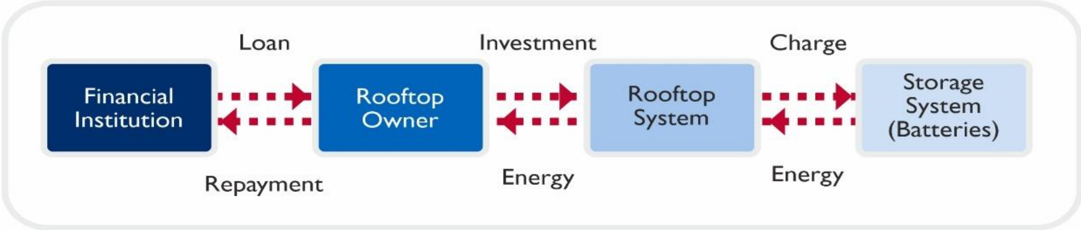


Figure 2. Captive or off-grid model

- Gross feed-in model: In this business model, the solar system is grid-connected and feeds all the energy generated to the grid. In exchange for the energy fed to the grid, the customer gets paid through a feed-in-tariff (FiT), which is approved by the regulator.

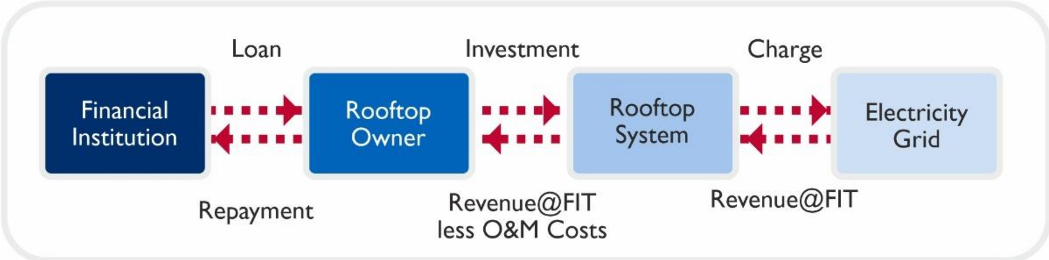


Figure 3. Gross feed-in model

- Net metering: In this model, solar energy is first consumed by the customer, then the surplus is fed to the grid, where it is banked with the utility. During non-generation hours, the customer draws power from the grid, and the banked energy is adjusted against draws from the grid, leading to a lower bill for the customer.

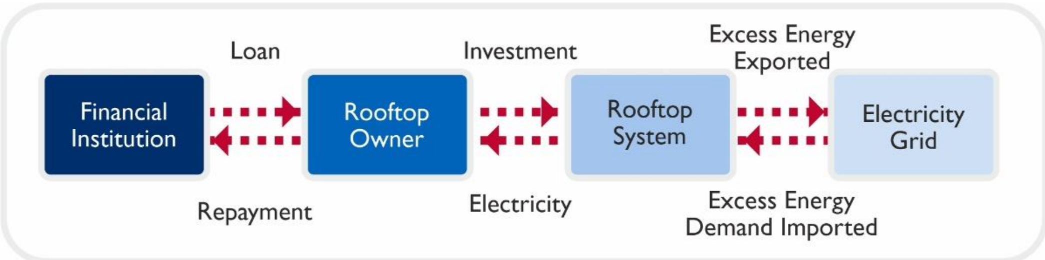


Figure 4. Net-metering model

THIRD PARTY–OWNED BUSINESS MODELS

Under this model, the third party, separate from the customer and DISCOM, (*e.g.*, the developer, investor, or RESCO) is the owner of the rooftop systems. Developers may lease the roof from the rooftop owner and then generate power, which can be sold to the DISCOM or the rooftop owner through a power purchase agreement, or any other third party may lease the system to the rooftop owner, who may utilize power from the system.

The pros and cons of the models are provided in Table 2.

Table 2. Pros and cons of popular business model

S. N.	Business model	Pros	Cons
A	**Consumer-owned**		
1	Captive or off-grid	Ideal for off-grid areas, where extending the grid for non-remunerative loads is not attractive for DISCOMs	• Need to build storage which increase the cost of electricity • Limited ability to meet higher and/or increasing demands
2	Gross feed	• No need for storage, thus cost of electricity is lower than off-grid projects • Safeguards the grid from migration and reduction of consumption of high paying customers • DISCOMs can socialize the cost of electricity procured from these systems, even if they are higher than the APPC of the DISCOM • Individual customers can participate irrespective of their contracted load	• In case the solar generation cost is higher than APPC, DISCOMs face additional burden • When solar generation costs are lower than APPC, returns to customers/investors are not attractive • Higher transaction costs for the DISCOMs due to additional number of PPAs
3	Net metering	• No additional outflow of money from DISCOM due to solar feed in • As investments are only undertaken by customers who can afford, no need for socializing costs thereby no negative impacts on other customers	• This model works only for customers whose tariff is higher than the solar generation cost • Such customers replacing their consumption with solar, reduces the revenue of DISCOMs • Existing regulations limit capacities to be put up, leading to sub-optimal utilization of rooftop space
B	Third party–owned business models	• No investment by customers thus leading to wider participation • Lesser transaction cost at DISCOMs and customers end	• Consumer acquisition, payment security from customers and DISCOMs are costly and risky • Honoring of PPAs and roof lease agreements is a challenge

The emergence of business models is a dynamic process, where investors, lenders, and project developers respond depending on the prevailing market conditions and regulations. DISCOMs became involved in the SPVRT business models as a result of pressure from the MNRE and the realization by DISCOMs that their highest-paying C&I customers were moving from their customer base.

DISCOM-BASED BUSINESS MODELS

The customer-owned and third party–owned business models have helped create a market for solar PV rooftops in India, but there are a few challenges associated with these business models, such as especially high upfront and transaction costs; high off-taker risks (in the case of RESCOs) and performance risks (in the case of CAPEX); limited availability of finance from mainstream financial institutions; lack of standardized procurement processes; and limited customer awareness which is hampering the deployment of SPVRT. These business models address problems linked to capital investment and operation and maintenance of the system, but they face some critical challenges such as payment security for the services provided; issues with the rooftop owner on access to the rooftop, follow-ups, and the approach of DISCOMs for interconnection; metering and billing arrangements; access to finance; contract sanctity; and others.

To address these issues related to implementation of solar rooftops with residential customers, DISCOM-based business models were developed. Involvement of DISCOMs in the solar rooftop market was initially limited to a facilitator role through a broad framework for interconnection. The new models expand the role of DISCOMs from simply facilitator to facilitator, mediator, and/or investor with varying level of risks. Table 3 below captures the responsibilities, returns, and risks under these various roles.

Table 3. Role of the DISCOM as a facilitator, mediator, investor

	Facilitator	Mediator	Investor
Activities/ Responsibilities	• Increase awareness of customers • Standardize components and services • Enlist vendors and establish rate list • Run procurement for the customers	• Procure systems and to customers under customer owned model • Procure power to supply to customers under RESCO owned model • Arrange roofs from customers for RESCOs for supply electricity to DISCOM • Collect interest and repayments on loans from customers	• Invest and own systems to provide services to customers (under net metering) or to DISCOM • (under gross metering)
Advantages to customers and developers	• Aggregation of demand leading to economies of scale • Better quality systems and services	• Payment security • Contract sanctity • Better project management • Better quality systems and services • Less risk to customers and developers	• Better project management • Better quality systems/services • No risk to customers
Return to DISCOM	Low/Nil – facilitation fee	Medium – project management fee/loan collection fee/low cost of supply	High – return on the projects
Risk to DISCOM	Low	Medium	High
Risk to customers and vendors	High	Medium	Low
Overall risk profile of project	High	Medium	Low

The other advantages of DISCOM-based business models are discussed in [9]. These models also were covered in detail by an earlier PACE-D 2.0 RE publication, "Best Practices Guide: Implementation of State-Level Solar Rooftop Photovoltaic Programs in India," for the National Solar Mission [30].

In India, a few DISCOM-based business models have been used for SPVRT. These are:

1. The 5 MW Gandhinagar Rooftop Solar Program deployed in Gujarat by Torrent Power under gross metering for government buildings and residential buildings. Here, the DISCOM acted as a facilitator.
2. Grid-connected rooftop/ground-mounted solar PV plants under a SOURA Natural Energy Solutions India (SOURA) scheme in Kerala supported by Kerala State Electricity Board (KSEB). Here, KSEB acts as an investor in the scheme, and solar rooftop plants are deployed on all types of buildings.
3. Andhra Pradesh's pilot for low-income, low-consumption customers. In this initiative, the DISCOM, Andhra Pradesh East Power Distribution Company, acts as a mediator for loans financed by Andhra Bank to customers.
4. UJALA Program for Energy Efficient and Affordable Lighting to All, implemented by several DISCOMs across many states. In this case, the DISCOMs act as investors.

Although each of the above cases has unique objectives and frameworks, they all demonstrate the efforts taken by state governments, DISCOMs, and implementing partners to develop solar PV rooftop projects in their respective states. Table 4 presents the key lessons from these models.

Table 4. Key lessons from states

S.N.	State/ Program	Key Features of the Model and Learnings from the Model
1	Gujarat	• It is the first pilot in Gujarat for solar PV rooftop projects. The projects were implemented in RESCO mode and the entire power was procured by Torrent Power Limited. About 4.6 MW solar power is implemented under the pilot. Based on the pilot, the scheme was repeated for other districts of Gujarat. • Different agreements were prepared under the pilot, such as PPA, power supply agreement, lease agreement, etc. • Consumers were provided with green incentives. *This model showcases a mechanism for compensation to the customers for their roof,* i.e., *based on the generation of the solar PV rooftop system. The program also suggests relevant documentation that will provide contract sanctity among customers, third party, and DISCOM*
2	Kerala	• The Government of Kerala launched the SOURA scheme to proliferate solar PV rooftop implementation in the state. Under the scheme, both engineering, procurement, and construction (EPC) and the RESCO are promoted. Under the RESCO mode, KSEB procures all power generated from the projects. The customers receive incentives in the form of energy rebates. *The SOURA scheme showcases a compensation model through energy credits for the participating customers. This incentive mechanism allows customers to gain more as it allows higher savings on energy bills as the customer tariff increases.*

3	Andhra Pradesh	• In the first model, the DISCOM, APEPDCL, has taken the novel step of providing financing to customers who are interested in implementing solar PV rooftop projects. Andhra Bank supports the scheme by providing the loan and repayment on an equated monthly instalment (EMI) basis. The target customers under the scheme are low-paying customers of the state who have electricity consumption of less than 200 kWh per month. • In the second model, APEPDCL compensates the customers directly for their roofs. *This model demonstrates how to select customers and develop a scheme for them. It suggests a compensation model,* i.e., *customers compensated for the roof by DISCOM as per the generation of the solar PV rooftop systems.*
4	UJALA Program	• The UJALA program introduced and successfully implemented the distribution of energy-efficient appliances through a cost-sharing approach. It demonstrated that the high cost of energy-efficient appliances can be funded by both customers and DISCOMs through their respective savings. *The UJALA program demonstrates the benefit-sharing approach, where the benefits are shared between DISCOMs and consumers, making it attractive for both.*

Further, details of the abovementioned programs are provided in Annex 1.

THE CASE FOR A NEW SPVRT BUSINESS MODEL

Models for deploying SPVRT range from the usual net- or gross-metering models to third party models and RESCO-based models using both gross and net metering. The USAID PACE-D 2.0 RE team conducted three stakeholder consultation workshops in Delhi, Ranchi, and Guwahati to understand why these existing business models have been unable to drive deployment of SPVRT with low-paying consumers.

- The customers, especially low-paying customers, do not have the bandwidth to make any upfront investments in SPVRT. Therefore, the usual gross- and net-metering models are not getting traction from LPC.
- RESCOs have rated the LPC low in terms of long-term contract security. This issue along with the relatively high cost of solar PV rooftop power as compared to subsidized power that these customers receive makes the RESCO models unattractive.
- The final option was a DISCOM-based model, but DISCOMs do not want to invest in the systems. In addition, the financial positions of many DISCOMs are weak.
- DISCOM-based business models have not considered the inherent advantage of SPVRTs in reducing aggregate technical and commercial (AT&C) losses—the most burning problem of the Indian power sector—by co-locating generation and consumption. This makes SPVRTs more attractive in customer areas where AT&C losses are higher. The higher AT&C losses mean larger gaps between cost of supply and revenue collection.

NEW BUSINESS MODEL—SUPER RESCO

Based on the study of existing business models for the deployment of SPVRT, input from consultation workshops, and international experience, the PACE-D 2.0 RE team innovated a new business model, the Super RESCO model, for deployment of solar rooftop systems for low-paying customers. Under this model, the DISCOM acts as a mediator, generator, and facilitator. The term Super RESCO (S-RESCO) refers to the aggregator of RESCOs. In this model, the DISCOM will act as the Super RESCO to aggregate RESCOs for the deployment of solar PV rooftop installations on the roofs of low-paying customers. This allows aggregation of capacity, which supports increased procurement, leading to economies of scale, a reduction in prices, and a lower cost of power purchase for the DISCOMs. The DISCOM will facilitate deployment of these systems by the RESCOs of solar PV rooftop systems on the premises of low-paying customers. The DISCOM will then buy all solar power generated by those systems. DISCOMs have the technical know-how and capability to monitor the quality and timely execution of projects, which will improve the deployment in the sector. Consumers will receive compensation for their roof in terms of a lease or discount on their electricity bill. Figure 7 presents the model graphically.

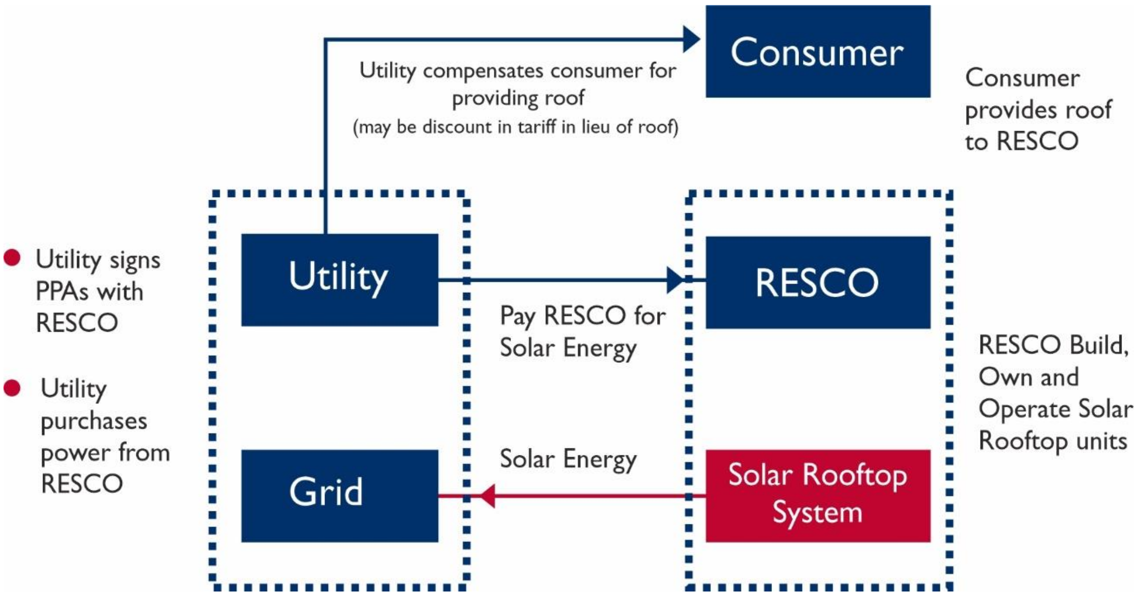


Figure 5: Super RESCO business model

The model works on the concept of gross metering, in which all electricity generated from the solar rooftop systems is fed into the DISCOM's grid. This helps reduce demand for conventional power and T&D losses for DISCOMs.

HOW THE PROPOSED S-RESCO MODEL ADDRESSES CHALLENGES?

The Super RESCO model helps to address the challenges of customers, developers, and DISCOMs. Table 5 below highlights the role of the Super RESCO in mitigating challenges for deployment of SPVRT for LPC.

Table 5. Challenges for SPVRT deployment with LPC using Super RESCO model

S. No.	Challenge of Deploying SPVRT for LPC	Proposed Model Solutions
1	Low customer tariffs	Low customer tariffs discourage domestic customers from investing in solar rooftop projects under net metering due to longer payback periods. Under the proposed model, RESCOs install systems on the premises of the LPC and sell the entire amount of solar generation to DISCOM Hence, LPC is not compelled to buy solar power or off-set their consumption. In addition, they receive compensation for leasing out their premises for solar installations.
2	Limited Capacity to Invest	No investment from LPC is required as RESCOs will invest in solar rooftop projects under the proposed model.
3	Hurdles for RESCOs	A major hurdle faced by RESCOs for LPC is the fragmented nature of the market increasing the transaction costs. Under the proposed model, JBVNL acts as an aggregator, combining the capacities of LPC to bring scale. Another major hurdle is the lack of creditworthiness of LPC. Since the RESCOs will sign a PPA with the DISCOM under the proposed model, the strong credit rating of the DISCOM will help RESCOs secure their investment and source cheaper capital. With the tripartite agreement with the DISCOM and LPC, risk for the project decreases further.

The S-RESCO model is more attractive than other DISCOM-based business models as it generates specific benefits to each stakeholder as mentioned in Table 6.

Table 6. Benefits of Super RESCO model for the stakeholders

Stakeholder	Benefit
Consumers	1. No investment from the customers 2. Additional income from the roof which is otherwise economically non-performing asset 3. Contribute to the environmental cause
RESCO	1. DISCOMs, trusted entities, allow high contract sanctity and low payment risks 2. Power Purchase Agreement (PPA) with DISCOMs allow competitive terms on financing from mainstream investors 3. High volume of projects, due to aggregation, allows RESCOs bulk procurement and better planning and implementation
DISCOM	1. No investment from DISCOM 2. DISCOM with their technical and legal capabilities can ensure high quality generating assets supporting their grid 3. Aggregation allows reduction in prices 4. Super RESCO model allows DISCOMs to focus on the area with infrastructure congestion, high losses for solar PV rooftop deployment so as to maximize the benefits

COMPLIANCE OF THE S-RESCO MODEL WITH REGULATORY PROVISIONS

The S-RESCO model has been tested for compliance with existing regulatory provisions for net metering and gross metering for RE and does not violate any provisions. The model is also compliance with present GoI guidelines for competitive bidding and subsidies. The tariff will be decided by competitive bidding and therefore will not be subjected to regulatory examination or approval. However, relaxation of the limitation of SPVRT capacity to the contracted load will enhance penetration of SPVRT. This has already happened in Gujarat; whose Solar Policy 2021 waived this limitation of SPVRT capacity to maximum of the contracted load for residential customers. We hope other states will follow the trend. In addition, guidelines provided by regulators on compensating customers for roofs will facilitate the deployment. Customers can be compensated in different ways for leasing out their roofs to RESCOs for deployment of SPVRT. Following are the most popular ways:

1. **Rent fixed by the DISCOM –** DISCOM can fix rent for leasing the roof from the roof owners. The rent can be a fixed monthly rent or tied to the electricity bill. Rent tied to the bill encourages the roof owner to cooperate with the RESCO, allowing better maintenance of the SPVRT.
2. **Rent negotiated by the RESCO –** RESCOs negotiate the rent with the roof owners on an individual basis. This allows for increased participation of the roof owners. However, the negotiations with individual roof owners can be cumbersome and lead to delays in implementation. Also, this allows for uneven compensation among roof owners, which could result in renegotiations during the life of the project.
3. **Energy credits by the DISCOM –** DISCOMs provide a percentage of the SPVRT generation in the form of energy credits to the customers as compensation for the roof. This arrangement is comfortable for customers because it can be received through the monthly electricity bill, which is simple and reliable. As the compensation is tied to the generation of SPVRT, roof owners are encouraged to cooperate with the RESCOs for better maintenance of the SPVRT systems. This compensation mechanism was adopted by Kerala State Electricity Board (KSEB) for their SOURA scheme, and KSEB has received tremendous interest from customers who want to provide their roofs for deploying SPVRT.

LIMITATIONS OF THE S-RESCO MODEL

The Super RESCO model also has some limitations related to customer acquisition and 25-year roof leases. We hope DISCOMs will play a more active role and support developers in customer acquisition. For leasing roofs, either the regulator or DISCOM needs to decide on the amount of compensation for lease of the roof. It can be left between the customer and developer, but the interests of the customer are probably best served if guidelines are established by the DISCOM or regulator. We discussed this with a few state regulators, and they are willing to consider it.

BUNDLING DISTRIBUTION FRANCHISE MODEL WITH S-RESCO MODEL

The distribution franchise (DF) model was introduced in India with the Electricity Act 2003. In this model, DISCOMs franchise some areas of operation to a third party for improving operational and financial efficiency, while remaining responsible to the regulator, customer, and government. After successful implementation of DF in the city of Bhiwani (Maharashtra state), this model has received lots of attention. Later a Shunglu committee was formed, constituted by the GoI, to improve distribution in more than 100 districts. After the Bhiwani example, the experience of DF has been mixed [41]. DF models are generally of two types: (1) revenue based or (2) input based. Their key attributes are provided in Table 7.

Table 7. Types of franchise models

	Revenue-based franchise	Input-based franchise
Objectives	Operational efficiency and customer satisfaction	Improvement of (a) financial performance; (b) operating, technical, billing and collection efficiency; (c) service quality
Responsibilities	Revenue collection based on set targets	Supply of power from the input points; operating & maintenance of assets; billing & collection; metering; releasing new connections
Payment	Fixed fee	Fixed fee plus incentives based on performance
States	Assam, Andhra Pradesh	Uttar Pradesh, Odisha, Bihar, Maharashtra, Jharkhand, Madhya Pradesh, Rajasthan

There is the possibility of bundling the S-RESCO model with the DF model to increase the financial attractiveness of both models. In the bundled model, DFs also will act as the RESCO. This will provide the DF better control of reliability and quality of electricity supply and services to the customers. In the unbundled DF model, power supply is provided by DISCOMs. This is more beneficial for the DISCOMs, as the responsibilities for maintenance of the network, addressing customer complaints promptly, meter reading, payment collection, and prevention of theft can be handled by the DF, resulting in improved financial performance of the DISCOMs. The DISCOMs can offer complete substations, where line losses are higher with less collection efficiency than a DF for deployment of SPVRT, along with operating the distribution business. Figure 8 presents a pictorial view of the bundled DF and S-RESCO model.

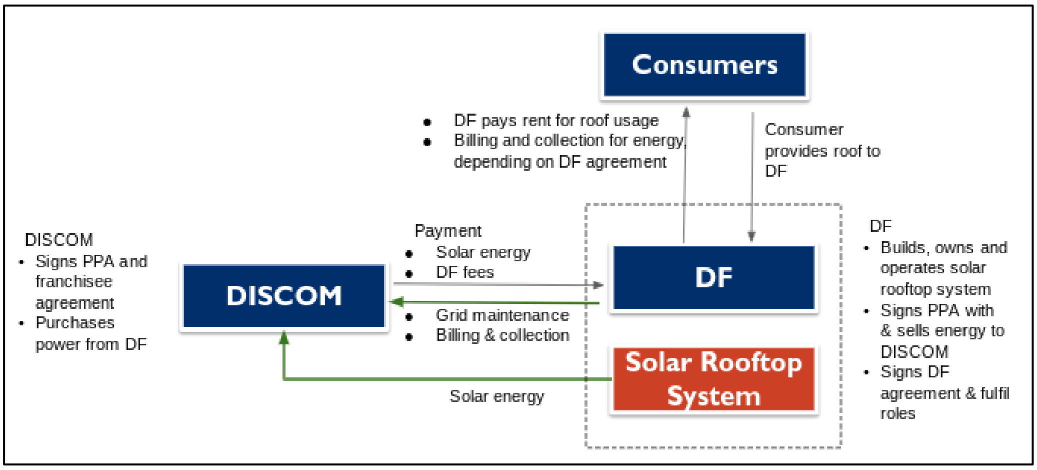


Figure 6: DF and S-RESCO model bundled

FINANCIAL AND ECONOMIC ANALYSIS

The previous section demonstrated the qualitative benefits of the Super RESCO model for each of the stakeholders. This section focuses on estimating the financial and economic gains for key stakeholders: DISCOM, state government, investor/RESCO, and customer. One important component of the cost of power delivered to the consumer is T&D losses. Higher T&D losses mean that higher costs for the power that delivered. Domestic consumers are predominantly connected on the low-tension (LT) side of the grid. Due to higher T&D losses for the LT grid, the cost of power delivered to the consumer is higher compared to high-tensions consumers. Since generation and consumption points are co-located for SPVRT, no T&D losses are involved. This makes SPVRT attractive compared to conventional power plants for supplying the power to residential consumers. When SPVRT is deployed in areas with higher T&D losses, DISCOMs gain more. These gains can be directly attributed to the Super RESCO model for DISCOMs. For the investor/RESCO, the gains are in the form of annual returns on equity invested for developing the SPVRT units.

To conduct the analysis, we used the Super RESCO model and focused on our two partner states, Assam and Jharkhand. The methodology, assumptions, and data were discussed and debated with key stakeholders of the two partners states, such as DISCOMs, state electricity regulatory commissions (SERCs), government, and developers/EPC. To have a large sample size, four mores states were identified, and analysis was conducted for them as well. Thereafter, the analysis was conducted at the national level. The results were determined for various levels of solar rooftop deployment. The low-paying customers were included by conducting the analysis at higher T&D losses. This following chapter provides the details about the methodology used in the analysis, assumptions made, sources of data, and results obtained for six states and at the national level.

METHODOLOGY

It was important to have data from the same year for all six states and at the national level to do a meaningful comparison. The analysis used FY 2018–2019 as the base year. Most of the data for the state analysis was taken from annual revenue requirement (ARR) petitions and regulatory orders of the respective states. The data for national level analysis is taken from Power Finance Corporation (PFC) report on Performance of State Power Utilities 2018-19 published in August 2020, and monthly reports published by the Central Electricity Authority (CEA). The cost of solar power at the customer's premise, inclusive of roof rent, is INR 4.5/kWh based on the market research conducted by PACE-D 2.0 RE. Annex 2 provides all the details about data sources, assumptions and models developed for this analysis.

The team conducted the financial and economic analysis for three different levels of SPVRT penetration: 5, 10, and 15 percent. The financial gains were further analyzed for three different levels of T&D losses for the 10 percent penetration level of SPVRT. The three different levels of T&D losses used the current value of T&D losses as the baseline and then increased this by 5 percent and 10 percent. The results are presented in the next section.

The economic analysis was carried out for four parameters: (1) carbon emission, (2) new investment, (3) increased reliability and quality of supply, and (4) employment generation. The quantitative analysis was conducted for (1), (2), and (4). We also developed an Excel-based model to determine the economic gains for three different levels of SPVRT penetration (5,10, and 15 percent). The economic gains will not vary significantly due to T&D losses.

FINANCIAL ANALYSIS

Table 8 presents the results of the financial analysis for SPVRT penetration of 5, 10 and 15 percent.

Table 8. Financial analysis for 5, 10, and 15 percent SPVRT penetration in residential sector

Parameters	Unit	Assam	Bihar	Gujarat	Haryana	Jharkhand	West Bengal	National
Sale to domestic customers	MUs	3,476	11,506	11,650	9,630	5,442	10,913	2,68,198
Cost of power purchase at state periphery	INR/kWh	4.01	3.77	3.84	4.35	3.99	3.45	4.64
T&D Losses	%	19.87%	30.94%	13.98%	18.08%	28.60%	23.00%	22.03%
Cost of supply at customer end	INR/kWh	5.00	5.45	4.46	5.31	5.59	4.48	5.95
Cost of energy from SPVRT (without subsidy)	INR/kWh	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Saving for DISCOM from SPVRT	INR/kWh	0.50	0.95	-0.04	0.81	1.09	-0.02	1.45
Cost of energy from SPVRT (with 30% subsidy)	INR/kWh	3.15	3.15	3.15	3.15	3.15	3.15	3.15
Saving for DISCOM from SPVRT	INR/kWh	1.85	2.30	1.31	2.16	2.44	1.33	2.80
5% of domestic sales supplied from SPVRT								
Energy supplied from SPVRT	MUs	174	575	582	482	272	546	13,410
Capacity addition from SPVRT	MW	117	386	391	323	183	366	9,005
Annual Saving to DISCOM (without subsidy)	INR Crore	9	55	(2)	39	30	(1)	1,946
Annual Return on Equity for Investor	INR Crore	19	63	63	52	30	59	1,459
Total Financial gains (without subsidy)	INR Crore	28	118	61	91	60	58	3,405
Annual Saving to DISCOM (with 30% subsidy)	INR Crore	32	132	76	104	67	73	3,756
10% of domestic sales supplied from SPVRT								
Energy supplied from SPVRT	MUs	348	1,151	1,165	963	544	1,091	26,820
Capacity addition from SPVRT	MW	233	773	782	647	365	733	18,010
Annual Saving to DISCOM (without subsidy)	INR Crore	18	110	(5)	78	60	(2)	3,892
Annual Return on Equity for Investor	INR Crore	38	125	127	105	59	119	2,918
Total Financial gains (without subsidy)	INR Crore	56	235	122	183	119	117	6,810
Annual Saving to DISCOM (with 30% subsidy)	INR Crore	64	265	153	208	133	145	7,512
15% of domestic sales supplied from SPVRT								
Energy supplied from SPVRT	MUs	521	1,726	1,747	1,445	816	1,637	40,230
Capacity addition from SPVRT	MW	350	1,159	1,173	970	548	1,099	27,014
Annual Saving to DISCOM (without subsidy)	INR Crore	26	164	(7)	117	89	(3)	5,837
Annual Return on Equity for Investor	INR Crore	57	188	190	157	89	178	4,376
Total Financial gains (without subsidy)	INR Crore	83	352	183	274	178	175	10,213
Annual Saving to DISCOM (with 30% subsidy)	INR Crore	97	397	229	312	200	218	11,268

The financial analysis was also conducted for existing T&D losses and for losses 5 percent and 10 percent higher than existing. Figures 9 through 11 present these results.

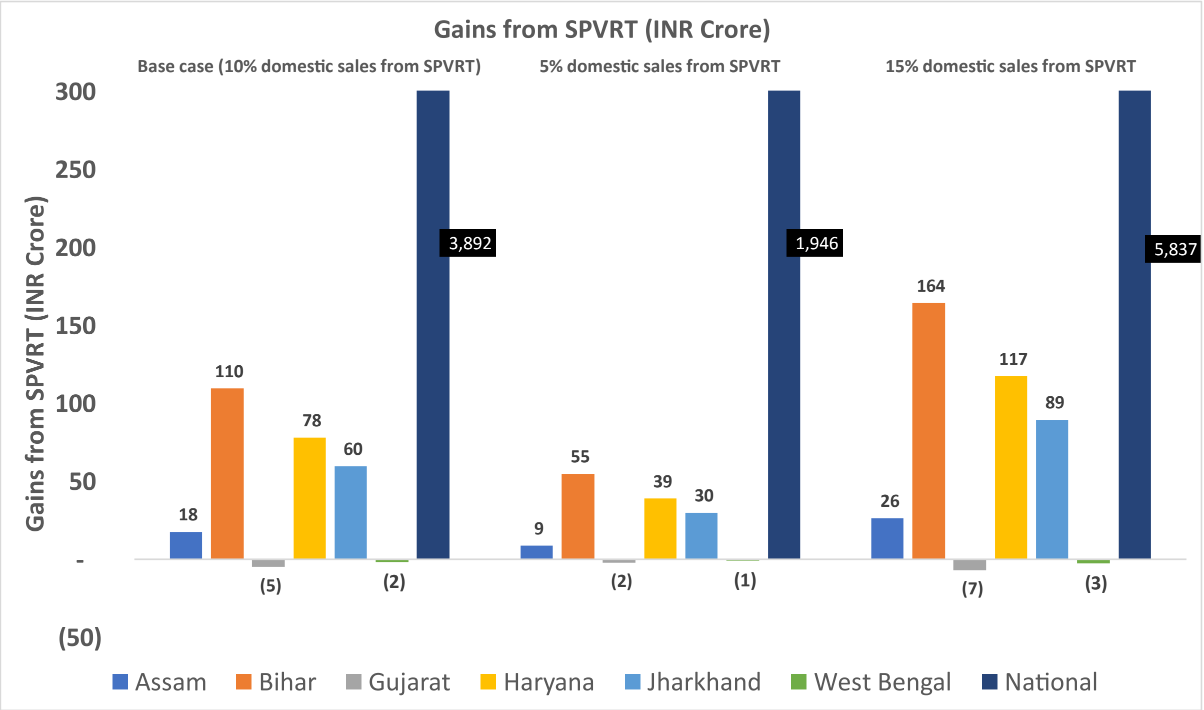


Figure 7. Financial analysis with actual T&D losses

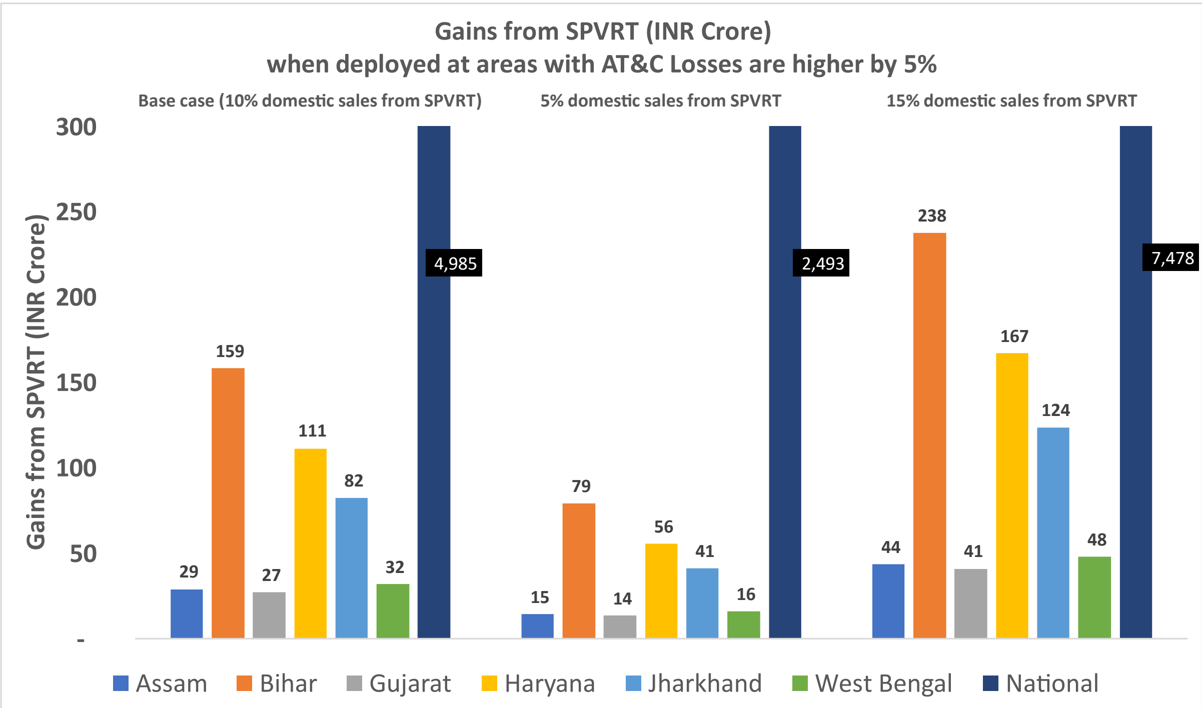


Figure 8. Financial analysis for T&D losses 5 percent higher than actual

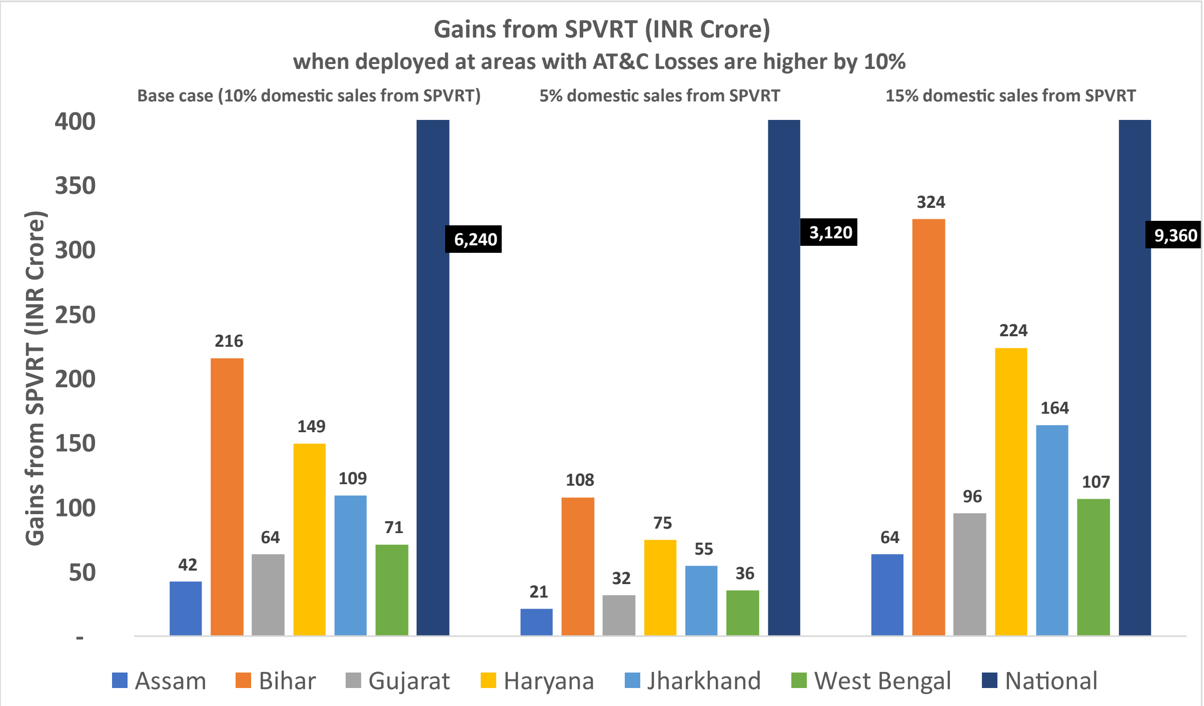


Figure 9. Financial analysis for T&D losses 10 percent higher than actual

Please note that DISCOM gains mentioned in the above are annual gains, but developer gains are one time only.

With subsidies, SPVRT is profitable for all states. Without subsidies, Gujarat and West Bengal are the only states that do not make a profit at all levels of penetration of SPVRT. The DISCOM benefit is dependent on two parameters—cost of power purchase and T&D losses. Gujarat's T&D losses are substantially lower, about 14 percent. In West Bengal, the power purchase cost is the lowest among all six states analyzed. Figure 10 illustrates that as the T&D loses are increased by 5 percent from the actual average, both Gujarat and West Bengal start making a profit. The T&D losses taken in Table 8 are average T&D loses. There will be pockets in Gujarat and West Bengal where T&D losses will be higher than the average. Thus, even Gujarat and West Bengal can implement SPVRT in the residential sector with profit for the DISCOMs. Therefore, we recommend deployment of SPVRT should start from the pockets where T&D losses are high. According to the above analysis, each DISCOM can work out their threshold level of T&D losses above which they can make a profit with SPVRT. The DISCOMs' per unit gains increase as T&D losses increase. However, penetration level does not increase per unit gain, just total gain to the DISCOM.

The investor makes a maximum and significant profit. The investor profit has been calculated with 12 percent return on equity. Generally, competition lowers the return on equity, reducing profit to the investor but lowering the cost of generation from SPVRT, which increases profit for the DISCOM.

Most states, including RE-rich states such as Gujarat, are unable to meet their renewable power purchase obligation (RPO) targets. To compensate for the gap in meeting the RPO targets, DISCOMs purchase renewable energy certificates (RECs) from the market. SPVRT in the Super RESCO model will help DISCOMs meet their RPO targets and will avoid the need to purchase RECs. At the 15 percent level of SPVRT penetration, Jharkhand, Haryana, Gujarat, Bihar, West Bengal and Assam can save INR 99 crore, INR 151 crore, INR 202 crore, INR 254 crore, INR 159 crore, and INR 59 crore per year, respectively, by avoiding purchase of RECs at a very conservative price of INR1.0 per REC. RPO analysis has been conducted using the RPO targets and achievements for the FY 2018–2019.

UTILIZATION OF FINANCIAL GAINS

Financial gains of the DISCOM can be utilized in several ways such as reducing the customer tariff, reducing the direct subsidy, reducing cross subsidy, and sharing the gains with SPVRT customers, etc. The Government of Haryana provides a subsidy of INR 0.84/ kWh to some residential customers. By replacing 15 percent of residential consumption with SPVRT, the Haryana Government can reduce the direct subsidy that it provides to its DISCOMs by INR 117 crore per year.

One of the greatest advantages of the deployment of SPVRT with LPC is the reduction of T&D losses in segments that are historically challenging for DISCOMs.

ECONOMIC ANALYSIS

The economic gains for 5 percent, 10 percent, and 15 percent penetration levels of SPVRT in the residential sector are presented below in Tables 9 through 11.

Table 9. Economic gains at 5 percent penetration of SPVRT

Parameters	Unit	Assam	Bihar	Gujarat	Haryana	Jharkhand	West Bengal	National
SPVRT capacity addition	MW	116	384	388	321	181	364	8,940
Investment in the state	INR Cr.	521	1,726	1,747	1,445	816	1,637	40,230
Employment generation	Nos.	579	1,918	1,942	1,605	907	1,819	44,700
Reduction in CO2 emissions	M tons/ annum	162	536	543	449	254	509	12,498

Table 10. Economic gains at 10 percent penetration of SPVRT

Parameter	Unit	Assam	Bihar	Gujarat	Haryana	Jharkhand	West Bengal	National
SPVRT capacity addition	MW	232	767	777	642	363	728	17,880
Investment in the state	INR Cr.	1,043	3,452	3,495	2,889	1,633	3,274	80,459
Employment generation	Nos.	1,159	3,835	3,883	3,210	1,814	3,638	89,399
Reduction in CO2 emissions	M tons/ annum	324	1,072	1,086	898	507	1,017	24,996

Table 11. Economic gains at 15 percent penetration of SPVRT

Parameters	Unit	Assam	Bihar	Gujarat	Haryana	Jharkhand	West Bengal	National
SPVRT capacity addition	MW	348	1,151	1,165	963	544	1,091	26,820

Investment in the state	INR Cr.	1,564	5,178	5,242	4,334	2,449	4,911	1,20,689
Employment generation	Nos.	1,738	5,753	5,825	4,815	2,721	5,457	1,34,099
Reduction in CO2 emissions	M tons/ annum	486	1,609	1,629	1,346	761	1,526	37,494

As is evident, there are significant economic gains. Generally, these gains are considered in an unquantified manner in the decision about the subsidy made by the state governments. Investment in the state and employment generation are often ignored. This analysis can help state governments make a more quantified decision about state subsidies. An investment of about INR 400 billion with 5 percent penetration of SPVRT will boost significantly the “Make in India” program of the Government.

IMPLEMENTATION OF SUPER RESCO MODEL

The Super RESCO model addresses several stakeholder challenges, but to get all its benefits, careful implementation is critical. The foremost implementation challenge is changing the role of the DISCOM from passive facilitator to active facilitator and generator. DISCOMs with strong financial positions, such as Gujarat's, should play the role of facilitator, generator, and investor. The maximum profit in the deployment of SPVRT is being made by investors and RESCOs (see Table 8).

This change in role and mindset at DISCOMs is required not just at the top level of DISCOMs but most importantly at the field level. The DISCOMs' customer contact field units know where T&D losses are high and roof space is available. They know about their customers' behavior and are responsible for interconnections with the grid, metering, billing, monitoring, and keeping a check on the services of the EPC.

Most importantly, DISCOMS should take an active part in SPVRT deployment because their future depends on it. The cost of solar generation is continuing to drop, which means that the market and consumers will find a way to keep SPVRT moving forward regardless of the role played by DISCOMs. It may take more time if DISCOMs do not play an active role, but it will happen. Many C&I customers have installed their own SPVRT, and DISCOMs are already feeling the loss of this revenue and business. The SERCs and state governments will not be able to protect DISCOMs for long by limiting installation capacity and the supply of excess generation to the grid. Ultimately, market economics will prevail. The sooner DISCOMS realize this, the greater their chance of survival. This realization represents 60 percent of the implementation challenge associated with SPVRT. The remaining 40 percent of implementation challenges are described in the following text.

IDENTIFICATION OF THE LOCATION

The model can be implemented across DISCOMs, but it is advisable to either conduct a pilot in a few locations or implement in stages as field results of the model are yet to come. As we have seen in Table 8, the model is not financially beneficial in areas where T&D losses are low. However, subsidized SPVRT for LPC provides financial gains in all areas. The location should be identified based on the following criteria in order of priority:

- Availability of roof;
- T&D losses; and
- Reliability of the power supply.

The selection of the location should be based on 33/11 kV distribution substations for ease of implementation and monitoring. If a roof in the area of one substation is not sufficient to implement at least 1 MW capacity, nearby substations should be combined. It is assumed that capacity of 1 MW is sufficient to keep the transaction cost low and achieve the economy of scale that will lower the cost of generation. The substations with higher T&D losses should be selected first as they will produce greater financial gains. Solar generation is wasted if there is no way to get the power to the grid. We hope a cost-effective technological solution to address supply challenges will develop soon. Until then, we should select substations where power supply reliability is good.

TENDER DESIGN

Tender design is important for the following reasons:

1. To elicit a good response from the market;
2. To select the right RESCO; and
3. To achieve quality and safety in SPVRT installations.

If the tender provides all the information required to submit a competitive bid, the response from the market is robust, and prices are competitive and practical. Therefore, we recommend not only a pre-bid meeting but also a pre-tender meeting and site visit. Holding these meetings at the involved substations is good. The tender must specify key standards and best-practice safety guidelines for the RESCO to follow during deployment. In addition to the usual information any tender document must have, the tender for an S-RESCO should have the following information or documents:

1. Power purchase agreement to be signed by customer, RESCO, and DISCOM;
2. Roof agreement to be signed by investor, RESCO, customer, and/or DISCOM; and
3. Evaluation criteria developed on the basis of low cost and technical parameters.

The PPA should clearly specify the interconnection scheme, installation capacity, metering, billing, payment mechanism, remedies/compensation for payment default, intended generation, etc. The roof agreement should specify obligations for each party during the project period. The important clauses to be covered are (a) physical parameters of the roof, (b) responsibilities, (c) security of SPVRT, (d) entry and access to roof, (e) conditions of default, and (f) compensations for roof.

CUSTOMER INVOLVEMENT

One of the keys to implementation of the S-RESCO model is customer involvement. Obviously, involvement and cooperation are inspired by:

1. Reduction in the electricity bill, and
2. Compensation for the roof.

Reduction in the electricity bill is directly related to the sharing of financial gains by DISCOMs. There can be several ways to do this. For example, (1) some percentage of electricity generation is free for the roof owner, (2) different tariffs can be set for electricity used from SPVRT and grid supply, and (3) a predefined tariff can be set for the electricity supplied to the grid after self-consumption. Similarly, compensation for the roof can be included as a reduction in the electricity bill or it can be paid separately on a month-by-month basis by the RESCO to the roof owner. Other customer advantages include:

1. Power supply of higher reliability and quality, and
2. Pride in contributing to clean energy generation and use.

Customer involvement efforts should be initiated from the very beginning. In addition to standard methods of advertisement, the customers should be invited to the substation or local office of the DISCOM, and all the details of the program should be explained. The reduction in the bill and roof compensation should be explained by example and with long-term calculations. Presenters should emphasize pride in supporting the country, environmental benefits, and the health of present and future generations. The level of SPVRT penetration directly depends on customer involvement.

CAPACITY-BUILDING OF DISCOM FIELD UNITS

DISCOM field units are the main point of contact for customers and also for RESCOs after the agreement is signed. Thus, it is important to explain to DISCOM field officers the award process for SPVRT; deployment of SPVRT; roles and responsibilities of DISCOMs, RESCOs, and customers; interconnection process; and provisions of PPAs and roof agreements. This should be done in writing and through one or two workshops. Field units should be encouraged to meet with customers; their attitude and approach greatly affect the success of SPVRT penetration.

MONITORING OF THE PROGRAM

The program should be monitored based on the following key parameters:

1. Electricity generation per KW of total installed capacity of SPVRT;
2. Electricity generation as a percentage of total domestic consumption;
3. Reduction in the customer bill of customer;
4. Reduction in T&D losses;
5. Financial gains to DISCOM;
6. System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) for reliability and quality of supply;
7. Reactive power, harmonics, and power factors; and
8. Accidents or safety incidents.

Each DISCOM has its own procurement guidelines. The GoI also provides guidelines for competitive bidding. If generation cost is the only criteria, sometimes impractical bids are submitted and the contract is awarded, but ground implementation does not take place. Therefore, it is important to weed out such bidders on the basis of technical parameters and criteria. All the above documents, such as PPAs, roof agreements, evaluation criteria, etc., are developed by the PACE-D 2.0 RE team as guidelines and are available at www.pace-d.com. They have been discussed and debated with stakeholders in Assam and Jharkhand with workshops conducted at Guwahati (Assam) and Ranchi (Jharkhand) to obtain views of RESCOs, EPC, and investors on these documents.

To the best of our knowledge, the S-RESCO model has not been tested on the ground. A tender has been released in Jharkhand to test it in a 25 MW pilot, and Assam and Bihar are considering active implementation of the S-RESCO model.

KEY RECOMMENDATIONS AND WAY FORWARD

To successfully implement this and achieve the gains identified in this paper, we make the following recommendations. The recommendations are largely drawn from the information and analysis provided in this paper, state visits, stakeholder consultations, consultations with professionals working in this area, and internal and external reviews. Here we provide a summary of the recommendations we have presented in this paper and implementation suggestions.

Recommendation No.1: Transforming the DISCOM from passive facilitator to active facilitator, generator, and investor

Relevance	As the most critical stakeholder, DISCOMs are the pivot point for SPVRT. Presently, DISCOMs are losing their most profitable C&I customers. It is important that they remain active to avoid losing profit from low-cost solar generation.
How it will be implemented	Capacity-building workshops for DISCOMs by government.
Who will implement it	Central and state governments.

Recommendation No.2: New business models for implementation of SPVRT

Relevance	As mentioned, the existing business models do not offer win-win situations for all key stakeholders. The Super RESCO model bundled with the distribution franchise model, or without, satisfies all key stakeholders.
How it will be implemented	DISCOMs need to internalize the process for implementation of SPVRT and realize this is necessary for their survival and growth.
Who will implement it	DISCOMs

Recommendation No 3: Government guarantee for financing risks

Relevance	Many times, DISCOMs and customers do not have adequate finances. The investors/RESCOs also are unable to get support from the bank, as the banks want guarantees. It becomes even more challenging since the capital equipment is on the roof of the customer. The financing risk guarantee by Government will ease the pressure on bank for safeguarding their finance.
How it will be implemented	Purchase of risk insurance or government assuming the default risk
Who will implement it	Government of India (MNRE)

Recommendation No.4: Not Limiting the Capacity of SPVRT to Residential Customer's Contracted Load

Relevance	In rural areas, most customers have much more roof/land than required to install SPVRT equal to the contracted load. Relaxing the limit will increase the penetration of SPVRT. Higher penetration of SPVRT will increase financial and economic gains to the stakeholders.
How it will be implemented	Regulations from SERC or policies from the state government
Who will implement it	SERC or state government

Recommendation No.5: Facilitation of Roof Lease Rent

Relevance	A guideline from the state government or regulations from the SERC that fix the roof lease rent, in cash or by way of electricity credit, create more confidence for the customers. DISCOM and RESCO will be able to calculate their gains more accurately.
How it will be implemented	Guidelines by state government or regulations by SERC
Who will implement it	State government or SERC

Recommendation No.6: Development of Model Documents (Tender Document, PPA, and Roof Lease Agreement)

Relevance	Customers lack technical and legal capacity to read and understand the procedural documents and apprehend risk in signing them. DISCOMs, banks, and RESCOs spend much time developing, discussing, and agreeing to these documents. Development of model documents after consultation with key stakeholders will simplify and speed up the deployment of SPVRT.
How it will be implemented	Issuing the model documents from the government or regulators and posting them on their websites
Who will implement it	Central and state government or SERC

Recommendation No.7: Capacity-Building of DISCOM Field Staff

Relevance	Customers contact field units of DISCOM for SPVRT. Many times, DISCOM field staff are unaware of important procedures and policies. Capacity-building will help field staff of DISCOMs understand that SPVRT is in the financial interest of DISCOM.
How it will be implemented	Written directions and capacity-building workshops
Who will implement it	DISCOM

Recommendation No.8: Consumer Awareness

Relevance	Consumer awareness will not only increase but accelerate the deployment of SPVRT. Implementation will also become easier.
How it will be implemented	Customers meet at substations, online campaigns, social media, posters, etc.
Who will implement it	State government, DISCOMs, and RESCOs and investors

ANNEX 1. CASE STUDIES: EXPERIENCE OF STATES IN ROLLING OUT SOLAR PV ROOFTOP PROGRAMS

5 MW Gandhinagar rooftop solar program

About the program – The Government of Gujarat launched the Gandhinagar solar PV rooftop program in 2010. It the first pilot demonstration of the PPP model, where the government engaged with RESCOs to implement solar PV rooftop projects on government and residential buildings in Gandhinagar. Being the first of its kind, the project faced many challenges, like the acceptance of solar PV installations on the rooftops by owners in residential and commercial sectors, the ability of the owner to execute the installations in their respective areas, readiness to invest and own the installations, funding arrangements, sale of power and revenue models, permissions and approvals, operation and maintenance, along with determining the appropriate system architecture, etc.

Business model – The Gandhinagar program had a total size of 5 MW and was implemented through a RESCO model. Azure Power and Sun Edison were selected through tariff-based competitive bidding and were allotted 2.5 MW each. The Gandhinagar program was implemented under a gross-metering mechanism with Torrent Power Limited, with the DISCOM supplying electricity to the Gandhinagar area as a buyer for the solar power. Roof owners receive a "green incentive" of INR 3/kWh instead of a flat rent from RESCOs for providing their roofs. Roof owners receive INR 3/kWh for electricity generated from solar PV rooftop systems. The incentive was designed to be generation based in order to motivate the rooftop owner to actively engage in the Gandhinagar program [31-32].

Grid-connected rooftop/ground-mounted solar PV plants under SOURA scheme

About the program – Under the Urja Kerala Mission, the Government of Kerala has launched the SOURA project to add 1,000 MW of solar power plants to the grid of Kerala State Electricity Board Ltd (KSEB). Out of 1,000 MW, the state has set a target of 500 MW from solar PV rooftop projects. In this regard, KSEB released a 200 MW tender under the SOURA program in 2019. KSEB is the facilitating organization and has identified 70,000 roofs that are feasible for solar PV rooftop projects. The organization will further engage with customers to acquire roofs and will provide the same to developers (EPC/RESCOs selected during bidding process) for setting up the solar PV rooftop projects.

Business model – KSEB has suggested both EPC- and RESCO-based implementation models under the program. Model 1 is RESCO based and involves KSEB using the roofs of interested customers and engaging with RESCOs for developing solar PV rooftop projects. The entire solar generation will be procured by the KSEB. Roof owners will get energy credits for 10 percent of the solar power generated on their roofs, whereas Model 2 and Model 3 are EPC based. In Model 2, the energy generated will be sold to the owners of the respective roofs at a fixed tariff. The tariff includes cost of generation plus a margin. In Model 3, KSEB will develop a solar PV rooftop system through an EPC developer and transfer it to customers. A total capacity of 200 MWp will be installed under the Program [33].

Andhra Pradesh's pilot for low-income, low-consumption customers

About the program – Realizing the potential savings in the case of low-electricity consumption customers (also cross-subsidized customers), Andhra Pradesh Eastern Power Distribution Company

Ltd (APEPDCL) has facilitated a "DISCOM-driven solar rooftop pilot" for residential customers with power requirements of less than 200 units in a month. It was implemented at two locations (Muralinagar and Madhurawada) in Visakhapatnam City to demonstrate the concept.

Business model – Under the pilot, both EPC and RESCO models are available. Model 1 is a customer-owned solar PV rooftop program using a net metering arrangement. The capacity of solar PV rooftop systems will be 1 to 1.5 kW. Financing of the solar PV rooftop systems is through a combination of the following: (a) capital subsidy extended by GoI and Government of Andhra Pradesh, (b) loan to customers at preferential terms, and (c) upfront equity contribution from customer. As part of the pilot, Andhra Bank extends loan to the customers at preferential terms. EMIs on loan is recovered by APEPDCL through their electricity bills to the participating customers. EMIs are designed not exceeding the current power bills during the loan tenure period. The EMIs collected by APEPDCL are passed on to Andhra Bank.

Model 2 is RESCO oriented and under gross metering. In this model, a RESCO will be selected through competitive bidding for the supply of power to APEPDCL for 25 years. The RESCO will utilize the rooftop spaces of willing customers. Consumers are compensated by APEPDCL at a rate of INR 0.5/kWh for solar electricity generated [34-35].

UJALA program for energy-efficient and affordable lighting to all

About the Program – In India, lighting accounts for about 20 percent of total electricity consumption. The conventional incandescent bulbs consume more power and thus increase the overall energy demand in the country. In 2015, the GoI took an initiative to reduce energy demand in the lighting sector and launched the nationwide program "Unnat Jyoti by Affordable LEDs for All (UJALA)." Under the program, the GoI promoted efficient lighting products, such as light emitting diode (LED) bulbs and tube lights.

Business Model – Energy Efficiency Services Limited (EESL), a public sector undertaking, has been designated as the implementing agency for this program. Energy-efficient appliances, especially bulbs, tube lights, and fans, lead to savings on electricity bills for customers and reduction in peak load for DISCOMs. EESL developed a business model through benefit sharing approach. Under this model, part of the cost of energy efficient appliances are recovered from customers rest is recovered from DISCOM to reduce the burden of upfront investment on the customers and DISCOMs, EESL recovers the costs over a period of time. EESL provides customers LED bulbs and tube lights at a rate of INR 70 and INR 290, respectively, which is below the market price. The rest of the cost is recovered from DISCOM. The upfront investment made by EESL is recovered in two ways:

a) **DISCOM Cost Recovery**: LEDs and tube lights lead to reduction in load for the DISCOM. The savings due to reduced load is estimated based on the peak procurement cost of DISCOM. These savings are used to calculate annuities for DISCOMs. The cost is recovered from DISCOMs over a period of three to ten years.

b) **On-Bill Financing**: Cost to customers is recovered through 8 to 12 monthly installments. DISCOMs collect these installments through the electricity bills and pass them on to EESL.

Under the UJALA program, over 36 crore LED bulbs have been distributed as of January 2020. This has helped in avoiding the peak demand by 9,000 MW and reducing greenhouse gas emissions by 38 million tons annually [36-37].

ANNEX 2. DATA COLLECTION, ASSUMPTIONS, AND MODELS

SELECTION OF THE BASE YEAR AND DATA COLLECTION

It was important to have data from the same year for all six states and at the national level to do a meaningful comparison. The analysis used FY 2018–2019 as the base year. More recent data were available for a few sates but not for all six dates due to delays in orders on the annual revenue requirement (ARR) and the effects of COVID-19. The objective of the analysis was to test the perception. Thus, current financial gains and losses can be calculated easily by using the current data and will not change the results of validation of the perception issue.

STATE LEVEL

Most of the data were collected from the ARR orders of the respective states. The data were verified and supplemented by the ARR petitions filed by the DISCOM, published consultants' reports, Power Finance Corporation (PFC) report on Performance of State Power Utilities 2018-19 published in August 2020, and annual report of the DISCOMs. The data collected included energy sales, quantity of power purchase, cost of power purchase (fixed and variable charges), transmission and distribution losses, direct subsidy, cross-subsidy, and tariff schedule.

NATIONAL LEVEL

In 2018-19, India had an annual energy sale of 9,57,509 million units (MUs), of which domestic, industrial, and agricultural sectors consumed 28.01 percent, 29 percent, and 22.44 percent of the total energy, respectively [6]. Thus, all-India energy sales in the residential sector was 268,198 MUs. Besides the PFC report, the other important sources used for data collection are the monthly power sector report published by the Central Electricity Authority (CEA). Table 12 presents the key data for the national analysis.

Table 12. Key data used (national level)

Assumptions	Unit	Value
Energy Sales to domestic customers	MUs	268,198
T&D losses	%	22.03%
Average power purchase cost	INR/kWh	4.64
Average revenue from energy sales in domestic sector	INR/kWh	4.38

ASSUMPTIONS

Table 13 presents the assumptions used in the financial and economic analysis for six states and for the national level.

Table 13. Assumptions used (state and national level)

Assumptions	Unit	Value
Cost of solar power at the roof of domestic customer*	INR/kWh	4.50
Plant load factor of SPVRT	%	17%
Cost of SPVRT installation	INR Cr./ MW	4.50
Interest rate	%	10
Debt equity ratio	%	70:30
Return on equity	%	12

CO_2 emission reduction	Kg/kWh	0.932
Employment Generation**	No.	5/MW

*The cost includes the roof rent. For details about options for roof rent Ref. section 2.8

**According to estimates of the Council on Energy, Environment, and Water (CEEW) and the Natural Resources Defense Council (NRDC), as of 2019, more than 38,000 workers were directly employed for 3.8 GW of total cumulative installed solar rooftop capacity, which is about ten jobs/MW in comparison to over 37,910 workers for 26.2 GW of total utility-scale solar projects [13]. As a part of this analysis, the number of jobs that can be generated has been considered at five per MW.

MODELS

In order to assess the benefit/loss of solar rooftop to DISCOMs, states, and customers, the power purchase cost (PPC) and landed cost of conventional power supply were calculated as follows:

$$PPC = Total\ approved\ quantum\ of\ energy/cost\ incurred\ in\ power\ procurement$$

$$Landed\ cost\ of\ conventional\ supply = PPC/(1 - \%transmission\ loss)/(1 - \%distribution\ loss)$$

In determining the benefit/loss the cost towards SLDC charges, O&M expenses, transmission charges, etc. have not been included as they will be same in the two scenario; without SPVRT and with SPVRT.

The rest of the analysis is simple. The existing cost of supply was determined to the domestic customer by adding the T&D losses in the power purchase cost. The cost of generation from SPVRT has been taken as INR 4.5/kWh based on the market understanding of the PACE-D 2.0 RE team. The difference in the two cost is financial gain/loss to DISCOM.

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