ADBI Working Paper Series

ROOFTOP SOLAR DEVELOPMENT IN INDIA: MEASURING POLICIES AND MAPPING BUSINESS MODELS

Gopal K. Sarangi and
Farhad Taghizadeh-Hesary

No. 1256
April 2021

Asian Development Bank Institute

Gopal K. Sarangi is an assistant professor at the Department of Policy Studies of TERI School of Advanced Studies, New Delhi. Farhad Taghizadeh-Hesary is an associate professor at Tokai University, Japan.

The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. Some working papers may develop into other forms of publication.

Suggested citation:

Sarangi, G. K. and F. Taghizadeh-Hesary. 2021. Rooftop Solar Development in India: Measuring Policies and Mapping Business Models. ADBI Working Paper 1256. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/rooftop-solar-development-india-policies-mapping-business-models

Please contact the authors for information about this paper.

Email: gopal.sarangi@terisas.ac.in

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

Rooftop solar (RTS) photovoltaic (PV) interventions are an attractive and promising energy ventures for developers, entrepreneurs, financial institutions, consumers, and electricity distribution utilities in India. These RTS systems are currently experiencing sluggish growth due to multiple technical, policy and regulatory, and financial hurdles encountered by them. The present study focuses on two crucial aspects of RTS development in India: it comprehensively maps and measures policy strengths at the sub-national scale, and it critically and comparatively examines the prevailing business models for RTS systems based on their characteristics and key features. A combination of theoretical arguments, empirical observations, and logical reasoning is employed to construct a composite index for measuring policy strengths, and literature review and expert solicitation surveys are carried out to assess the business models and their characteristics. Analysis of policy strengths indicates that while states like Andhra Pradesh, Gujarat, Jharkhand, Karnataka, and Telangana are ahead in terms of policies, states such as West Bengal, Tripura, Punjab, Uttarakhand, and other parts of northern India, emerge as having poorly designed state RTS policies. Assessment of business models and their risks reveals that consumers bear a significant proportion of risks in the CAPEX model compared to the OPEX model.

Keywords: rooftop solar PV systems, policy strength, business models, India

JEL Classification: Q4, Q42, Q48

Contents

1. INTRODUCTION

India's energy system is at a critical transition point, as the country's fossil fuel–dominant energy mix is gradually being replaced by an increasing share of renewables. It is reflected both in the installed capacity terms as well as the energy generation mix figures. The latest available statistics on installed capacity reveal that close to 24% of total installed capacity in the country is from renewable energy sources (Central Electricity Authority [CEA] 2020), and the energy generation mix figures show that renewables constitute about 9.21% of the total energy generation in the country (CEA 2019).

This transformation is driven both by domestic needs and global commitments of the country to move on a sustainable development trajectory. Domestic drivers including growing demand for more energy, rapidly increasing urbanization and it's consequent environmental and climate effects such as air pollution are the key underlying forces behind this transition. Projections reveal that energy demand in the country will surge owing to better energy access conditions, changing socioeconomic profile of the country, and increased rates of urbanization due to the country's emerging middle class. The International Energy Authority (IEA 2020) projections indicate that energy demand in the country will double by 2040 and electricity demand will be tripled during the same time frame. It is estimated that around 814 million people will be living in urban areas by 2050. Most importantly, emerging problems like air pollution are becoming a major domestic threats and roadblocks in the country's sustainable development growth path.

Apart from domestic factors, India also has global commitments, which are largely associated with the efforts to arrest the imminent threats of climate change and the need to drive the country on a sustainable development trajectory. The most important commitment is the declaration of India's Nationally Determined Contributions (NDCs) and commitment to expand the renewable energy mix in the country to 40% by 2030. In addition, the goal reduces the emission intensity by 33%–35% in 2030 from 2005 levels clearly reveals such commitments. These commitments clearly establish the need to shift to a decarbonized energy system. India is committed to accelerating its effort to achieve the Sustainable Development Goals (SDGs) as well, particularly Goal 7, with its emphasis on universal access to electricity and clean cooking fuel, increasing share of renewables in the country, and enhancing energy efficiency levels, which untangles the process of on-going energy transition in the country.

All of these stated commitments clearly stress the imperative for strategic policy action plans to accelerate renewable energy development in the country. There have been structured policy goals devised for accelerating the use of renewable energy in the country based on a multi-pronged approach. The target of deploying 175 GW of renewables by 2022 clearly speaks to the emphasis laid on renewables in line with global commitments and domestic drivers. Within renewables, solar has received pride of place and is being prioritized in the energy policy agenda as a key energy technology. The latest statistics show that while the installed capacity of renewable energy had touched a new high of 84 GW by December 2019, solar occupies an important place next to wind energy, and its share rose to 32.52 GW by December 2019.

One of the priority areas within solar energy is the roof-top solar (RTS) photovoltaic (PV) segment. RTS has, in recent years, shown itself to be an attractive and promising energy venture for developers, entrepreneurs, financial institutions, consumers, and electricity distribution utilities in India. There have been targeted policies promoting

RTS as a cost-effective, efficient, and easy-to-implement energy intervention. The set goal of deploying 40 GW of RTS by 2022 is transformative and unprecedented in the Indian context, given that energy plays a crucial role in the country's sustainable development trajectory (Sarangi et al. 2019). A variety of technological, deliverable, and business models have been experimented, and a steady rise in the RTS market in the last couple of years has been observed, with cumulative installed capacity standing at 4375 MW as on 31 March 2019 (Bridge to India 2019).

RTS PV differs from other forms of solar interventions due to its inherent features and technical characteristics; one of the key technical features of such systems is their modularity. They can technically be designed based on the requirements of the beneficiaries. These interventions could be offered in varying operational forms such as stand-alone systems, grid-connected systems, and hybrid types. The second key reason to promote RTS PV in India draws from its strengths: it is less demanding in terms of land, which is important in a country that is already land starved.[1] Not only does India face land scarcity, the process of land acquisition is also quite cumbersome, as land is enshrined as a state subject in the Indian constitution. It takes almost six to nine months to procure land for utility-scale solar and wind projects (Kumar and Thapar 2017). Another major benefit of RTS PV is its cost savings. It is reported the prevailing tariffs for commercial and industrial consumers are comparatively high. Studies point out that while the commercial and industrial grid tariff lies between Rs 6–11/kWh, the levelized cost of electricity (LCOE) for RTS is estimated to be between Rs 3–5/kWh (Garg and Buckley 2019). Hence, the cost savings for commercial and industrial consumers is a major driver in the deployment of RTS PV systems. RTS systems also have reduced interconnection costs. Because India is facing both high aggregate technical and commercial (AT&C) losses and transmission and distribution (T&D) losses, it has been argued that RTS PV could save a significant amount of the energy lost while transmitted through grid (Rathore et al. 2019). Indeed, it has been reported that AT&C losses continues to be high, stand close to 22.01% in 2018–2019 (Power Finance Corporation 2020).

RTS can also be beneficial to distribution utilities by helping them to meet their renewable purchase obligations (RPO) requirements, manage their day-time peak load, reduce their grid congestion and loading, manage their purchasing of costly power, reduce high transmission and distribution losses, and defer their capital expenditure (CAPEX) on distribution infrastructure. Studies have pointed out that DISCOMs gain significantly from RTS installations; DISCOMs gain an estimated 22 paisa for kWh of electricity generated from the roof-top system. This gain is largely due to avoided generation capacity costs, the cost of procuring power, costs related to transmission charges and distribution capacity, and buying renewable energy certificates (Neeraj et al. 2018). It is argued that proper control of PV resources employing smart inverters could be beneficial for the distribution grid as well (Alboaouh and Mohagheghi 2020). RTS systems can contribute to the quality and reliability of the power supply too, which continues to be a major and persistent problem for the Indian power sector, as 50% Indian households do not receive electricity more than 12 hours a day according to a report by Government of India (GoI 2018). Additionally, RTS can create local eco-systems by provisioning electricity to the energy-deprived small-to-medium enterprise (SME) and micro, small and medium enterprises (MSME) sectors. More than 4 million micro-enterprises in rural areas have unreliable access to or receive only poor quality of power. RTS PV could act as a panacea for these enterprises and could accelerate local economic growth through employment and livelihood generation. Similarly, small-scale systems like RTS could enhance

[1] The country supports 17% of the global population, with a 2.4% share of the global land mass.

agricultural productivity through mechanization of irrigation systems, application of fertilizers, and assisted seed sowing and cold chain activities.

Despite the recognized inherent benefits of RTS systems and GoI's push to broaden the spread of these interventions, progress is still insufficient. While the target is to produce 40 GW through RTS PV by 2022, there has been limited achievement so far, and a meager 12% of the target (4.4 GW) has been met by December 2019. Out of the total RTS deployed in the country, the residential sector has been the worst performer, at 16%, compared to other competing sectors such as industrial and commercial. Procedural complications have also slowed down the growth momentum. Persistent policy-level inconsistencies have been a primary cause of the slow down, and it is argued that poor and piecemeal implementation of net metering policies at the sub-national scale is a major roadblock for uptake of RTS PV. Apart from regulatory and technical constraints, there are also societal and informational constraints. Poor understanding of the benefits of RTS among users is a major challenge, which is compounded by the high upfront capital cost to deploy such projects, particularly for residential consumers. Studies highlighting the poor penetration of RTS among residential consumers posit that while these systems require bottom-up approaches focusing on intense consumer engagement, the current policy and regulatory regime is designed on the principles of a top-down approach with a uniform set of policies and regulations that lack flexibility (Devi et al. 2018). There is no adequate understanding of how the existing intervention types are performing in varying policy, regulatory, and governance environments (Satsangi et al. 2019).

The development of RTS PV systems thus appears to be characterized by quite complex interactions of technological advancements, policy and regulatory pronouncements, market mechanisms, and social considerations. While the transition at the macro-scale looks quite smooth, a more detailed analysis unraveling the micro-transition processes of RTS PV systems and pathways offers ample research grounds to assess crucial aspects of these processes. In this context, the present paper pursues the following set of research objectives:

- to critically map RTC policies and regulations and assess the phased evolution of such policies and regulations in India,
- to identify and assess policy strengths at the sub-national scale, and
- to systematically analyze the key characteristics and associated risks of various business models employed for the promotion of RTS systems in India.

The data are collated from both secondary and primary sources by mining the literature in the field and carrying out deep interaction with a set of experts. Policy strength is mapped and measured using a combination of theoretical arguments, empirical observations, and logical reasoning. Empirical estimation is done by constructing a composite index considering a set of the most pertinent policy elements. Similarly, business models are compared drawing from the literature and expert solicitation surveys on key parameters and characteristics of various business models.

2. RTS STATUS AND ACHIEVEMENTS

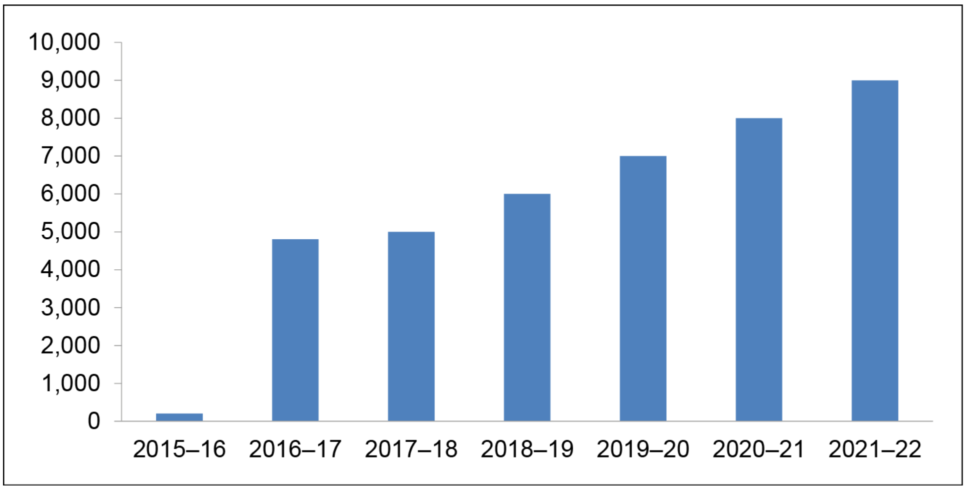
RTS PV systems are deployed on the roof of a building or installed on open contiguous land. Typically in India, a 1 kWp RTS plan requires 10 m^2 (MNRE 2019) of roof size. For the central schemes, RTS systems with a capacity between 1 kWp and 500 kWp are considered within the purview of this system.

RTS interventions can take three different forms: grid based, off-grid, and hybrid. In a grid-based system, the RTS is connected to the grid, which is owned, operated, and managed by the local distribution utilities. Often these systems have net-metering facilities, where surplus power can be fed into the grid and grid power becomes a back-up in cases of power deficit. Off-grid systems are not connected to the grid and operate on a standalone basis. These systems have battery storage facilities to maintain a steady power flow. These systems become highly relevant for countries where many rural and remotely located households are either under served through the grid or completely deprived of grid electricity. These off-grid and standalone systems do not require investment in T&D infrastructure. Hybrid systems combine the best from both grid-based and off-grid solar systems, and can be configured as off-grid systems with utility back-up power or grid-based systems supported by battery storage facilities.

Depending on the energy accounting systems, two different types of metering arrangements are associated with grid-connected RTS systems (PWC 2018). For gross metering RTS systems, energy generated through the system is fed directly into the grid and the consumer gets paid based on feed-in-tariffs (FiTs) set by the electricity regulator of the respective states. In contrast to the gross metering system, the net metering system has the provision of selling and/or banking the generated energy with the utility, allowing withdrawal when needed.

RTS systems are promising energy ventures for countries like India and possess huge future potential. A study by TERI (2016) revealed that the market potential of RTS in India stands at 124 GW. However, potential estimates by the National Institute of Solar Energy (NISE) indicate that the potential for RTS in India is around 42.8 GW, which was perhaps the basis for setting the target of 40 GW to be achieved by 2022. Year-wise targets as well as state-wise targets have been set by the GoI for RTS. While the year-wise targets (Figure 1) are set considering the current financial resource constraints and the ability to deploy RTS, the state-level RTS potential appears to have been apportioned based on the solar energy potential of the state as well as the proactive policy and regulatory framework that governs the sector.

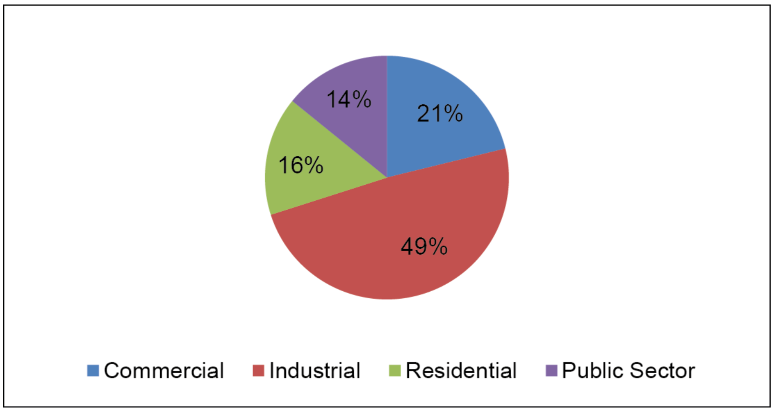
Figure 1: Year-wise Roof-top Solar Photovoltaic Target
(in MW)



Source: Author's construct (Data collated MNRE).

Deployment statistics for RTS PV show that in fiscal year 2018–2019, a capacity of 1836 MW had been added to the RTS segment. Total cumulative capacity of about 4375 MW had been deployed by the end of March 2019 (Bridge to India 2019), of which 3066 MW was installed in the commercial and industrial RTS segment and 690 MW in the residential sector, while the remaining 619 MW was installed by government agencies. These interventions appear to be more suitable for commercial and industrial consumers, which prefer larger size systems, so, over time, the average size of RTS systems has increased, with close to 30% having a capacity of more than 1 MW. Within the industrial sector, the manufacturing sector is emerging as the biggest consumer constituting about 14% of the total share, followed by infrastructure and real estate at 9%, education at 8%, and automotive at 7%, while textiles 7% and other sectors constitute the rest of the market share (Bridge to India 2019).

Figure 2: Total Installed Roof-top Solar Photovoltaic Capacity Deployed as of 31 March 2019



Authors' construct (Data Source: Bridge to India).

Different business models have been tried out in India for the deployment of RTS systems. However, two models—CAPEX and OPEX— are prevalent, whereas the aggregator and lease models are emerging business models for RTS ventures. Within these different models, CAPEX models constitute about 3055 MW and OPEX models are becoming increasingly popular in recent years, and its share has increased to 30% of the total capacity deployed. Bridge to India (2019) analysis indicates that the top five states deploying RTS in India constitute close to 55% of the total deployment capacity: Maharashtra (with a capacity of about 473 MW), Tamil Nadu (312 MW), Karnataka (273 MW) Rajasthan (270 MW), and Uttar Pradesh (223 MW). Madhya Pradesh, Odisha,[2] and Telengana are also emerging as fast-growing RTS states. To map the development status of RTS in India, an RTS attractive index known as the State RTS Attractiveness Index (SARAL) was prepared by the GoI for the year 2018–2019. Four states—Karnataka, Telangana, Gujarat, and Andhra Pradesh—received the highest ranking (i.e., A ++) for their performance, whereas seven states—Bihar, Mizoram, West Bengal, Manipur, Tripura, Meghalaya, and other states from northern India—received the lowest ranking (B), which suggests poor development of RTS in these states.

[2] In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

3. POLICIES SHAPING RTS DEVELOPMENT IN INDIA

The origin of RTS PV development in India can be traced back to the declaration of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010; the initial target was to deploy 2,000 MW of RTS by 2022. The target as revised in 2015, and a new target of installing 40,000 MW was set to be achieved by 2022. The emphasis was set on demonstrating the relevance and importance of RTS projects for meeting the country's energy needs. The first set of incentives, structured around 2010, was to provide generation-based incentives (GBIs) for the deployment of RTS. In 2012, a net metering policy was introduced for the first time to accelerate the development of RTS. Under this scheme, the excess generated energy was fed into the grid, and the owner was credited for every unit of this energy. However, it was realized that the sector was not gathering the desired momentum and there was a need for additional stimulus. A phase-wise development plan was then envisaged for RTS development.

Phase I of RTS development received approval from the GoI in 2015 with the declaration of the "Grid Connected Roof-top and Small Solar Power Plants Programme." The goal was to install 4,200 MW by 2019–2020, of which 2,100 MW would be deployed through the Central Financial Assistance (CFA) and the remaining 2,100 MW would be installed without funding support. Provision of "Achievement-Linked Incentive/ Awards" was introduced in 2016 as part of this program, and the budgetary provision accordingly increased from 6,000 Million INR (in 12th Five-Year Plan (2012–2017) to 50000 million INR for the five-year period ending in 2019–2020; 30% of the benchmark costs was provided through CFA. In this phase, the OPEX model was introduced in 2016 in parallel with the CAPEX model. The operational artifacts of the OPEX model are that consumers continue to pay for the energy they consume. However, the developer possesses ownership rights, often known as RESCOs. Performance statistics reveal that a total of 2158 MW of RTS was installed by December 2018. Recognizing that Phase I of the RTS scheme did not show as much promise as expected, Phase II was announced. It has been reported that the slow growth of RTS in the phase I was primarily due to a lack of interest among distribution utilities in combination with a lack of necessary finance to support RTS interventions.

In Phase II, RTS development received a further boost with the introduction of the Sustainable Rooftop implementation for Solar Transfiguration of India (SRISTI) scheme in 2017, which aimed to give much-needed impetus to RTS use. Because DISCOMs are the key leveraging point for the success of RTS interventions, the scheme gives primacy to DISCOMs in the implementation process by providing financial incentives to DISCOMs so that they can actively participate in the scheme. As a nodal agency, DISCOMs give approval for installation and manage the distribution network. The GoI approved the scheme in February 2019. In Phase II, it was projected that a total capacity of 38,000 would be deployed, of which 4,000 would be deployed through residential RTS, and the remaining 34,000 would be through social, government, educational, PSUs, Statutory/Autonomous bodies, Private Commercial, and Industrial Sectors, among others. The incentive structure for DISCOMs was designed based on performance. CFA (up to 40% the benchmark cost of the RTS systems of 3 kWp and 20% of the benchmark cost of RTS system with capacity between 3 kWp and 10 kWp) was provided only to the residential sector. A total budgetary allocation of 66,000 million INR was earmarked for the residential sector. Distribution utilities were also incentivized to install RTS for social, institutional, and government buildings along with commercial and industrial consumers in their distribution zone. Incentives for distribution utilities were designed by setting the baseline and achievements beyond the baseline[3] for a total target up to 18 GW. Incentive schemes revealed that there would be no incentives if the achievement was less than 10% of the benchmark, while a 5% incentive would be provided if the DISCOM added between 10% and 15% beyond the benchmark level. Finally, a 10% incentive would be provided if the achievement was beyond 15% of the benchmark. INR 49500 million was kept as CFA to incentivize distribution utilities (MNRE 2019).

Many policies have been developed at the sub-national scale to promote RTS in each state. Almost all states have come up with net metering policies, with differing provisions to drive RTS PV. However, net metering policies have unfortunately been withdrawn in certain states for commercial and industrial consumers, (e.g., which generate negative impacts on future installed capacity). For instance, Maharashtra, Tamil Nadu, Uttar Pradesh and Rajasthan have plans to end the benefits of net metering to consumers. In Maharashtra, Uttar Pradesh, Rajasthan, and Tamil Nadu, for example, net metering benefits are only for residential and agricultural consumers.

Interestingly, several states have taken proactive policy initiatives in driving RTS systems. Indeed, efforts at the state level even go beyond the streamlined efforts undertaken at the federal scale. The key policy initiatives undertaken by the states are worth considering. For instance, the solar policy of Gujarat declared in 2009 specifically mentions the importance of RTS systems, and the state declared an innovative initiative called ‘rent-a-roof program’ in 2010 in this regard, which was supported by the IFC. An FiT of INR 11.21 was provided to procure solar electricity generated through RTS systems. A PPP model was designed for the operation of the interventions. Initially, two energy companies, Azure Power and SunEdison, were provided roofs on a lease basis for 25 years. Companies were required to pay USD 0.05 per unit of energy produced to the roof-owner. In return, the companies received USD 0.18 from the state government for every unit of energy fed into the grid. This initially started with two cities in Gujarat (Gandhi Nagar and Vadodara), and the model was further extended to another five cities. Similarly, in Tamil Nadu, along with CFA, the state government also provided subsidies of INR 20,000 per kWh for individual applicants for up to 1 kWp for grid connected RTS systems for the residential sector. As in other states, both CAPEX and third-party (RESCO) models are employed in the state. The government of Odisha also plans to deploy 15 MW of installed capacity through RTS by identifying 900–1,000 buildings in seventeen cities across states. This is in addition to 4 MW of RTS systems deployed in the twin cities of Cuttack and Bhubaneswar. Technical support was provided by IFC, and a PPP arrangement was made to deploy the RTS systems. Several other states have employed other innovative models of deploying RTS systems, and the next section analyzes the strength of specific state policies and regulations.

4. MEASURING POLICY STRENGTHS: DO RTS POLICIES DIFFER ACROSS STATES?

Policies are thought to play a crucial role in driving the renewable energy in the country (Sokolowski 2019). Public interventions and public support schemes are considered vital and an integral component in the markets for environmental technologies. Finding an optimal policy mix thus becomes crucial and reflects that how much priority is laid on certain goals (Quitzow 2015).

[3] Baseline is defined by the cumulative RTS capacity achieved in the previous financial year.

A detailed mapping of RTS policy making in India reveals that heterogeneous approaches exist in the emphasis for RTS development and RTS policy making at the sub-national scale. This is due to the varying energy potential of states, coupled with differing levels of willingness and ability of state level entities to drive the sector. In this context, the present section maps a detailed analysis of net metering policies declared by various states.

A cursory glance at the key elements of net metering policies reveals that most states do have such policies, but these policies vary significantly in terms of content, structure, and operational modalities. Variations are observed in terms of (1) amendments introduced, (2) capacity of RTS systems allowed under the net metering schemes, (3) declaration of maximum capacity to be connected to the grid, (4) total capacity to be connected to the transformer, (5) export of electricity to the grid compared to self-consumption, (6) billing period for settlement, (7) compensation period for surplus, and (8) compensation for surplus. In terms of net metering permission, almost all states set an upper limit of 1 MW, although variations exist; similarly, the minimum capacity set is 1 kW, although differences can be found across states: West Bengal, for example, has set the minimum capacity of 5 kW. Similarly, maximum capacity for sanctioned load largely varies from 50% to 100% of the sanctioned load. Varying limitations on transformer capacity are particularly noteworthy. In most cases, it is less than 50% of the transformer capacity, although in some states it is close to 100%. For instance, Jharkhand allows deploying RTS capacity up to 100% of the transformer capacity, while Tamil Nadu has provisions for allowing RTS capacity up to 90% of the transformer capacity. Another crucial policy provision concerns the export of electricity allowed compared to consumption. Most states allow export above 100% of consumption, although in some states this threshold is set above 90%. In most states, the billing period is monthly and the compensation period is set as yearly, again with differences across states. Compensation for surplus is of largely two types: either through average power purchase cost (APPC) or a tariff determined by the state electricity regulatory commissions (SERCs). Based on these factors, policy strength is measured by assigning binary values for each of these policy elements. A composite index is then constructed by standardizing the values for each state. The detailed list of elements and their direction is captured in Table 1.

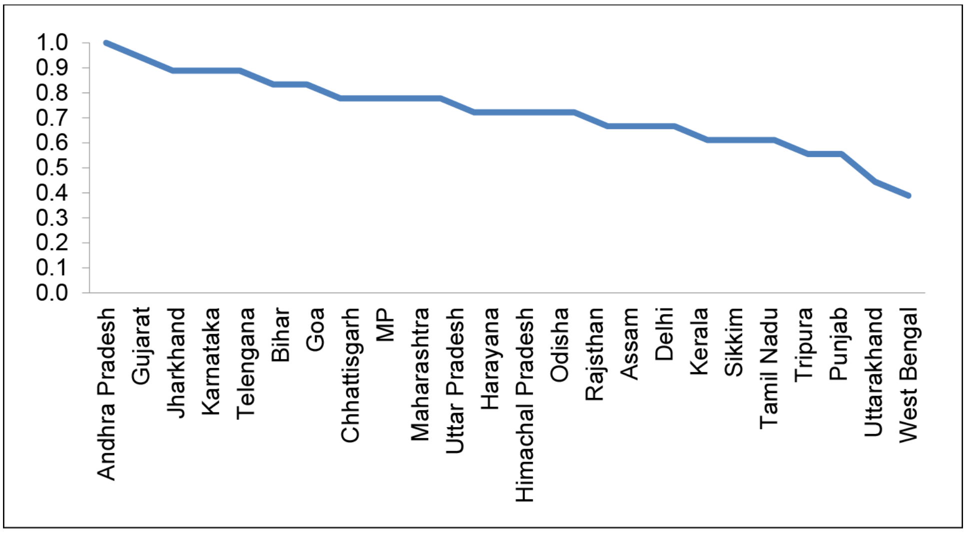
Table 1: Mapping of Policy Elements and Their Characteristics

Key Aspects	Policy Elements	Graded Approach	Direction
Policy dynamism	Policy declared and amended	When was the policy declared? How many times was it amended?	Positive
Technical configurations	Capacity range allowed	Lower: 1 kw; Max: 1 MW	Positive
	Max. capacity with regard to sanctioned load	% of sanctioned load: 100% or less than 100%	Positive
	Limitations on transformer capacity	% of transformer capacity: 100%; between 50%–100%; less than 50%	Positive
Tariff/pricing incentives	Export of electricity allowed compared to consumption	% of consumption: Above 100% or below 100%	Positive
	Billing period for settlement	Duration of settlement; monthly or bi-monthly	Negative
	Compensation period for surplus	Duration of settlement; annually or quarterly?	Negative
	Compensation for surplus	APPC rate or regulatory tariff	NA

Source: Authors' Construct.

The analysis carried out for the twenty-five states is presented below (Figure 3). While Andhra Pradesh stands out as a top state in terms of its policy strength, West Bengal appears to have a weak policy structure. In the top five, along with Andhra Pradesh, are Gujarat, Jharkhand, Karnataka, and Telangana, while Tripura, Punjab, Uttarakhand, and other parts of the northern India appear to have poorly stated net metering policies.

Figure 3: Strength of State-level Policies



Source: Authors' construct.

5. COMPARISON ACROSS MODELS

Unlike the fossil fuel sector, renewable energy in India is largely driven by private sector. To meet the ambitious target of installing 40 GW by 2022 set by the GoI will require an estimated investment of USD 40–50 billion (TERI 2016). It is estimated that with a weighted average capital cost of INR 75,000 per kWp, a target of 40 GW will require an approximate investment of INR 3,000 billion (roughly equivalent to USD 45 billion; TERI 2016). If this investment amount is bifurcated into equity and debt at 30:70 ratios, it would be necessary to support 2,100 billion INR through debt, which is quite a substantial amount.

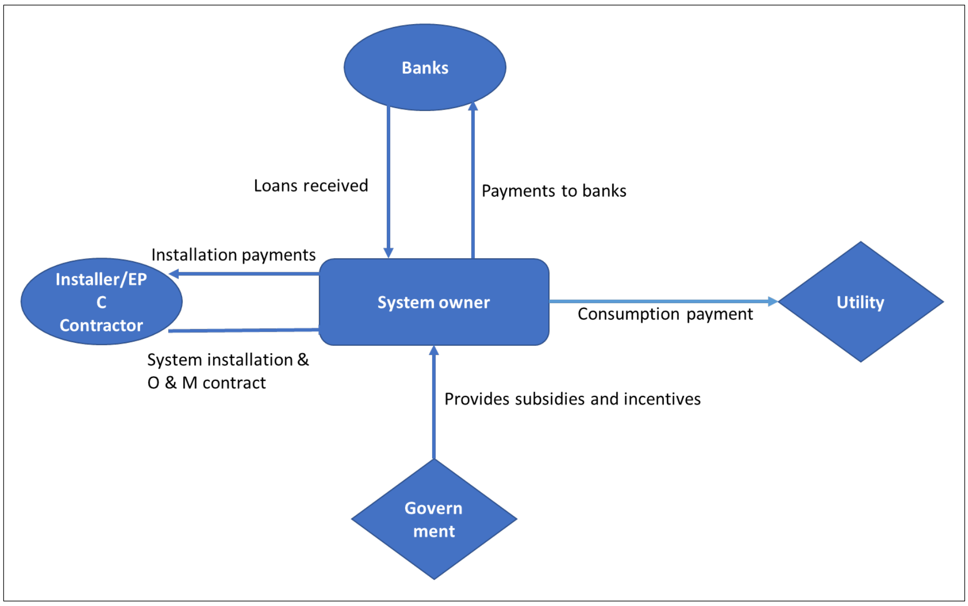
However, given the persistent fiscal constraints of the government exchequer and consequent emphasis on downsizing public investment, the private sector is incentivized as a key player to drive the renewable energy sector in India (Sarangi 2020). Given the size of the investment required to drive the RTS sector, it is crucial to design and promote innovative business models supported by well-designed fiscal and financial incentive structures. These business models are designed to mitigate the existing roadblocks for the larger uptake of RTS PV systems in India, and their diversity is in line with models to promote RTS deployment in various other countries. Models such as CAPEX, OPEX (often known as RESCO), rent-a-roof/lease, community based, utility scale (SPV having share of the utility), and plug-in RTS have been deployed to varying degrees in various states throughout India. There are also hybrid models that combine different energy sources such as RTS PV – wind, RTS PV – solar thermal, and RTS PV – biomass hybrids, all of which have been tried and tested. Two business models have, however, become prominent in the country, and these are discussed below.

5.1 CAPEX Model

The CAPEX model is the most commonly employed model in India for the deployment of RTS. In this model, consumers own the system, fund it, and consume the energy generated, so the consumer is responsible for the risks associated with the operation, management, and maintenance of the system. Often the consumer finances this through bank funding. The owner can apply for the capital subsidy provided through the CFA and additional subsidies provided by the respective state governments. However, in this model, the owner has the maximum risk. About 90% of RTS installed so far falls under this category.

This model has several advantages, including a fast payback period, risk-accommodative returns, and sole ownership structure. However, it has several loopholes, such as high risks for investors, delays in subsidy disbursement, and risks in the export of additional energy to the utility. This model is common in the residential sector, where the consumers pay the entire cost up front; this type of model is common in other countries as well, such as Germany. This model is simple and straight forward. The graphical mapping of the model is presented in Figure 4.

Figure 4: CAPEX Model



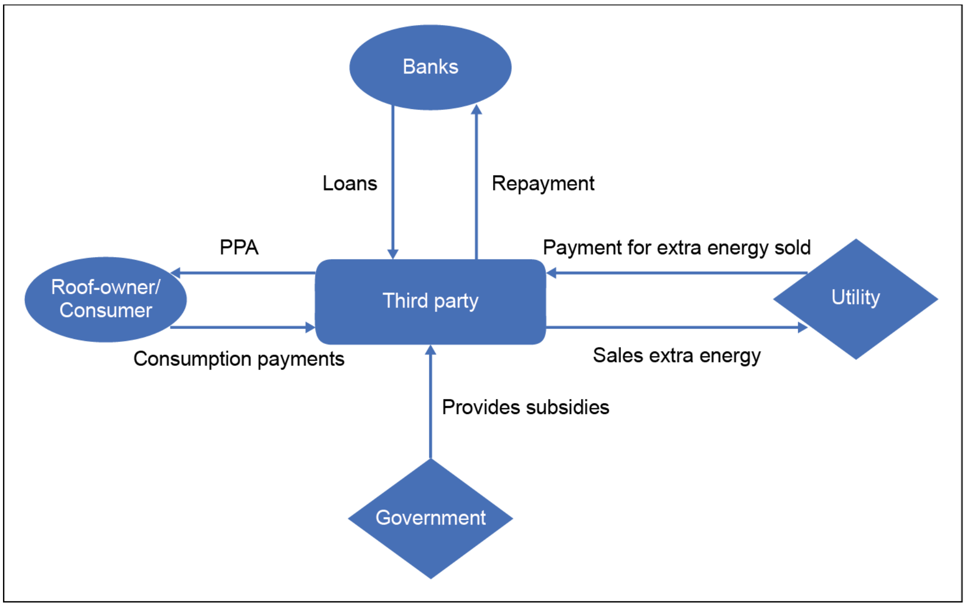
Source: Authors' Construct.

5.2 OPEX Model (RESCO Model)

The OPEX model (also known as the RESCO model or third-party financing model) involves an energy company, RESCO, arranging the necessary capital for the RTS projects and bearing all of its associated risks (Figure 5). In this model, the developer makes an agreement with the roof-top owner. This model is increasingly becoming attractive, and its share has increased over the years. However, the challenge is mobilizing low-cost capital for meeting the requirements of system deployment. This model is again divided into two different types, depending on the choice of consumption: (1) roof-top leasing or (2) power purchase agreement (PPA). In the roof-top leasing model, the roof-top is leased to developers and the roof owner receives a fixed rental fee over time and RESCO sells the energy to the utility at pre-determined tariffs fixed by the regulator. In the case of the PPA model, the RESCO invests in the roof-top assets and sells the energy generated to the roof-top owner at a lower tariff. The additional energy could be sold to the utility by the roof owner, with the condition that the RESCO sells the energy to the roof-top owner at a tariff less than the grid tariff, but which would still allow the RESCO to maintain a margin.

One of the key advantages of this model is that the risks are borne by the RESCO, and the roof-top owner does not need to make any upfront investment in the system deployed. The complexities associated with system ownership, such as the cap on system size, limits on transformer capacity, and problems related to roof-ownership, are also taken care of by the developers. However, the challenges tend to be associated with the payment-related risks associated with PPAs. This model also involves the huge transaction costs of aggregating small systems. This kind of model is widespread in the United States. There are also variations in these business models depending on whether gross or net metering is involved.

Figure 5: OPEX Model



Source: Authors' Construct.

An analysis of both of these models reveals that they have varying technical, operational, regulatory, and financial features. It is evident from Table 2 that in the CAPEX model, most of the responsibilities rest on the consumer, while for the RESCO or OPEX model, the RESCO takes on all of the activities. However, when it comes to financial matters, although the risk is very high for consumer under the CAPEX model, the potential benefits accrued are also equally high.

A risk mapping exercise was also carried out to assess the various associated risks under both business models. From this assessment it emerges that, under CAPEX, the consumer bears more risk than under the OPEX model, as shown in Table 3.

Table 2: Characteristic Features of Both Models

Characteristics Features of the Models			
Dimension	**Key Features**	**CAPEX Model**	**OPEX Model**
Technical	Ownership structure	Consumer	RESCO
	Operation, management and maintenance	Consumer	RESCO
	Installation	Consumer	RESCO
	Arrangement with utility	Consumer	RESCO
Financial	Capital investment	Largely by consumer	Through bank finance
	O&M Expenses	Consumer	RESCO
	Cost to consumer	Capital and O&M Expenses	Negligible investment by the consumer
	Tariff setting	Per regulations	Tripartite agreement between RESCO, consumer and utility
	Payback period	4–6 years	Not applicable

Source: Authors' Construct.

Table 3: Risk Mapping for Consumer under Different Business Models

Risk Mapping for Consumer			
Dimension	**Risk Types**	**CAPEX Model**	**OPEX Model**
Technical	Installation risk	High	Low
	Interconnection risk	High	Low
	Risks related to import/export of energy	High	Low
	Risks related to technical constraints such as system sizing, limit on transformer	High	Low
Financial	Liquidity risks	High	Low
	Payment risks	High	Low
	Payback period risks	High	Low
	Risks of arranging funds	High	Low
	Project management risks	High	Low
	Off-taker arrangement risks	High	Low
Regulatory	Risks of interfacing consumer with utility	High	Low
	Change in regulation risks	High	Low
	Transaction costs	High	Low

Source: Authors' Construct.

6. CHALLENGES AND WAY FORWARD

Despite the efforts to incorporate RTS into the mainstream energy sector in India, this process has not been wholly successful due to policy conundrums, ill-designed institutional and governance structures, distorted market mechanisms (e.g., poor contract enforcement systems), and technical challenges such as those involving grid connectivity. A related and yet quite pertinent aspect is that the push so far has been on the supply side of these interventions, without giving adequate weight to demand-related concerns. Most importantly, there is no adequate understanding of how the existing intervention types are performing in varying policy, regulatory, and governance environments (Satsangi et al. 2019). In this section, we attempt to capture some of the persistent challenges and offer a way forward.

One of the first sets of challenges is associated with policy-level inconsistencies. Poor and piecemeal implementation of net metering policies at the sub-national scale is a major roadblock for the uptake of RTS PV in India. Most of the state regulations on net metering set the maximum capacity limit at 1 MW per metering point for RTS systems to be connected to the distribution grid, which hinders large-scale deployment. Often this capacity ceiling is imposed based on the poor financial health of the distribution utilities. The current policy framework is thus obstructive, and these arbitrary caps hinder the uptake of RTS PV.

Although RTS PV requires bottom-up approaches through consumer engagement and participation, the current regulatory and policy regime has been structured in a top-down manner with a uniform set of policies and regulations for all types of interventions (Devi et al. 2018). The most recent evidence of such policy-level obstruction is the withdrawal of net metering policies in certain states for commercial and industrial consumers, such as in Uttar Pradesh, where it would generate negative impacts on the adding capacity. Similarly, other states like Maharashtra, Tamil Nadu, and Rajasthan, have plans to reduce net metering benefits for consumers, while in states like Maharashtra, Uttar Pradesh, Rajasthan, and Tamil Nadu, net metering benefits are only for residential and agricultural consumers.

Another challenge is very much connected with the poor information available to consumers about the benefits of RTS. The existing information asymmetry is a major challenge for the large-scale uptake of RTS projects, especially in the residential segment. Poor understanding and information of the benefits of RTS by users have become the prime reasons for unwillingness to deploy such systems. In one study surveying five Indian cities, it appeared that close to 50% of respondents were unaware of RTS technology and their applicability in household context. Low awareness has been found to be a major hurdle for the uptake of RTS (Devi et al. 2018). In addition to the general information asymmetry, there is also a substantial lack of knowledge about the specific products, processes, and approval systems inherent with these systems. Lack of credible and objective sources of information has led to consumers relying on vendors for information. Spreading the message about the benefits of RTS widely has been recognized as necessary to accelerate its uptake and increase access to the incentives provided by the government.

This lack of information is further compounded by the high upfront capital cost to deploy these systems, as these are often not within reach of the larger section of the society. Although there has been a dramatic reduction of cost for RTS in recent years, the initial cost continues to be a major hurdle even for small projects. The lack of necessary financing for the sector does not help. Banks and financial institutions are reluctant to lend funding for these projects due to their small scale. It is reported that, traditionally, banks charge a high interest rate to developers (10%–12%, or up to 14%) depending upon the associated risks, nature of the project, and credit rating of the borrower.

Lack of technical capacity often acts as a barrier to scaling up these interventions, particularly in rural settings. The needed market eco-system has not been created, and the much-needed supply chain has not yet been established. Although there have been dedicated GoI funds allocated for capacity building, implementing agencies (i.e., distribution utilities) have not been active in playing the needed role to build that capacity.

Policy learning has taken place, however. Given the implementation process requires approaching multiple agencies, it was realized in Phase II that DISCOMs would be the focal point for implementation of RTS projects. Because DISCOMs have direct contact with users, they can provide approval for installation, management, and distribution of the network, as well as having a billing interface with roof-top owner. Policy level inconsistencies could be addressed by modifying the net metering policies and their obstructive provisions. The removal of capacity constraints would be attractive not only to existing consumers, but to new consumers as well. This would also be in tune with the current developments, given the large scale of most of the RTS systems.

Policies favoring a particular group of stakeholders at the sub-national level add another constraint to RTS use and uptake, and some stakeholders are not adequately incentivized and represented. Even if it is not possible to have uniform policies across states, policies could be formulated considering state level nuances characterized by factors such as unmet RPOs and the strength of distribution utilities. There are many barriers to promoting RTS system in India, but a structured approach could go a long way in arresting some of the challenges currently encountered. The best way to minimize the regulatory burdens and procedural complexities is to institutionalize a single window facility for the entire eco-system of RTS PV deployment that would encompass connectivity, net metering, electricity inspection, and limitations on sanctioned load. RTS PV can contribute significantly to the building up of SMEs and MSMEs in India. Supporting a robust and successful RTS PV sector could generate wide-ranging multiplier effects and further contribute to job and employment growth, which are essential for the development of the country as a whole.

REFERENCES

Alboaouh, K.A. and S. Mohagheghi. 2020. Impact of roof-top PV on distribution system, Journal of Renewable Energy, https://doi.org/10.1155/2020/4831434.

Barnes, D.F. 2010. The Challenge of Rural Electrification: Strategies for Developing Countries, Earthscan.

Bridge to India. 2019. India solar roof-top market analytics, Bridge to India.

CEA. 2019. CEA Annual Report 2018–19. Central Electricity Authority, Ministry of Power, Government of India.

———. 2020. Executive summary on power sector. Central Electricity Authority, Ministry of Power, Government of India.

Devi, A., U. Narayan, and T. Mandal. 2018. "Here Comes the Sun: Residential Consumers' Experiences with Rooftop Solar PV in Five Indian Cities," Working Paper. Bengaluru: World Resources Institute. Available online at http://www.wri.org/publication/here-comes-the-sun.

Garg, V. and T. Buckley. 2019. Vast potential of solar roof-top in India, Institute for Energy Economics and Financial Analysis.

GoI. 2018. Villages with availability of electricity for domestic use, Mission Antodaya, Government of India.

IEA. 2020. India 2020: Energy Policy Review. International Energy Agency, Paris.

Kumar, A. and S. Thapar. 2017. Addressing land issues for utility scale renewable energy deployment in India. A Report Prepared by TERI SAS and Shakti Foundation.

MNRE. 2019. Annual Report 2019–20, Ministry of New and Renewable Energy (MNRE), Government of India.

Neeraj K., Saji, S. and Chawla, K. 2018. Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs', CEEW.

Power Finance Corporation. 2020. Report on Performance of State Power Utilities. Power Finance Corporation, Government of India.

PWC. 2018. Roof-top solar in India: looking back and looking ahead, A Report by PWC and Climate Investment Funds.

Quitzow, Rainer. 2015. "Assessing policy strategies for the promotion of environmental technologies: A review of India's National Solar Mission." Research Policy 44 (1): 233–243.

Rathore, P.K.S., D.S. Chauhan, R. P. Singh. 2019. Decentralized solar rooftop photovoltaic in India: On the path of sustainable energy security, Renewable Energy, 131. Pp. 297–307.

Sarangi, G.K. 2020. Random Selection or Conscious Decision? An Analysis of the Choice of Policy Instruments and their Interactions in Promoting Renewables, Talk delivered at IIT, Kanpur.

Sarangi, G.K., A. Mishra, Y. Chang and F. Taghizadeh-Hesary. 2019. Indian electricity sector, energy security and sustainability: An empirical Assessment, Energy Policy, 135.

Satsangi, K. P., D. B. Das, G.S. Sailesh Babu, A.K. Saxena. 2019. Real time performance of solar photovoltaic microgrid in India focusing on self-consumption in institutional buildings, Energy for Sustainable Development, 52, pp. 40–51

Sokolowski, M.M. 2019. When black meets green: a review of four pillars of India's energy policy. Energy Policy.

TERI. 2016. Grid parity of solar PV roof-top systems for the commercial and industrial sectors, The Energy and Resources Institute (TERI), New Delhi, India.