सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Electricity from Renewable Energy Sources in Indian Cities

TRAINING MANUAL

NIUA | C3 Climate Centre for Cities

RMI ENERGY. TRANSFORMED.

ClimateSmart Cities Assessment Framework

Energy and Green Buildings

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Training manual

Developed by:
Climate Centre for Cities, NIUA in association with RMI and RMI India.

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Executive Summary

Cities are a significant contributor of carbon emissions aggravating climate change. At the same time, cities are also exposed to and impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the seventh most affected country from climate related extreme weather events (storms, floods, heatwaves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually[i]. Cities are increasingly at the forefront of addressing both urbanization and climate change. To strengthen climate-sensitive urban development, a holistic understanding of urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment

of CSCAF. The training on the 'electricity from renewable energy sources' under the thematic areas of Energy and Green Buildings in the CSCAF is developed in association with RMI and RMI India.

As part of its Nationally Determined Contribution (NDC) to the Paris Agreement, India has set a goal to achieve 175 GW of renewable energy (RE) by the year 2022. Of this, 100GW needs to come from solar, of which 40GW should ideally be achieved by Roof Top Solar (RTS). Given that only ~17% of the RTS goal has been achieved so far, there lies tremendous scope for RTS growth in the near term. RTS can be installed onsite with relative ease and is less capital intensive than other options renewable energy technologies, especially in the city context that tends to be occupied by buildings and provide abundant rooftop real estate. Therefore, RTS offers a great avenue for cities to increase their 'total electricity from renewable energy sources', especially on government buildings' rooftops, and improve their ranking on the said indicator for CSCAF. However, sub-national and local governments may also face challenges in procuring RTS due to limited understanding of RE technologies, the policy and institutional framework governing them, as well as how to go about procuring it.

By catering to these specific gaps in knowledge on part of government users, this training manual attempts to improve RTS uptake in cities. Users of this manual will get an overview of different types of RE and then dig deeper into the RTS landscape, including learning about some key considerations for RTS procurement such as regulations, business models, and financing options. The manual also provides an overview of the steps needed to be undertaken to move from this knowledge and ambition to action and procurement. Lastly it also showcases case studies that exemplify successful RTS adoption by local governments.

- Who is the training manual designed for?
- What is the focus of the training manual?
- How to make use of this manual?
- What are the Learning outcomes of the training?
- Scope and limitations of the training

This manual is designed for government officials at the sub national and local/ city level and anyone interested in learning more about the rooftop solar landscape as well as the basics of rooftop solar procurement. It would be ideal if the users of this manual are familiar broadly with the renewable energy landscape.

The training manual briefly introduces the different types of renewable energy and the indicator aligning to this in the CSCAF 2.0. A major portion of the manual is designed to dive deeper into the rooftop solar space, its associated benefits and challenges, the policy and institutional structure governing it, the financial landscape facilitating its proliferation, and translating this knowledge to procurement of RTS systems. The manual ends with a couple of case studies to show specific experiences of local governments with RTS.

A brief guideline for users is that they should treat this as a beginner's guide to rooftop solar procurement. Some additional sources of interest can be found under the list of reference materials. The manual also points towards online tools that can help conduct techno-economic assessments of potential RTS sites. This manual can be used alongside the recorded training webinar by RMI and RMI India in association with C-Cube.

Participants should be able to familiarize themselves with different types of renewable energy and the electricity indicator. They should be able to learn about rooftop solar from different case studies, learn about the process for procurement of RTS, as well as employ some basic tools for remote site assessment and techno-economic analysis. The objective behind designing the manual this way is that state and city governments may be able to improve their CSCAF score on the electricity indicator and also drive up the achievement of rooftop solar in their specific regions.

While this manual attempts to offer a comprehensive view of the rooftop solar landscape, it should be treated as a 'beginner's' guide to rooftop solar procurement. Further information can be sought using the resources listed in the 'list of reference materials'. Additionally, electricity is a concurrent subject, and rules around RTS implementation can differ from state to state. Therefore, users must be able to complement their learnings from this manual with the city-specific, ground level realities.

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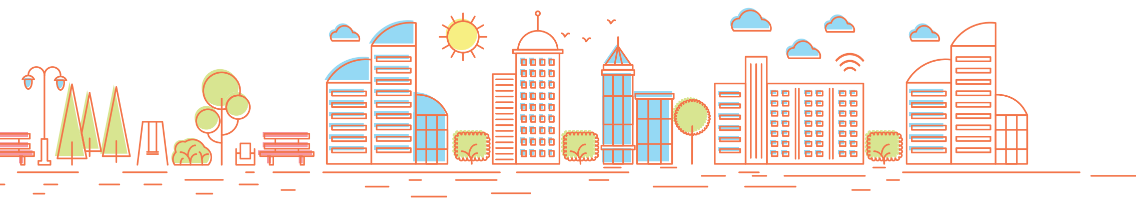
Abbreviations

BG	Bank Guarantee
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
C&I	Commerce and Industry
C-CUBE	Climate Centre for Cities
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFA	Central Financial Assistance
CPSU	Central Public Sector Undertaking
CPBG	Contract Performance Bank Guarantee
CSP	Concentrated Solar Plants
CSCAF	ClimateSmart Cities Assessment Framework
DISCOM	Distribution Company
EESL	Energy Efficiency Services Ltd
FDR	Fixed Deposit Receipts
FiT	Feed-in-Tariff
GBIs	Generation based incentives
GW	Giga Watt
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPGCL	Indraprastha Power Generation Company Ltd.
JNNSM	Jawaharlal Nehru National Solar Mission
LoA	Letter of Agreement
LoI	Letter of Intent
kW	Kilo Watt
MNRE	Ministry of New Renewable Energy
MoU	Memorandum of Understanding
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MW	Mega Watt
NCT	National Capital Territory
NDC	Nationally Determined Contribution
NISE	National Institute of Solar Energy
NIUA	National Institute for Urban Affairs
OA	Open Access
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
PV	Photo voltaic
RE	Renewable Energy
RESCO	Renewable Energy Service Company
RPO	Renewables Purchase Obligation
RTS	Rooftop Solar
SARAL	State Rooftop Solar Attractiveness Index
SECI	Solar Energy Corporation of India Ltd.
SEDA	State Energy Development Agencies
SERC	State Electricity Regulatory Commission
SNA	State Nodal Agency
STEPS	Stated Policies Scenario
ULBs	Urban Local Bodies
UTs	Union Territories



1

Introduction

1.1. Context setting

According to the International Energy Agency (IEA), India is expected to experience an increase in electricity demand by 4.7% each year in the stated policies (STEPS) scenario[ii]. This is on account of increased electrification of end use sectors, increasing use of electrical appliances especially for cooling, increasing electricity access and urbanization. Further, India has committed to increasing the share of installed electric power capacity from non-fossil fuel energy resources to 40% by 2030. The country also plans to reduce its emissions intensity of GDP by 33%-35% by 2030 based on 2005[iii] levels. India receives approximately 4-7 kwh/m2 of solar insolation and 300 sunny days in a year, implying immense potential in harnessing solar.

In this context, it becomes extremely crucial to plan for, invest in, and implement actions for climate informed urban development. RMI and RMI India are supporting the Climate Centre for Cities (C-Cube) at the National Institute for Urban Affairs (NIUA) in imparting training to city officials across India on integrating renewable energy into city use. This is part of C-Cube's ClimateSmart Cities Assessment Framework (CSCAF) 2.0, that encourages cities to move progressively along stages on a five-step framework for various indicators, including those for energy and green buildings.

This manual will walk city officials and other potential users through the different types of renewable energy, and then deep dive into the rooftop solar landscape as a prospective and appropriate technology that could be adopted by Indian cities.

1.2. Aligning with the ClimateSmart Cities Assessment Framework

1.2.3. Introduction to the Indicator

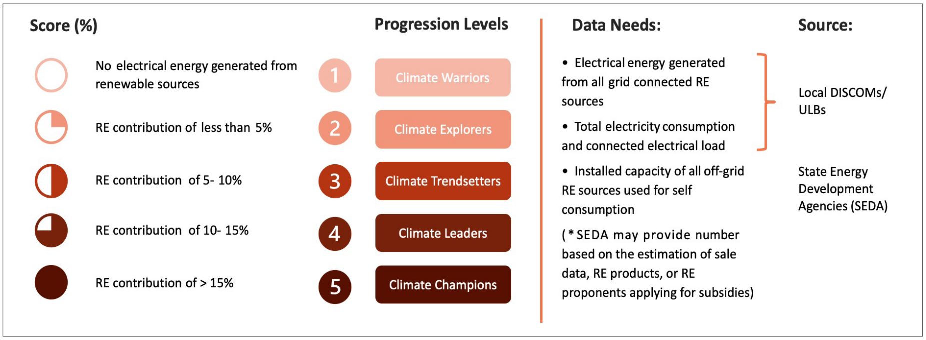
Figure 1: Formula for 'Total electrical energy in the city, derived from renewable energy sources'

$$\text{Score} = \left[\, \underbrace{0.8.}_{\text{weightage}} \times \underbrace{\frac{\text{Total electrical energy consumption (kWh) from all } \textbf{on-grid RE} \text{ sources and is used in the city}}{\text{Total electricity consumption (kWh) in the city}}}_{\text{Percentage of city's electricity consumption (kWh) derived from grid connected RE}} + \underbrace{0.2}_{\text{weightage}} \times \underbrace{\frac{\text{Cumulative installed capacity (kW) of } \textbf{off-grid RE} \text{ sources for self consumption}}{\text{Total connected electrical load (kW) in the city}}}_{\text{Percentage of city's total electrical load derived from off-grid RE for self consumption – personal/ captive systems}} \,\right] \times 100$$

The indicator this manual is concerned with is called the 'Total electrical energy in the city, derived from renewable energy sources'. The indicator combines (i) the total electricity consumption (kWh) in the city that's coming from grid connected (on-grid) renewable energy (RE) sources, and (ii) the share of total installed capacity of RE that is off-grid and may be used for self-consumption, from the total electrical load (kW) in the city (See Figure 1).

Once the relevant data is inserted in this formula, the indicator yields a percentage score which determines the progression level at which the city stands. For example, a score of

25 indicates RE contribution under 5% and lands you at progression level 2. Similarly, a score of 75w indicates RE contribution of 10-15% and lands you at level 4 – 'Climate Leaders', and so on (see Figure 2). This framework is aspirational and the intent is for all cities to become reach progression level 5 – 'Climate Champions'.



1.2.4. Data collection method

For the purpose of calculating this indicator, users will need the following information from DISCOMS or urban local bodies (ULBs):

- Electrical energy generated from all grid connected RE sources in the city
- Total electricity consumption in the city (kWh)
- Total connected electrical load of the city (kW)

Users will also need the following information from the State Energy Development Agencies (SEDA):

- Total installed capacity of all off-grid RE sources used for self-consumption within the city (not for supplying to the grid)

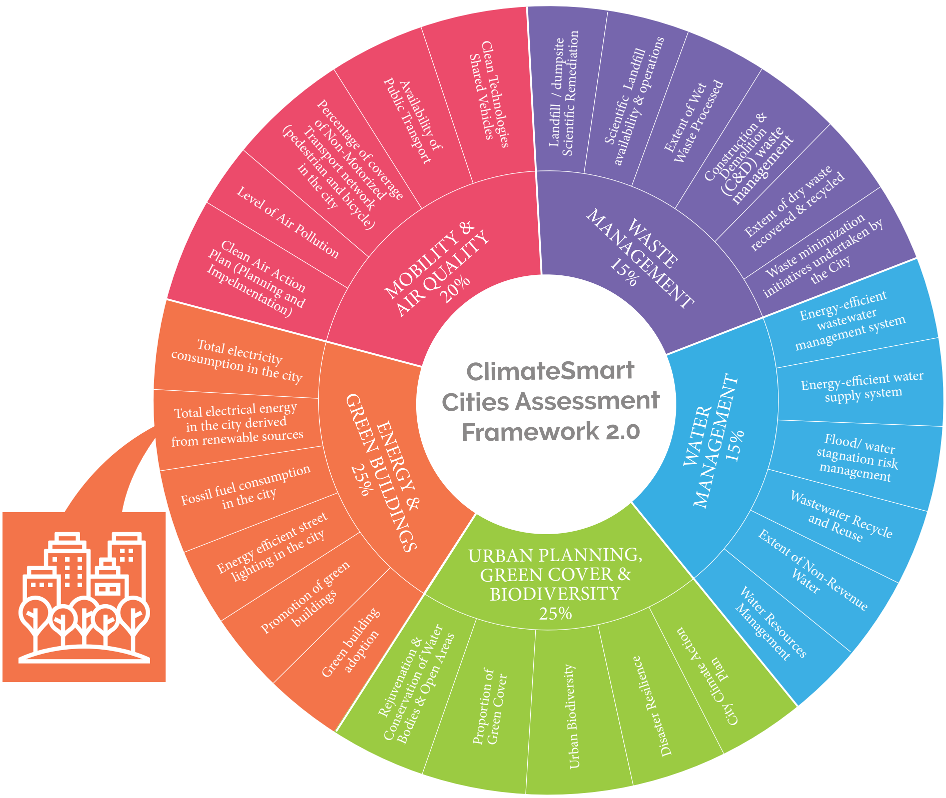
How can cities collect data?

- Identify sources of data and who in the respective discom or urban local body will be able to provide that data
- Appoint a data officer, responsible for relevant data collection, maintenance, sharing, and prevention of misuse.
- Prepare a framework/ pathway/ process for easing future data collection and acquisition

1.2.5. Analysis process

Once you have calculated your score and identified where your city stands in terms of progression level, you can begin to determine next steps. If there is scope in the city to adopt more RE in the near term, it should start identifying buildings, their requirements, and consider the type of RE technology that will be most suited for them and implement it. This process includes steps that are elaborated upon in Section 4 later in the manual.

Figure 2: ClimateSmart Cities Assessment Framework (CSCAF)



2

Different types of RE and their suitability

RE is used for generating electricity using cleaner and sustainable energy sources. These include solar, wind, hydropower, biomass, geothermal, etc. It can be used in cities for providing electricity and also for fueling transportation, and for providing thermal comfort in buildings and spaces - whether that's heating or cooling. Employing more RE contributes to India's 2030 goals of reducing carbon intensity of its economy by 45% compared to 2005 levels, and achieving 50% installed power generation capacity from renewables by then. However, this is only one way of reducing emissions from energy use.

Figure 3: Ways to reduce emissions from energy use

Renewable Energy

- Replacing fossil fuels with cleaner and sustainable sources of electricity
- Aids India's aim of reducing emissions intensity of GDP by 33-35% by 2030 from 2005 levels and achieve total non-fossil fuel based electric power installed capacity of 40% by 2030

Electrification

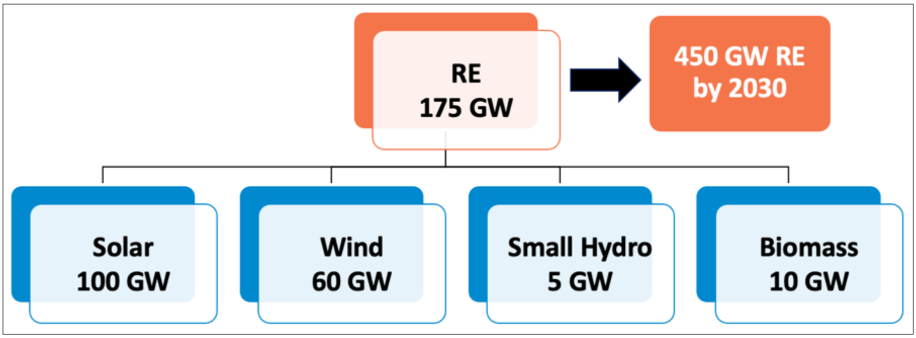
- Bringing more end-use sectors on the electric grid while simultaneously decarbonizing electricity generation is key to achieving a low carbon future
- Since electrification increases electricity consumption, energy efficiency becomes all the more important

Energy Efficiency

- Getting more use out of a unit of electricity, or reduction in electricity demand with no change in use. For example, LED bulbs are more efficient than incandescent bulbs
- Costs less than setting up new power plants
- Can include demand side interventions

Adoption of more RE can replace existing fossil fuel generated electricity or can be used to add incremental capacity. Other ways include electrification of end-use sectors (for example cooking, transportation, etc.) while also decarbonizing electricity. A third way is to improve electricity efficiency, which implies getting more use out of per unit of electricity generated, signaling elimination of losses.

Figure 4 India's renewable energy goals for 2022



As part of its Nationally Determined Contribution (NDC) to the Paris Agreement, India has set a goal to achieve 175 GW of renewable energy by the year 2022. This includes individual goals for solar, wind, small hydroelectricity (hydro) and biomass. The goal for solar is 100 GW, for wind is 60 GW, for small hydro is 5GW, and for Biomass is 10GW. Glasgow held in November 2021, the Prime Minister raised India's 2030 renewable energy goal from 450 GW to 500 GW.

Types Of Renewable Energy

Solar: Solar energy is produced using the sun's radiation that is transformed into electricity through solar photovoltaic (PV) panels. Solar PV panels are used at massive scales in setting up utility scale solar plants or solar parks, where panels are installed on the ground (also called ground mount solar). These tend to be installed 'offsite', and the electricity generated is transmitted to locations of use through the power grid. In cities, solar panels can also be used in different types of 'onsite' systems, such as rooftop solar (RTS), on top of car parking structures, etc.

Wind: Wind energy is generated when the blades on wind turbines move due to wind and set off an electric generator. Wind turbines typically need wide open spaces, and therefore coastal states tend to do well with wind. Tamil Nadu, Gujarat, and Maharashtra, for example, are the leaders in on-shore wind installation capacity. Wind turbines can also be installed off the coast in what is called off-shore wind farms.

Small Hydro: Hydroelectricity is produced when flowing water rotates an electric turbine. This can be in the form of large-scale dams that store large amounts of water from streams and rivers at an elevation. On the other hand, 'small hydro' typically uses river flow to apply pressure on a turbine. A third type of system is called pumped hydro, that first uses electricity to pump water to an overhead reservoir, and then generates electricity by releasing it from a height on the turbine

Biomass: Biomass is essentially organic material such as wood pellets, or agricultural waste like bagasse from sugarcane fields. It is generally used for being burned for cooking or heating. However, it can also be combusted to produce electricity.

Geothermal: Geothermal uses heat or hot water from inside the earth to generate electricity. This is still in the pilot stage in India in places like Ladakh and Gujarat. The government is only targeting about 1GW of geothermal electricity by 2022, which is not part of the overall goal of 175 GW.

The choice of renewable energy type depends on a few different factors (see Table 1). Due to its versatility, we propose the onsite solar technology of rooftop solar as best suited to the urban landscape.

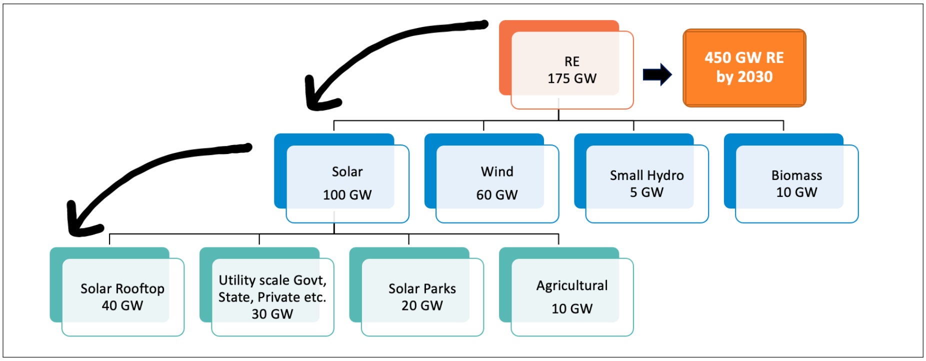
Table 1: Comparison of different RE technologies

	Off site	On site	Types of Customers
Solar	· Ground mount · Solar PV systems · Large PV parks · Concentrated solar plants (CSPs)	· Ground mount · Solar PV Systems · Rooftop solar (RTS) · Parking Canopies	· Government · Residential · Commercial and Industrial · Utilities
Wind	Off-shore Wind farms		· Utilities · Commercial and Industrial
Hydro	· Conventional large-scale hydro · Small hydro · Pumped hydro storage	· Small, mini, micro hydro	· Utilities
Biomass	· Using Bagasse, and other agricultural waste · Using landfill gas		· Rural entities (farms, dairies, rural industries) · Utilities
Geothermal	· Geothermal power plants		· Currently in pilot stage
Suitability depends on:	· Limited space available for generation · Large system (MWs and GWs) · Can be both off grid (Distributed RE for remote locations/ captive industrial consumption) or on grid (powering large systems/ settlements, earning revenue)	· Available space · Small systems (kWs and MW) · Favorable metering regulation · Can be both off grid (sufficient to power individual buildings/ systems) or on grid (to get economic benefit, improve resilience)	

2.1. Rooftop Solar in India

As mentioned above, India aims to achieve 100GW of solar by 2022. This goal is further broken down into different technologies and applications. Out of 100GW, 40 GW is expected to come from rooftop solar (RTS) that can be installed onsite with relative ease and is less capital intensive than other options. The rest of the 60GW is divided between utility scale solar (30GW), solar parks (20 GW), and use for agriculture (10 GW).

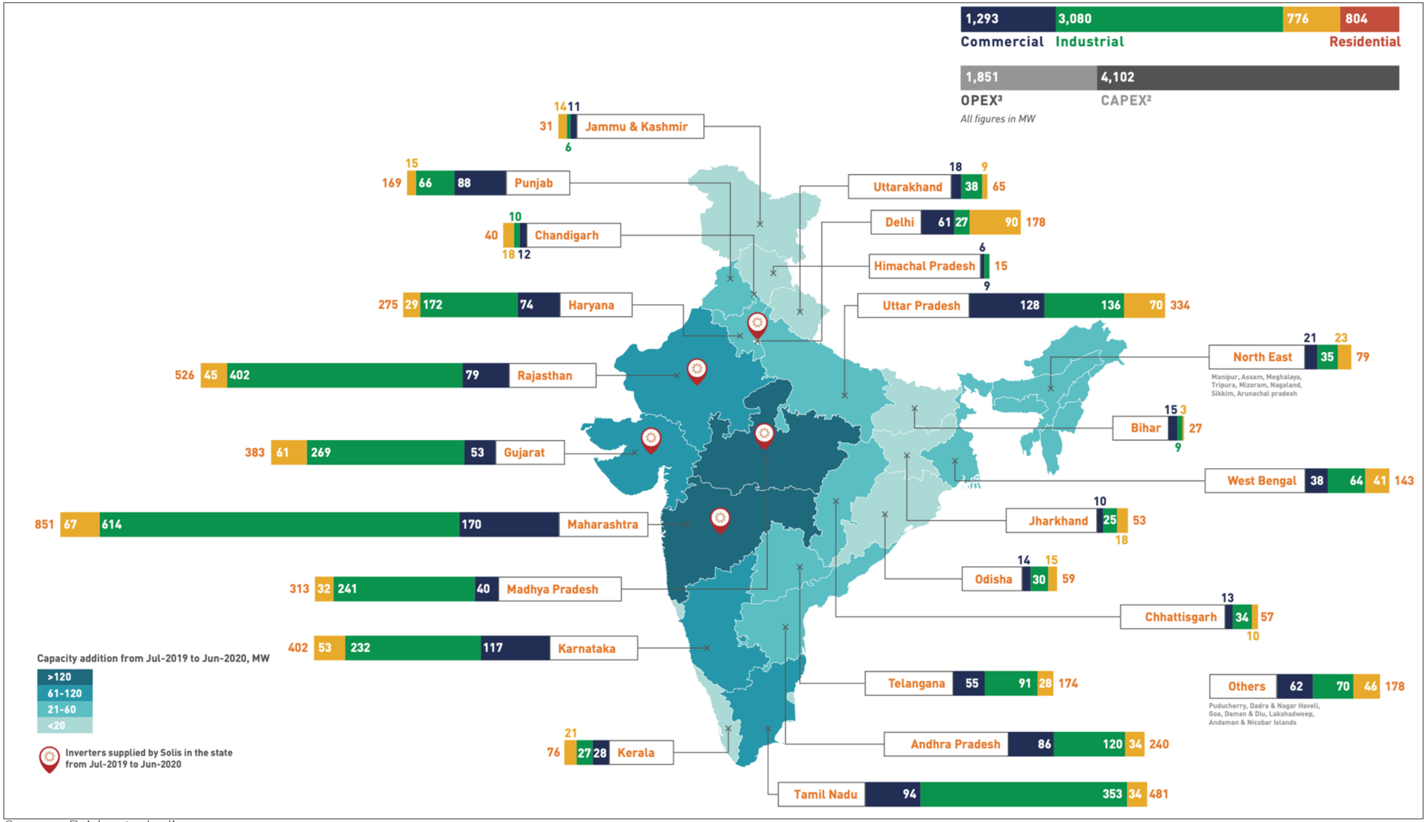
Figure 5: India's Renewable Energy Goals for 2022



The country has immense potential for RTS. Notably, the Indian RTS market is expected to grow at a compounded annual growth rate (CAGR) of more than 25% for the next years[iv]. In terms of having the most potential for solar power generation, states like Rajasthan, Jammu & Kashmir with Ladakh, Maharashtra and Andhra Pradesh rank high[v]. However, the story is slightly different in the RTS segment. For example, India's State Rooftop Solar Attractiveness Index (SARAL) launched by the Ministry of New and Renewable Energy (MNRE) in 2019 ranked Karnataka as the best state in terms of attractiveness and readiness of the rooftop solar ecosystem. The state was followed by Telangana, Gujarat and Andhra Pradesh[vi].

The SARAL system currently captures five aspects that affect RTS attractiveness: robustness of policy framework, implementation environment, investment climate, consumer experience and business ecosystem in the states. This indicates that the potential for solar power generation, which is dependent in part on solar irradiation, system design, etc. needn't directly equate to rooftop solar attractiveness. The states of Maharashtra, Rajasthan, Tamil Nadu, Karnataka, and Gujarat on the other hand are leading the way on total installed capacity of RTS, accounting for nearly 46% of the total RTS capacity in the country[vii]. (see Figure 6 below). The consumer segment of Commerce and Industry (C&I) have the most installed capacity of RTS, followed by residential RTS.

Figure 6: Rooftop Solar Map as on June 2020

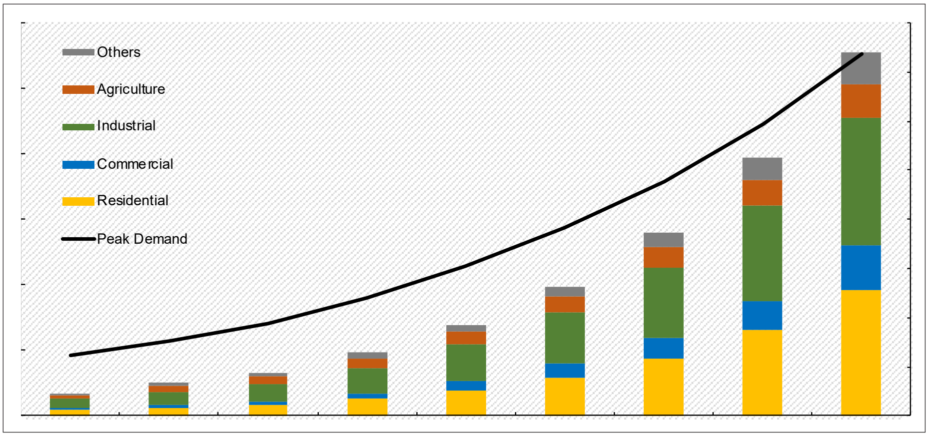


Source: Bridge to India

2.2. Government as active RTS stakeholders

India's power demand is set to quadruple between 2020 and 2040 on the back of rising urban population, improved electricity access, higher use of electric appliances such as air conditioners, as well as more end use sectors such as transport getting electrified. Nearly 400 million people are set to transition to cities by 2050[viii] as India treads on its path of urbanization. In fact, demand for air conditioning alone will contribute approximately 44% to peak electricity demand in India in 2050 under a business as usual scenario[ix].

Figure 7: Sector wise electricity demand in India till 2050



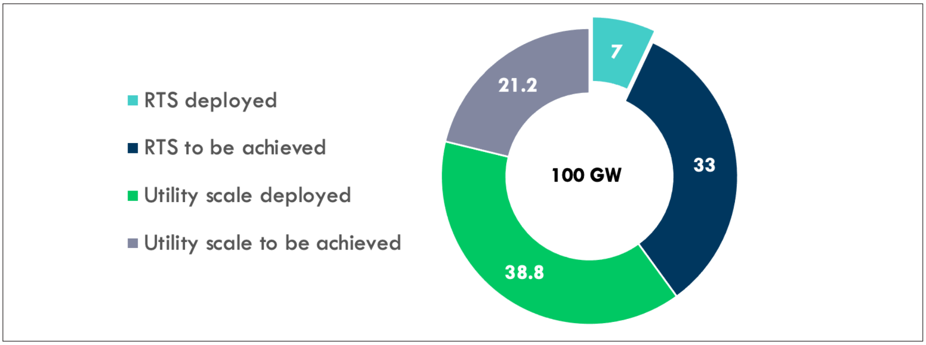
Source: CEA, IMF, OECD, RMI Analysis

In this scenario, not only does RTS offer a way to decarbonize the grid, but also a way to diversify and decentralize electricity generation sources. (Benefits of RTS are detailed in *Section 3.3* below). The push for solar as a critical piece in electrification of cities has been evident in the programmes that the government has been framing for a few years now. For example, in 2015, the central government launched the Smart Cities Mission to promote sustainable urbanization with adequate and 'smart' infrastructure. City ULBs jointly contributed to the implementation of this effort along with the respective state governments. 'Smart Cities' were expected to reduce their dependence on non-renewable sources of energy and source a minimum of 10% of their energy requirement from solar[x].

At the same time, MNRE's Solar City program aimed to assist ULBs in preparing master plans for reducing the projected demand for energy from fossil fuel sources by a minimum of 10% at the end of a five-year period, through RE adoption as well as efficiency measures[xi]. In 2020, the MNRE asked states and Union Territories (UTs) to identify a city each, whose electricity needs will entirely be met through RTS power[xii]. This is expected to create demand for a domestic manufacturing ecosystem for solar equipment such as ingots, wafers, cells, and modules, and reduce dependence on imports from China. In total, 60 cities have been identified across the country, of which five are model cities, and 13 are pilot cities, and for which states received financial assistance to prepare a master plan[xiii].

Despite the seeming encouragement from the government on RTS as a means for clean electrification of cities, the achievement of about 45 GW of 100 GW solar by 2022 has come predominantly from utility scale solar (38.8 GW). Only 6.9 GW (~17%) of the RTS goal has been achieved so far (See Figure 7). Therefore, there is still tremendous scope for achievement as far as RTS is concerned. And cities hold opportunity as they provide abundant rooftop real estate.

Figure 8: India's still lagging behind in achieving its goal for rooftop solar



Governments at all levels (centre, state, cities) have an important role to play in enabling the technology as well as its adoption. Notably, about 30% of the total commercial space in India is owned by the public sector[xiv]. Further, according to data on up to 50 ministries/ departments collated by the MNRE, there is nearly 5.9 GW in rooftop solar potential for government buildings[xv]. As on June 2020, only 776 MW[xvi], or about 13%, of this potential has been realized. Leveraging public procurement and projects would contribute to the improved performance of buildings and help create domestic markets and capabilities

Some recent initiatives such as electrification of transport further offer potential use cases for RTS. For example, public parking sheds can be converted to solar powered electric charging stations or solar carports. RTS also supports the expansion of clean urban microgrids that, together with battery storage, can offer grid balancing and grid resilience services to power distribution companies (Discoms).

3

Deep Dive into Rooftop Solar

3.1. Policy background and Institutional framework

When discussing electricity, it is important to mention that it is a concurrent subject. This implies that both governments at the centre as well as the state level jointly govern and engage in decision making for electricity. Therefore, by extension, the same applies to electricity generated from RTS as well.

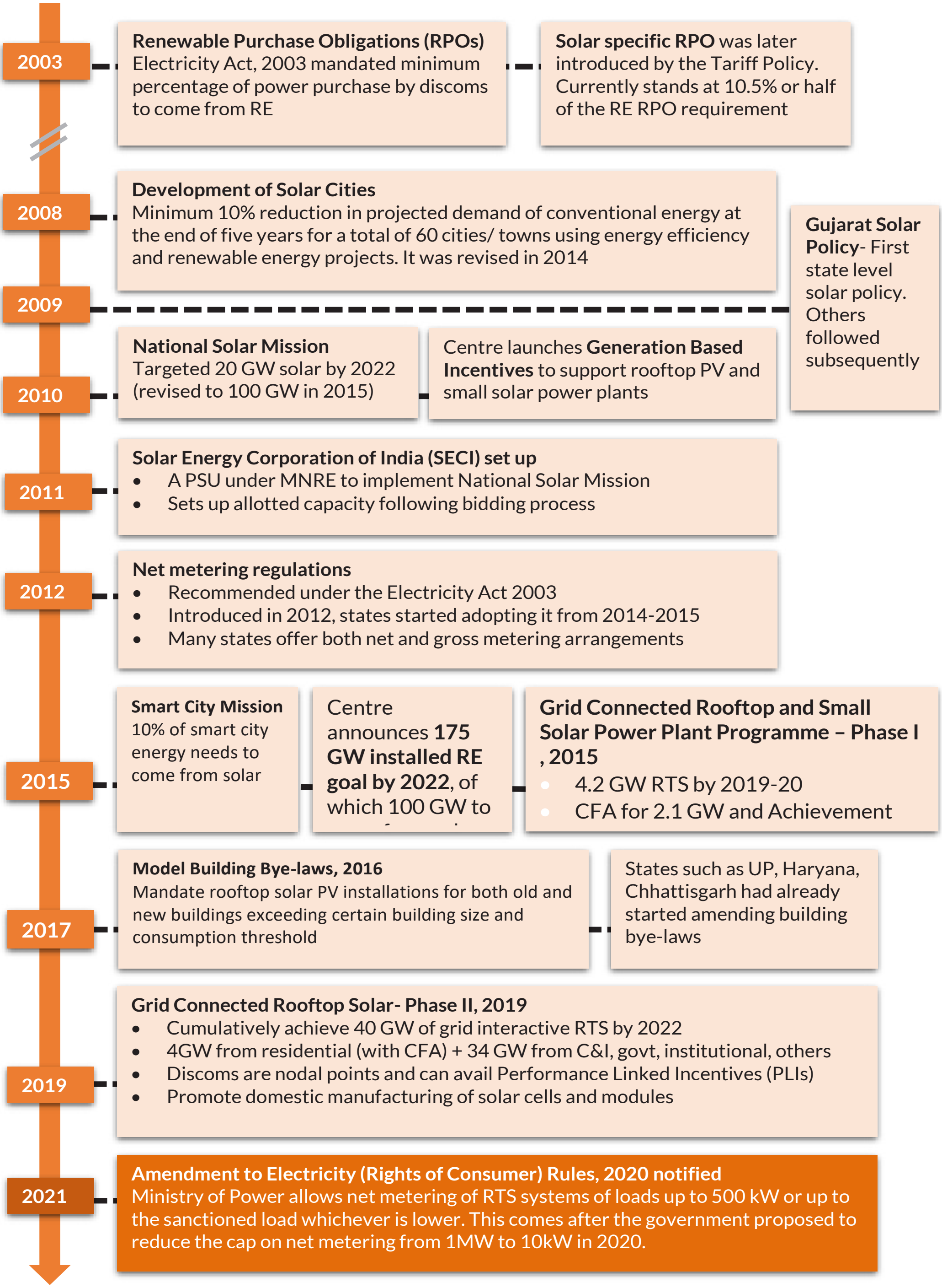
The rooftop solar journey for India has been backed by multiple policies and regulatory enablers over the past two decades that have supported expansion of renewable energy in general. Back in 2003, the Electricity Act introduced the renewable purchase obligations (RPOs).

The RPOs have especially been mandated by state electricity regulatory commissions (SERCs) to provide a fillip to the ambitious renewable energy targets of India. As part of RPOs, discoms, captive power plants, and other large electricity consumers are supposed to purchase a certain percentage of their electricity requirement from renewable energy sources. Eventually, specific solar RPOs have also come into place.

The Jawaharlal Nehru National Solar Mission (JNNSM) was inaugurated in 2010 with the goal of achieving 2,000 MW (2 GW) of RTS by 2022. To support this goal, generation-based incentives (GBIs) were announced as well. The central government also setup the Solar Energy Corporation of India Limited (SECI)[xvii], a central public sector undertaking (CPSU) under the Ministry of New and Renewable Energy (MNRE) in 2011 to implement JNNSM.

In 2012, the net metering regulation was introduced for the first time. Under net metering, any surplus electricity generated from the RTS system could be fed back into the grid. The owner of the system would be compensated for every unit of this surplus electricity either

Figure 9: Timeline of central and state policies and regulations that have facilitated RTS growth



at a feed-in-tariff, or as credit against their bill. These regulations can differ from state to state.

When these incentives were still falling short of the required boost that the sector needed, a phased approach to RTS development was adopted by the government with the launch of Phase-I of the "Grid Connected Rooftop and Small Solar Power Plants Programme" in 2015. Under this programme, rooftop solar customers could avail of "Central Financial Assistance" (CFA), and project developers could avail of "Achievement linked incentive/ Awards".

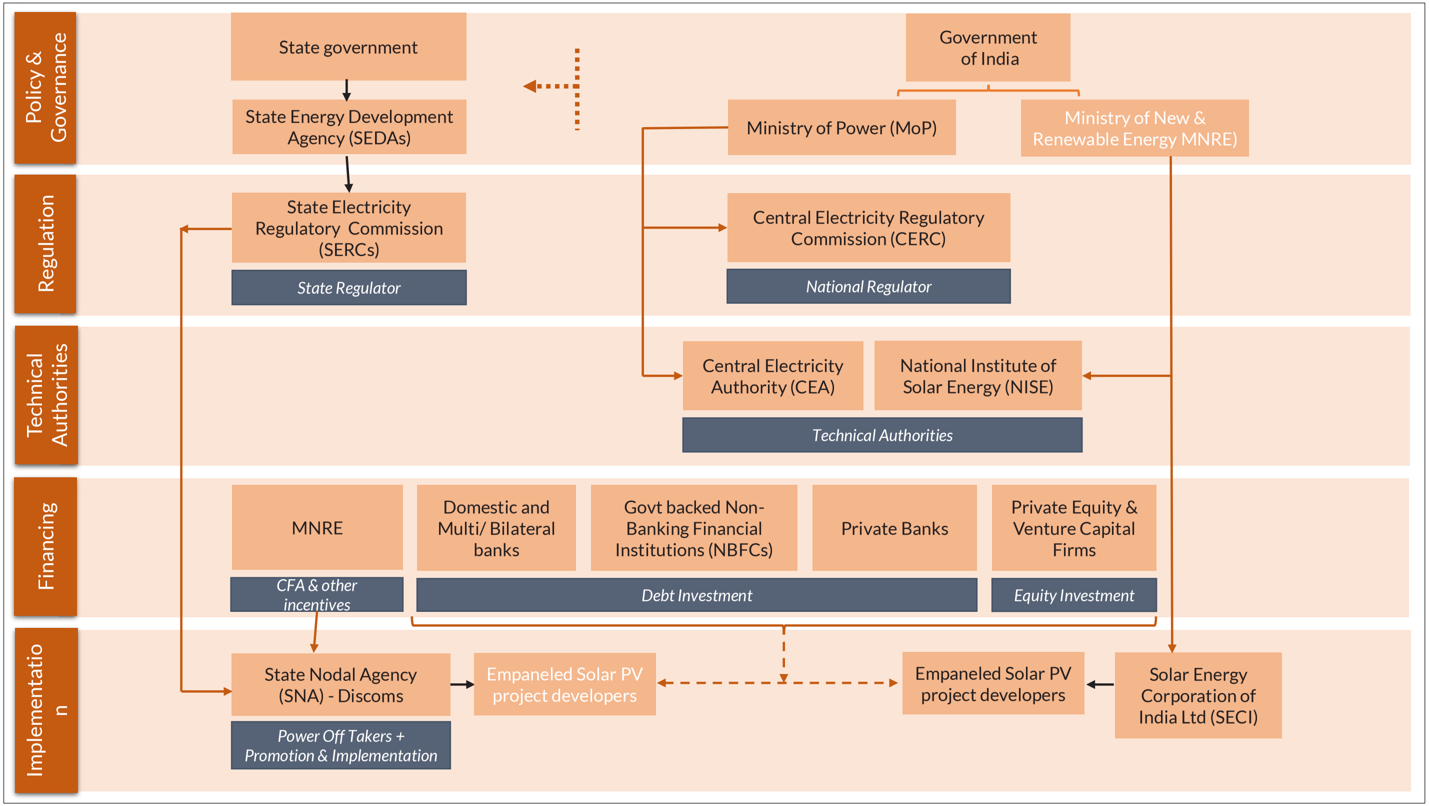
Subsequently, the government announced Phase II of the same program, popularly known as Grid Connected Rooftop Solar (GCRTS) programme in February 2019 to provide further boost to RTS. At the same time, the RTS goal was raised to 40,000 MW (40GW) by 2022, as it currently stands. Discoms were appointed as the state nodal agencies (SNAs) to grant approvals for installation and manage distribution network and given financial incentives to drive RTS implementation in their jurisdictions. This mostly included CFA that increased progressively with RTS installation compared to the benchmark level.

Between these two phases, the central government released the Model Building Bye-Law in 2016 that laid down norms for RTS for buildings in different categories. Essentially, building bye – law can mandate installation of rooftop solar in both old and new[xviii] buildings greater than a certain size and power consumption threshold. States can then adapt these to prepare their state specific building bye-laws.

Most recently, the Ministry of Power notified the amendment to Electricity (Rights of Consumer) Rules 2020, that raised the cap on net metering from the proposed 10kW in the draft amendment to the Rules, to 500kW.

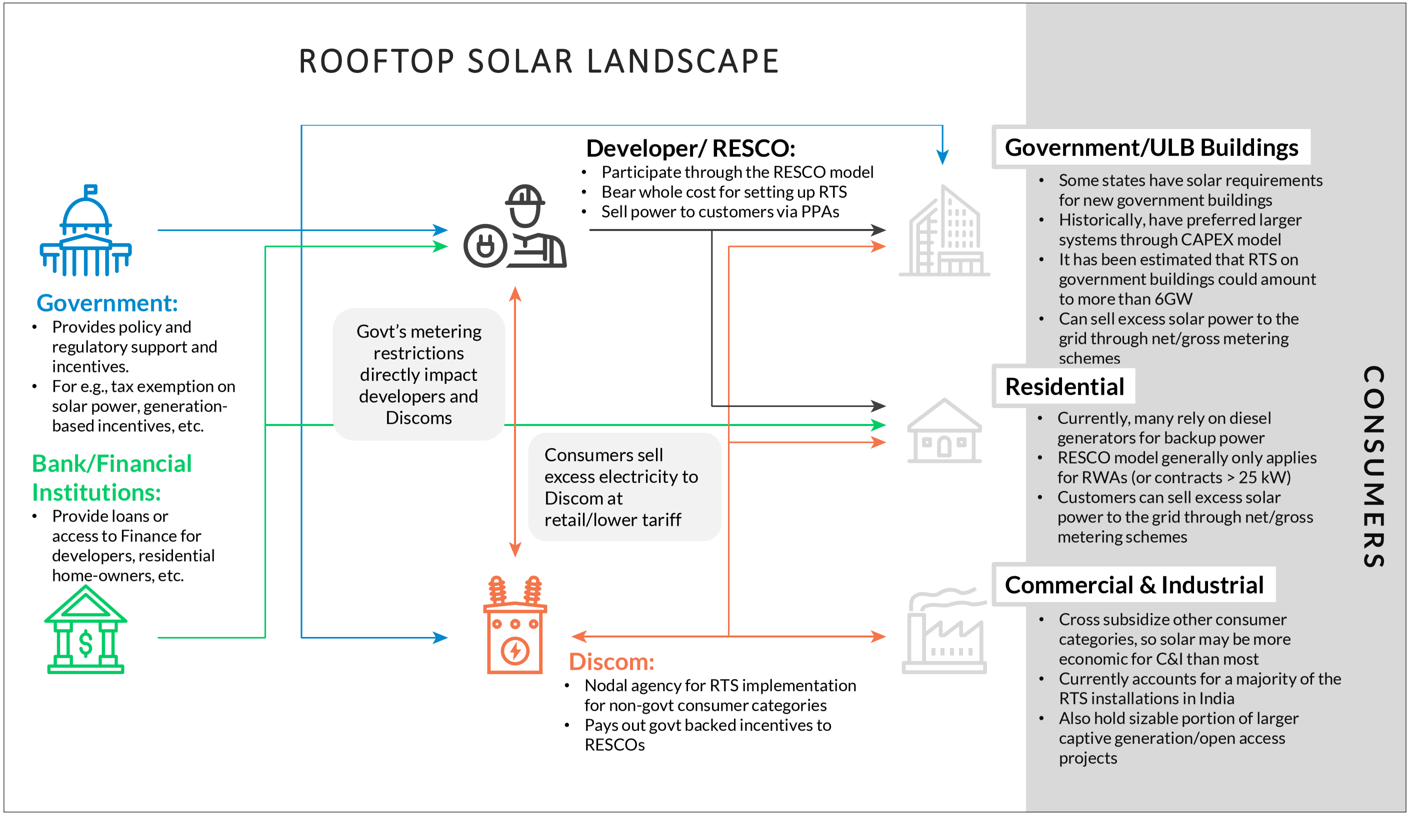
The policies and regulations form the context in which RTS related transactions occur. Next, Figure 10 provides a snapshot of the institutional bodies[xix] that play a role in implementing planning, imposing regulations, securing incentives, etc.

Figure 10: General institutional arrangement for RTS in India (Adapted from TERI)



3.2. Stakeholder Landscape

Figure 11: Broad stakeholder landscape for rooftop solar (List of stakeholders is not exhaustive)



1. **Government: Central and state governments, regulatory commissions**
    i. Both the central and state governments have a central role to play in the expansion of RTS across the country. The central government acts as the central authority that carves out plans and goals relating to renewable energy, including setting the 175 GW of RE to be achieved by 2022, and 40GW of rooftop solar within that. Most recently, the central government introduced Phase II of the Grid Connected Rooftop Solar Program. The state governments have the authority to setup state specific goals on RTS achievement.
    ii. Government also act as facilitators for RTS by offering incentives. This is evident in creation of mandates such as RPOs, adapting building bye-laws, and making Discoms the nodal agency for implementing the rooftop solar programme.

2. **Discom**
    i. Being the state nodal agency for implementing the Grid Connected Rooftop Solar scheme, Discoms become central to the RTS discussion. Power distribution companies ("DISCOMs") are crucial to achieving 40GW RTS by 2020. They provide connections for RTS installation on building premises, manage approval and implementation processes, and run all billing.
    ii. Their relationship with their customers is likely to be impacted by the regulations that are set. For example, the question of metering.
    iii. Their customers include residential sector, commercial and industrial sector, as well as small and medium enterprises.
    iv. Through the Grid-Connected Rooftop Solar Program Phase II, DISCOMs can avail of progressive incentives – up to 10% benchmark cost – for installing additional RTS capacity over the end of the previous financial year's capacity in all sectors. This is limited to the first 18GW of solar connected via DISCOMs in the country, so there is incentive to act quickly[xx].
    v. RTS can help DISCOMs fulfill their renewable purchase obligation (RPO) under which 10.5% of the electricity procured needs to come from solar energy by 2022. Currently, most states are lagging in their achievement towards this goal[xxi].
    vi. Discoms also conduct public awareness drives

3. **Commercial and Industrial (C&I) sector:** C&I has by far been the largest adopter of RTS and represented almost 70% of the growth in this market between 2012 and 2018.
    i. Since C&I pay higher electricity tariffs that discoms direct towards cross-subsidizing other consumer categories, they have a higher incentive to adopt rooftop solar.
    ii. Net metering obviously ends up benefitting C&I because not only does it allow them to save on tariff, they also get a chance to earn revenue from sale of excess

electricity generated. Under gross metering, economic gains are relatively less.

4. **Residential housing societies**
   i. Residential buildings have also been taking up RTS installation, and there are subsidies that they can avail. RTS can help replace residential buildings' dependence on diesel generator sets for backup, in addition to supporting the main electricity load.
   ii. Now because their total load consumed tends to be much smaller in comparison to C&I, it is likely to remain unaffected by the net vs gross metering regulation.

5. **Government Buildings that installs RTS on their rooftops (Urban local bodies).**
   i. Buildings such as government schools and hospitals, office buildings, etc. can install RTS on their rooftops
   ii. The government may be more interested in capex models or large RESCO models
   iii. These buildings can sell excess solar power back to the grid
   iv. RTS installation on government buildings is most likely being driven by central/ state mandates, building regulations, and RE goals. Currently, there are no central financial incentives available to them, and therefore economic benefit accruing from RTS may be a co-benefit/ by-product.

6. **Third party Developers**
   i. Third party developers of RTS participate in RTS installation through the Opex/ RESCO model. They bear the entire cost for setting up the systems on users' rooftops.
   ii. They enter into power purchase agreements (PPAs) with users to sell them electricity generated from the RTS.
   iii. While C&I is their biggest consumer segment, the potential advent of gross metering for medium to large systems could shrink their market as it would make RTS less economically attractive to C&I and MSMEs.

7. **Banks and financial institutions**
   iv. Help facilitate the implementation of RTS through provision of loans and other financial instruments.

3.3. Benefits of Rooftop Solar

Last year (2020), GoI asked all states and union territories to identify cities that will source their entire electricity consumption through RTS, in order to boost domestic solar manufacturing and contribute to state and national solar targets. There are multiple benefits that RTS has as a decentralized/ on-site technology. Since on-site solar systems are co-located with city facilities, they offer some unique features and advantages – including visibility and educational opportunities, lower utility bills, and—when paired with energy storage—enhanced resilience. They may also provide local jobs and economic development. These are highlighted below:

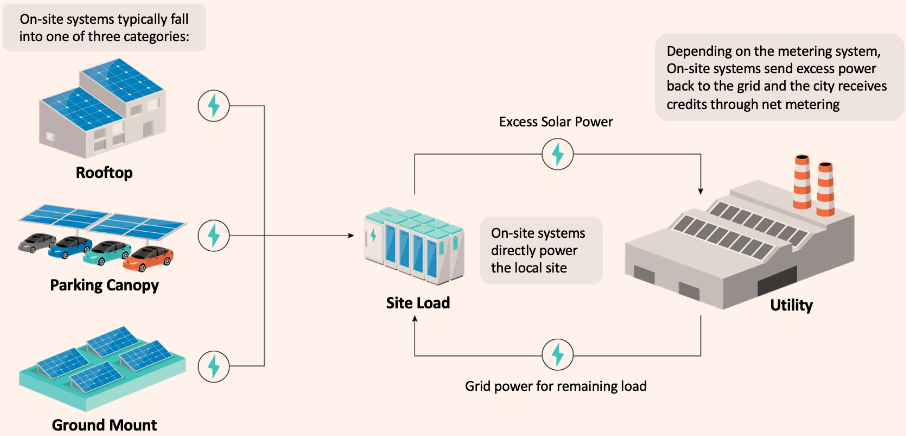
On-Site Solar

To put rooftop solar into context, it is important to understand what 'on-site solar' is and how it operates.

On-site solar photovoltaic (PV) systems are installed on rooftops, parking lots, or land at the same locations where electricity is consumed. These systems are directly tied to a facility's electrical system – they are "behind-the-meter" and can directly reduce the facility's need to purchase electricity from the grid. If an on-site solar project produces more electricity than the facility needs at any given moment, the excess electricity is exported to the grid.

In those states that have passed net-metering legislation, the system owner receives a credit on their utility bill for any excess solar energy generated at their location. On-site systems can be installed even if net metering is not enabled, but they tend to be more financially attractive in regions with net metering, high electricity prices, good solar potential, and local incentives.

RTS can also be installed as off-grid systems that are essentially standalone systems with likely support from battery storage. Such systems work well for remote or rural areas that may not have connection to the grid. RTS can also be installed as part of hybrid systems that are off-grid systems with the option of connecting to the grid for back-up



- **Modularity:** They can technically be designed based on the requirements of the beneficiaries. RTS can be offered as stand-alone systems, grid-connected systems, and hybrid types[xxii].
- **Minimal land requirement:** In a country where land is at a premium and settlements tend to be dense, a system that doesn't necessarily need land for installation is opportune. This also helps avoid the process and associated challenges of land acquisition, which can take between six to nine months for larger utility scale solar[xxiii]

- **Price stability and resiliency:** RTS can offer long term price stability for municipal governments as well as cost savings. Adoption of RTS in government buildings could deliver annual savings of nearly Rs 830 crores (approximately $100M USD)[xxiv]. It also offers opportunity to earn revenue by sale of surplus power generated. As technology costs continue to decline, RTS could potentially be paired with behind-the-meter battery energy storage as a resilience solution, offering a cost-comparable noise- and air-pollution-free alternative to back-up diesel generators (In 2019 India's diesel generator market was slightly over $1 Billion USD[xxv]).

- **Increase in local jobs:** Increased deployment of RTS solar could help India begin to recover the some of the more than 100 million jobs lost due to COVID-19. Meeting India's 40 GW rooftop solar goal could create nearly 1 million job-years[xxvi].

- **Increase efficiency gains:** Due to the co-location of generation and consumption, RTS reduces transmission and distribution losses[xxvii] in the electricity distribution system, and network augmentation costs for Discoms[xxviii]. These systems also help ease the day-time peak load—which match the diurnal peak of solar generation and would otherwise be met by expensive, polluting fossil generation. This peak co-incidence will become all the more important with the increasing penetration of air conditioning, which is expected to contribute 45% in the peak electricity load by 2050, up from about 10% today[xxix].

- **Improves environmental quality:** Switching to solar energy provides environmental benefits in the form of avoided GHG emissions from fossil fuel based electricity. This also leads to cleaner air, better health outcomes, and contributes to climate action.

- **Provide benefits to the surrounding community:** As RTS proliferates, utilities must upgrade local distribution grid infrastructure to handle interconnection and the bi-directional power flows required for net metering. These upgrades will increase reliability for all customers served by the upgraded lines.

3.4. Gaps and Challenges

Despite the benefits, there are various challenges that potential users of RTS may come across. This can differ depending on the particular state or city since local laws and regulations will differ from state to state.

1. Economics

i. Typically, consumers tend to be deterred by the high upfront capital cost of RTS system. However, studies have shown that costs can be recovered in 3-4 years post installation.

ii. Developers may further face challenges in aggregating RTS demand in case individual demand is too small to be economical for them.

iii. Banks and lending institutions may not understand the technology, its scale, or potential returns from it given its unprecedented nature.

iv. Since C&I can benefit economically from adoption of RTS under net metering, already financially strained Discoms may be disincentivized from potentially losing their high tariff paying (C&I) customers.

2. Awareness and Informational Constraints

i. A definite information asymmetry plagues the RTS landscape with customers and financiers, both having limited understanding of the RTS technology, its benefits, financing avenues, etc.

ii. For government entities, challenges lie in terms of limited understanding of the techno-economics assessments, as well as the larger process of procurement of RTS, including planning, securing approvals, and issuing tenders.

iii. Data needs:

   a. Absence of a country-wide assessment of existing suitable rooftops, RTS capacity, and potential RTS capacity (with new builds)

   b. Absence of digitized data that helps planners, consumers, policy makers

3. Technical

i. Installing RTS on rooftops adds to the load on building structures. For existing buildings, structural strength/ load bearing capacity may need to be assessed for structural soundness before installing RTS.

ii. At the same time, RTS requires predominantly shadow-free areas. This can be at risk from neighbouring buildings or emerging buildings and future constructions in the neighbourhood that could cast shadows on the concerned rooftop and affect RTS capacity.

4. **Policy Evolution and Uncertainty**
    i. Inconsistent policies regarding metering have been concerning to large scale producers of solar energy, as they directly affect the financial viability and economics associated with the investment in solar/ RTS system[1].
    ii. Similarly, any uncertainty around import duties on component parts of RTS can affect the cost incurred by contractors and third party developers, and affect the bid prices and tariff offered to their customers.

5. **Operational Constraints –**
    i. Implementing RTS can require substantial coordination among several different agencies. Once the buildings have been identified by the government entity, a procurement agency will conduct the tendering process on behalf of the discoms and the said government entity. The developers will have to fulfil certain criteria as laid down in the tender, in addition to identifying suitable locations for RTS installations themselves. The appropriate ULB will enforce the building bye-laws."
        a. A *document on RTS adoption by ULBs* by USAID and MNRE highlights the overlap between the provisions under the Smart City proposals and respective building bye-laws for 20 smart cities, indicating the challenge with determining what's mandatory/ applicable and what's not.[xxx]

    ii. For developers, the duration of finding customers, carrying out demand aggregation, securing all approvals and final installation in a decentralized manner can be long. This may also hinder their ability to access finance from banks.

3.5. Key Considerations

Having understood the broad contours, benefits and challenges pertaining to RTS, it is prudent to look at the key considerations pertaining to adoption of RTS next. Therefore, the following section covers the more practical and operational factors that affect the decision to adopt and process of procurement. Table 2 summarizes these key considerations and questions.

---

[1]*Most recently (December 2020), the MoP had released 'Electricity (Rights of Consumers) Rules, 2020 that proposed capping net metering for loads at 10kW, instead of the earlier limit of 1MW. This decision would have negatively impacted RTS uptake among large consumers and developers. Subsequently, in 2021, it amended these rules to permit net metering for loads up to 500kW, and gross metering for loads above 500kW.*

Table 2 Summary of Key Considerations for Rooftop Solar Adoption

Key Considerations	Factors	Key questions to consider
Space	Rooftop Space Availability	Do your buildings have the minimum adequate space available for installing an RTS system?
Economics & Business Models	Tariffs and Incentives	How do RTS rates compare to your current electricity tariff? Can you avail central and/or state subsidies for RTS?
	OPEX vs. CAPEX model	Do you have access to adequate capital for installing the RTS system? Do you prefer paying for the system upfront? Are you capable of undertaking the required operations and maintenance tasks over the lifetime of the system? Are you able to find interested third party developers?
Regulation around Buildings	Building By-laws	Does your state or city mandate RTS for buildings of a certain size? Are you able to access any incentives as part of building regulations (e.g., relief on property tax)?
	Sanctioned Load	Does the desired system size match the percentage of sanctioned load that is authorized in the building?
Regulation around Metering/ Billing Mechanism	Net Metering vs. Gross Metering	What is the policy on metering in your state/ city? Does it apply to the public sector? What is the size of your RTS system? Does the desired size get affected by metering regulations?
	Billing vs Compensation period	What is the frequency of compensation against sale of surplus electricity generated through RTS? Does this affect you as a government entity?
	Sale of Surplus vs Consumption	Does the total electricity generated exceed the total consumption? Does the limitation of not being able to sell surplus electricity apply in your state?

3.5.1. Regulations

**Note that the terms 'customer' and 'consumer' refer to the municipal corporation*

1. **Regulations relating to Buildings**
   i. **Building Bye-law:** While building regulation is a state subject, the 'Model Building Bye-Laws – 2016' was issued by the erstwhile Ministry of Urban Development as a standard for states to follow/ adapt. It mandated that for all non-residential buildings, including government buildings, RTS is compulsory if the plot size is 500 sq mt. or above and have shadow free area > 50 sq mt. In this case a minimum of 5% of connected load or 20W/sq ft for "available roof space", whichever is less, is required to come from RTS installation on the building rooftop. Sanctioned load: This is the total load or pool of supply that is authorized to a meter. Consuming electricity beyond the sanctioned load affects the fixed charges on your electricity bill and may even invite a penalty from the concerned discom.

2. **Regulation relating to Metering and Billing**
   i. **Net Metering:** Under net metering arrangement, purchase and sale of electricity cancel each other out. In effect this means that you're getting paid the same retail tariff for the electricity you sell to the grid that the discom charges you for purchasing it. You would only pay when you are a net electricity purchaser. If there is excess electricity generated, it can be sold to the grid at a feed-in-tariff/ a tariff determined by the state, or be credited to your bill for the next month. This set-up can be facilitated through a single bi-directional meter that measures total units of electricity being consumed and produced (also known as the 'prosumer' model) per billing period. It also allows for a payment mechanism known as 'on-bill financing', wherein an amount of profit earned through this approach is put towards monthly payments for eventually owning the RTS system.

   ii. **Gross Metering:** Under gross metering arrangement on the other hand, the entire energy generated by the solar PV system is fed back directly into the grid at an agreed upon 'feed-in-tariff'. The feed-in-tariff is generally lower than the retail tariff consumers pay for purchasing electricity from the grid. Therefore, gross metering is usually less profitable than net-metering for consumers. Gross metering typically involves the use of two single-direction meters (one to measure incoming electrons from the grid, and the other for 'outgoing' electricity from the solar system). This tends to be beneficial from the discoms' point of view.

As per the 2021 Amendment to the Electricity (Rights of Consumers) Amendment Rules 2020, prosumers may now avail net metering for systems up to the size of 500 kW (up from the proposed 10 kW ceiling that received strong pushback), and gross metering beyond 500 kW.

3.5.2. Business Models/ Mode of Operation

There are primarily two business models under which one can operate– Opex (operational expenditure) and Capex (capital expenditure). These models of RTS deployment were introduced in 2016, giving consumers the option of choosing how they wanted to participate in the adoption and financing of RTS. While the Capex model is a traditional purchasing structure, Opex models – which tend to favour customers unable to pay high upfront costs – have steadily been growing in popularity. A third Discom-led aggregation model is slowly gaining traction too. Discoms have the ability to aggregate rooftops and solar demand to offer an innovative approach. By taking advantage of economies of scale, the Discom-led aggregation model may offer more attractive project economics if designed and implemented appropriately.

These are discussed in more detail below:

1. **Capex model:** The Capex or capital expenditure model, as the name suggests, is where the consumer outright purchases and subsequently owns the system. In addition to utilizing the electricity produced by the solar plans, the system owner can earn revenue by selling the excess electricity to the grid. At the same time, the customer incurs the entire capital cost and is responsible for maintaining the system.
    i. **Lease model:** This model is akin to financing the Capex through a loan or Equated Monthly Instalment (EMI). The customer owns the system from day one and is responsible for all operation and maintenance related issues.

2. **Opex/ RESCO model:** In the Opex model, the customer doesn't own the rooftop solar system, thereby avoiding any upfront capital investment. A third-party vendor will develop the system and sell the customer electricity at a tariff (typically at a lower rate compared to what the local discom offers) as documented in a bilateral power purchase agreement (PPA). Alternatively, the developer may choose to pay the customer rent for rooftop space but sell the entire amount of generated electricity directly to the discom under a gross-metering set-up. This so-called RESCO model pays for itself through the savings on electricity costs by the consumer/ rooftop owner (or any rent agreement for rooftop space). Since the third-party is responsible for operations, maintenance, and supplying electricity, a customer faces reduced performance risks and avoids the considerable upfront payment associated with the Capex approach. Given these benefits to the customer, the savings delivered by the opex model are generally less than savings from a project developed with the capex model.
    i. **Build-Own-Operate-Transfer (BOOT):** In this model, customers have the option to slowly pay the third-party additional capital fees and eventually own the RTS system. This is typically done through 'On-bill financing' wherein the rooftop owner/customer sees an additional 'solar capex fee' on their electricity bill each month. This continues until the entire upfront expenditure (plus additional interest) is paid completely. After the transfer of ownership, the rooftop owner takes over the net-metering agreement with the local discom.

3. **Discom-led aggregation models:** Discoms may choose to aggregate demand for solar energy with the supply of real estate on which to build solar systems. An aggregation model may follow either the Capex or Opex route depending on customer preferences but the approach hinges upon active facilitation by the local Discom. This route is ideal for those who wish to source clean energy but do not have access to adequate rooftop space. It utilises a version of Net-metering known as 'Virtual Net-metering' wherein customers may own a portion of a larger off-site solar system that feeds electricity directly into the grid. Each customer's energy bill then gets credited a certain amount based on the total output of the system and their individual ownership stake. While these projects aren't necessarily sited on municipal-owned rooftops, the models allow customers to procure a similar capacity of solar to that of a rooftop project. We're including it in this manual given it may be a suitable alternative to building solar on your own roof.

To benefit from economies of scale, a **municipal body** may also aggregate rooftop projects across its various buildings and tender a collection of solar systems under one pooled project. A collection of projects can be financed through municipal bonds as discussed in the next section. Aggregation can also help distribute risk allocation, that may in turn reduce financing costs and make project economics more attractive. These benefits apply regardless of which business model is being utilised.

In terms of suitability, Opex/ RESCO model are more appropriate for large systems where large capital investments are required. Capex is better suited either for customers who need small systems, or those who have adequate capital to finance the purchase of a solar system. Note that either mechanism of metering can be used regardless of which 'business model' has been selected unless otherwise mentioned above.

3.5.3. Financing Options

RTS is a relatively under-explored segment by traditional financiers. A study by CPI, SEI, and ICRIER found that credit risk is the second biggest hindrance to raising third party finance for RTS projects. This section mentions potential sources of finance for municipalities adoption of RTS and how municipalities can aid third party developers in raising finance for RTS implementation.

1. **Municipal bonds for capex projects:** A majority of municipal infrastructure is financed through public coffers (central/state) and municipality revenues raised from local taxes. With the growth of the municipal bond market in India, cities can now play a more active role in raising external finance for their infrastructure development plans. Municipal bonds are debt instruments issued on behalf of a municipal government that is raising finance for a set of infrastructure projects. So far, ten ULBs have raised nearly INR 4,138 Crore through bonds . Notably, Pune Municipal Corporation in 2017 issued a bond that raised over INR 200

Crore for its development plans under the Smart Cities Mission. An exercise by CPI in partnership with ICRIER and SEI shows that of ~94 rated civic bodies in the country, over half are investment-grade and will feasibly be able to collectively finance RTS through bond issuance, should they choose to do so.

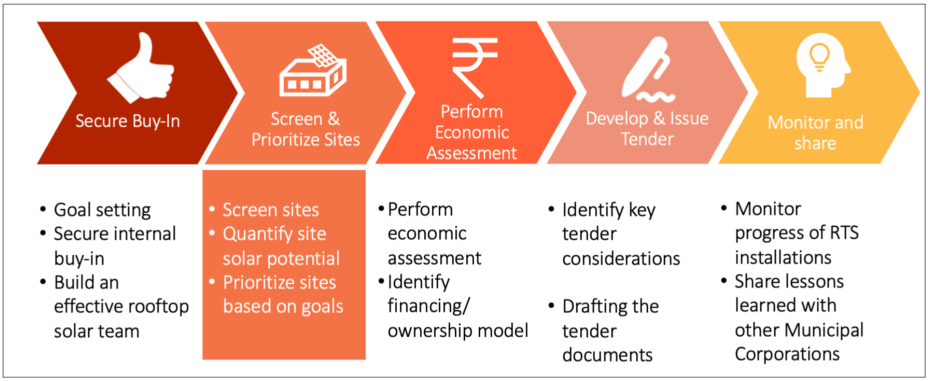
i. The emergence of group net metering and virtual net metering, bolstered by support measures undertaken by the Ministry of Housing and Urban Affairs (MoHUA) and the Securities and Exchange Board of India (SEBI), are likely to enable municipal bonds for funding aggregated RTS projects going forward.
ii. MoHUA provides subsidies for municipal bonds up to INR 200 Crore through an interest subvention program under Mission Amrut. Lucknow recently availed this
iii. SEBI constituted a Municipal Bonds Development Committee to support cities raise funds for their infrastructure development plans. The Committee can be contacted directly for technical assistance here: *mbdc@sebi.gov.in*

2. Fundraising support for third party developers: This point is mostly for any municipal government's information since they tend not to be directly involved in fundraising by third party developers. However, Municipalities can play a role in facilitating raising of low-cost finance for developers by providing sovereign payment guarantees and support in ensuring timely and efficient approvals. Doing so allows third party developers to in turn raise finance at favourable terms. The following list of financiers may be approached by third party developers to raise funds for PPP/Opex projects:
   i. Debt: Banks like PNB, Syndicate Bank, IDBI, Canara Bank provide loans for RTS projects, as do NBFCs such as Bajaj, Edelweiss, cKers Finance, Tata Cleantech etc. SIDBI, IREDA, SBI, NABARD have access to low cost lines of credit through international funds such as the World Bank, GCF, and ADB. However, the process of applying and approval can be long and requires larger ticket sizes. Tapping into these resources will make most sense if a number of RTS projects can be pooled together for a collective fundraise.
   ii. Grant support: Accelerators such as the US India Clean Energy Fund provide grant support to developers looking to deploy rooftop solar in India. Such a fund may be tapped into if a large enough collection of projects can be proposed by a municipality.

4

Ambition to Action - Exercise

Figure 12: Summary of steps to procure rooftop solar



1. Form Your Team and Your Goals

The first step in executing an on-site solar project is to form a team with the necessary skills. Moreover, in order to ensure this team is set up for success, it is worth ensuring that all the key internal and external stakeholders are aligned with the project and your team's priorities.

Forming your team:

It is important to establish a core on-site procurement team with specified roles and responsibilities. Your team may be a combination of internal city officials or staffers and external subject matter experts. It will need a mix of skills, including project management, on-site solar assessments, energy modeling, and tender development. These core members will likely:

- Perform or oversee on-site solar siting assessment;
- Analyze and decide on the solar ownership model;

- Run the process — develop and issue the tender, select and negotiate with the contractor(s), and sign the contract(s)
- Work with your city communications team to share your on-site solar project success stories.

The core team for rooftop solar development may include people from the following departments:

- **Environment or Sustainability Department:** If your city has developed a department focused on the environment or sustainability, they may be involved in the project management of this effort.
- **Power department:** You will need to request consumption and rate structure information from the person who manages municipal electricity contracts in order to perform the techno-economic analysis, as well as work closely with them through the planning and procurement process.
- **Building or Building Development department:** You should plan on engaging engineers or building managers from building department/ state development authority/ public works department to understand any building structural issues, future site plans, and minimize workplace disruptions during site visits or the solar installation.
- **Engineers or Engineering Department:** If there are no engineers embedded in the buildings or power departments, you will want to engage a city engineer to assist in the techno-economic assessment.
- **Financial officer(s):** You will need to work closely with your city's internal finance team to evaluate any potential deals from a financial perspective.
- **Legal expert(s):** You may require some aid from your internal legal department to consider what contractual requirements may be necessary to accommodate local bylaws, administrative policies, and city tender requirements.
- **Tender Department:** You should plan to engage with those responsible for the tender process to understand city restrictions and requirements for tender processes.

Aligning on goals

As stated above, there are many different benefits and considerations to analyze when developing rooftop solar projects. You should work with the team you have assembled to discuss what your top priorities are for the rooftop solar projects or sites. Common priorities are:

- **Economics:** Depending on electricity tariffs and how buildings use electricity, some sites may be better suited and more economic for rooftop solar than others.
- **Visibility and education:** Cities can lead by example by prioritizing solar at highly visible municipal sites or where there are educational opportunities (e.g., schools, libraries). This helps accelerate community-wide solar adoption, as solar PV adoption has shown to be contagious when visible.
- Generating Local **jobs**
- Increasing **resilience** of the power distribution network

2. Screen & Prioritize Sites

When considering rooftop solar, it is important to first understand your city-wide solar energy generation potential. This not only helps you understand the potential impact of your project on reaching broader renewable energy goals, but also identifies the municipal sites with the greatest solar energy potential.

First, list all municipal buildings, parking lots, and lands (e.g., land near water treatment plants, airports) connected to an electric meter using an organized template such as RMI's RTS Siting Tool (accessible here: *https://niua.org/c-cube/content/screening-tool-roof-top-solar*). Next you can use the National Renewable Energy Laboratory's (NREL's) PVWatts Calculator tool (accessible here: *https://pvwatts.nrel.gov/*) to determine information to help prioritize sites using the tool's 'Draw Your System' function (under the System Info tab). Please review the instructions in the excel RTS Siting tool and attached training recording for step by step directions on how to perform desktop rooftop assessments(Refer to recording of RMI training).

Additionally, you will want to consider key questions as highlighted in Section 3.5 above, including your state's interconnection size limitations and net or gross metering regulations. Data on state solar regulations can be found here: *https://www.ceew.in/sites/default/files/demystifying-india-rooftop-solar-policies.pdf* .

3. Perform Economic Assessment

Once you have refined your list of prioritized sites, you will need to conduct a high-level economic assessment to get the internal buy-in necessary to move ahead with the project – i.e., decide on an ownership structure and move to the tender process.

There are a few online solar rooftop calculators/ tools that can help with some basic analysis:

- SPIN: *https://solarrooftop.gov.in/rooftop_calculator*
- Centre for science and environment: *http://solarmyroof.cseindia.org/*
- MySun: *https://www.itsmysun.com/solar-calculator/*
- Renew Power: *https://renewpower.in/rooftop-solar/solar-calculator/*

Some key benefits and considerations of business and financing models are described in section 3.3, above.

4. Develop & Issue Tender

Having identified preferred sites and ownership model, you are now ready to find a developer to build the project. The issuing of tenders for public buildings can be done in coordination power Discoms, or with specialized agencies such as SECI if MNRE schemes provide for that, or through entering into Memorandum of Understanding (MoU) with selected developers or public sector undertakings such as Energy Efficiency Services Ltd. (EESL). Depending on your local government's experience with solar projects and local contractors, there may be several different solicitation processes. Govt. of National Capital Territory (NCT) of Delhi, for example, issued RTS tenders through a state power generation company (more in this in the case study in Section 5.1).

5. Monitor and Share

We recommended that the core team documents lessons learned throughout the procurement process and following completion of the project, capturing these insights to inform future projects. This is particularly important to accelerate learning cycles and to ensure institutional knowledge and capabilities are developed in case of staff turnover. Our recommendations include:

- Iterating and updating work plans based on actual hours and timelines required to achieve specific milestones.
- Developing templates for future projects (e.g., for tenders).
- Documenting key criteria for decision-making, approval processes, and key issues that arose during the project.
- Developing an after-action report based on debriefs of team members and critical stakeholders on what worked, what didn't, what they would do differently next time, and lessons learned.

5

Case Study

5.1. Delhi government schools adopt rooftop solar

Figure 13: 36kW Rooftop solar system at RPVV, Hari Nagar.

Source: Principal, RPVV school Hari Nagar, Delhi

Delhi has a Solar Energy Policy, 2016 that states its goal of achieving 2GW of solar by 2025. In this regard, the government schools[1] have been doing very well by participating in RTS adoption with the support of Delhi's Department of Education, reducing their own electricity bills in the process of supporting the state's solar goals

[1] *According to a report by GIZ, the educational sector pays among the highest tariffs in the country, since educational institutes fall under the commercial tariff category.*

1. **Description of the Project:**
    i. The Delhi Department of Education plans to install RTS in a total of 500 schools. Approximately 10-15% of the roughly 1000 government schools in the city have already adopted rooftop solar.
    ii. Adoption of RTS has not only allowed the schools to generate savings, but also to create another revenue stream (from sale of surplus electricity generated). The total capacity of the projects will be a little over 21 MW and reduce annual power bills by Rs. 8.8 crore. In addition to this, the sale of surplus electricity to discoms will fetch them Rs. 8.5 crores. Over the 25 year life cycle of the RTS system, total savings and earnings are estimated to be more than Rs 433 crore.

2. **Methodology of Planning**
    i. The Department of Education, under the broad mandate of Delhi's Solar Energy Policy, 2016 identifies the schools that have the optimal rooftop space for setting up RTS systems.
    ii. The process of procurement is outsourced to Indraprastha Power Generation Company Ltd. (IPGCL), that has been identified by the Govt of NCT of Delhi as the central agency for tendering and execution of solar projects in Delhi on behalf of the SNA.[2] Therefore, IPGCL prepares and issues the tender for RTS for the Department of Education.

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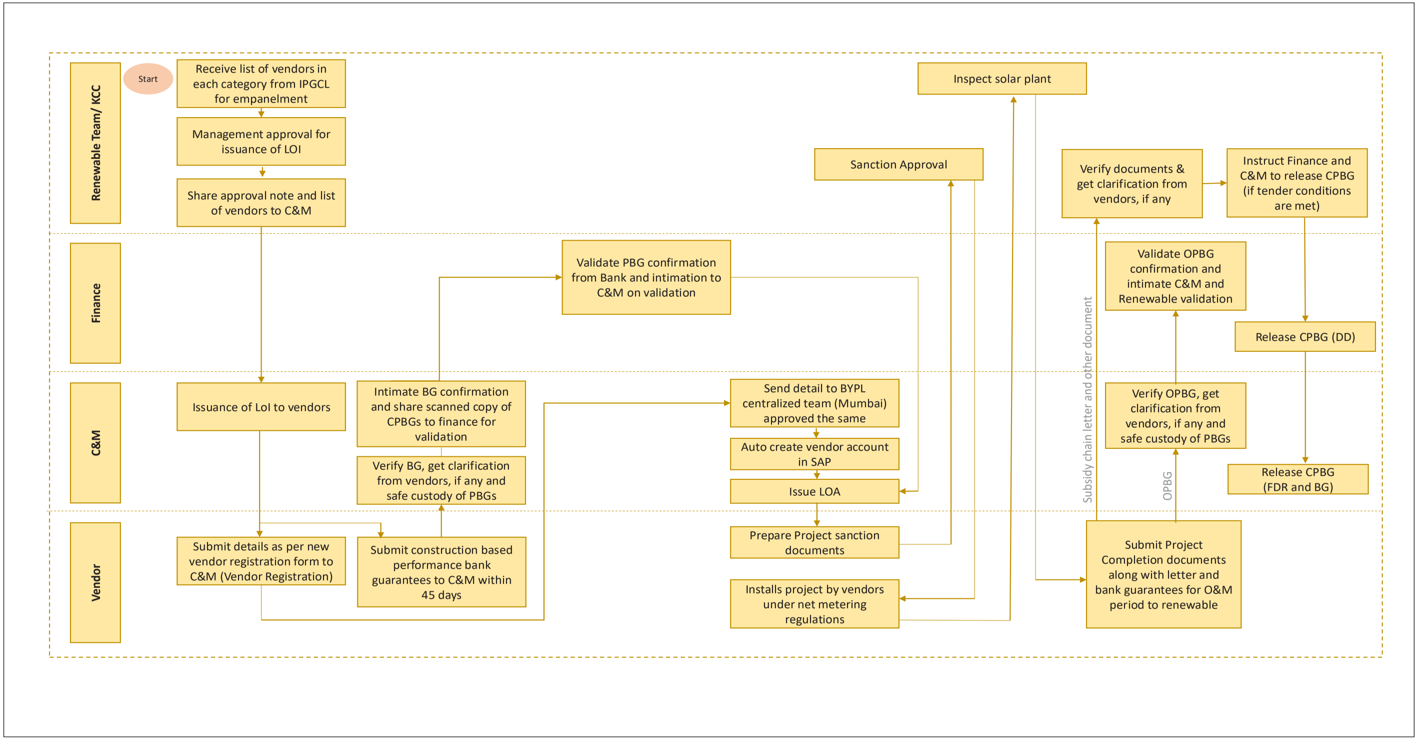
[2]At the time of issuing this tender, the state nodal agency for RTS implementation was the Energy Efficiency & Renewable Energy Management Centre). Under GCRTS Phase II, Discoms have become the SNAs for RTS implementation.

iii. In the case of solarisation of government schools in Delhi, IPGCL floated the tender to invite bids for RTS development under both Capex and RESCO modes in 2019. The e-tender document for the same is available here.
iv. The developers are identified through the process of competitive bidding.
v. In this case, the bid norms and draft contract were prepared and kept ready before floating the tender.

3. **Implementation Steps**
   i. Implementation is done by third party agency once selected by DoE through IPGCL
   ii. The eligible third party vendors are identified through competitive bidding and based on certain criteria/ bid norms. They subsequently undertake scoping of target locations and begin installation of the system.
   iii. The third party vendors setup the system under the RESCO mode and enter into individual PPAs with the respective schools. Schools receive a reduced tariff for electricity (~Rs. 3.13 or Rs. 3.75 per unit, which yields about 65% - 40% reduction in electricity bills compared to what the discoms charge).
   iv. The discoms will pay ~Rs. 5.65 per unit to schools for each unit of surplus electricity sold to the grid.
4. **Financing:**
   i. At the time this program started, the central government had a capital subsidy scheme as incentive for RTS adoption by government buildings in place. Therefore, it took care of 25% of the upfront capital cost accruing towards the developer. The schools themselves did not have to invest any capital except offering the physical rooftop space.
   ii. Third party vendors are able to recover their cost over the 25 year lifetime of the RTS system.

5. **Monitoring of the RTS system:**
   i. The third party developers are responsible for undertaking all operations and maintenance for a certain number of years (~10-15 years) depending on the arrangement with the school
   ii. In case of any operational issues, the school can directly contact the vendor for repair and maintenance.
   iii. It is possible for a team comprising officials from the school and the Department of Education to be monitoring the system from time to time, or a team comprising only officials from the school as well. The school is authorized to directly contact the developer in case any unscheduled repairs and maintenance are needed.

Figure 14: RTS application process flow in Delhi



Source: MNRE

5.2. Municipal Solar in the United States

The economic feasibility of on-site solar in the US depends on state policy, local incentives, as well as solar resource. Since 2015, over 700 MW[xxxi] of solar have been installed on-site at municipally owned buildings, one third of which has come online in the past year and half. Local governments in the U.S. have deployed on-site solar in a variety of different ways, a few different examples include:

Kansas City, Missouri[xxxii]

- Installed 1.5 MW in 2013 across 60+ municipal buildings
- Utilized a solar lease because PPAs are not enabled in Missouri
- The solar lease was estimated to save $40,000 per year

Washington, D.C.[xxxiii]

- Installed 11.4 MW in 2016 across 34 municipal sites
- Expected to save District taxpayers >$25 million over the 20-year contract
- Catalyzed $20 million in local spending, creating more than 140 jobs (85 in construction)

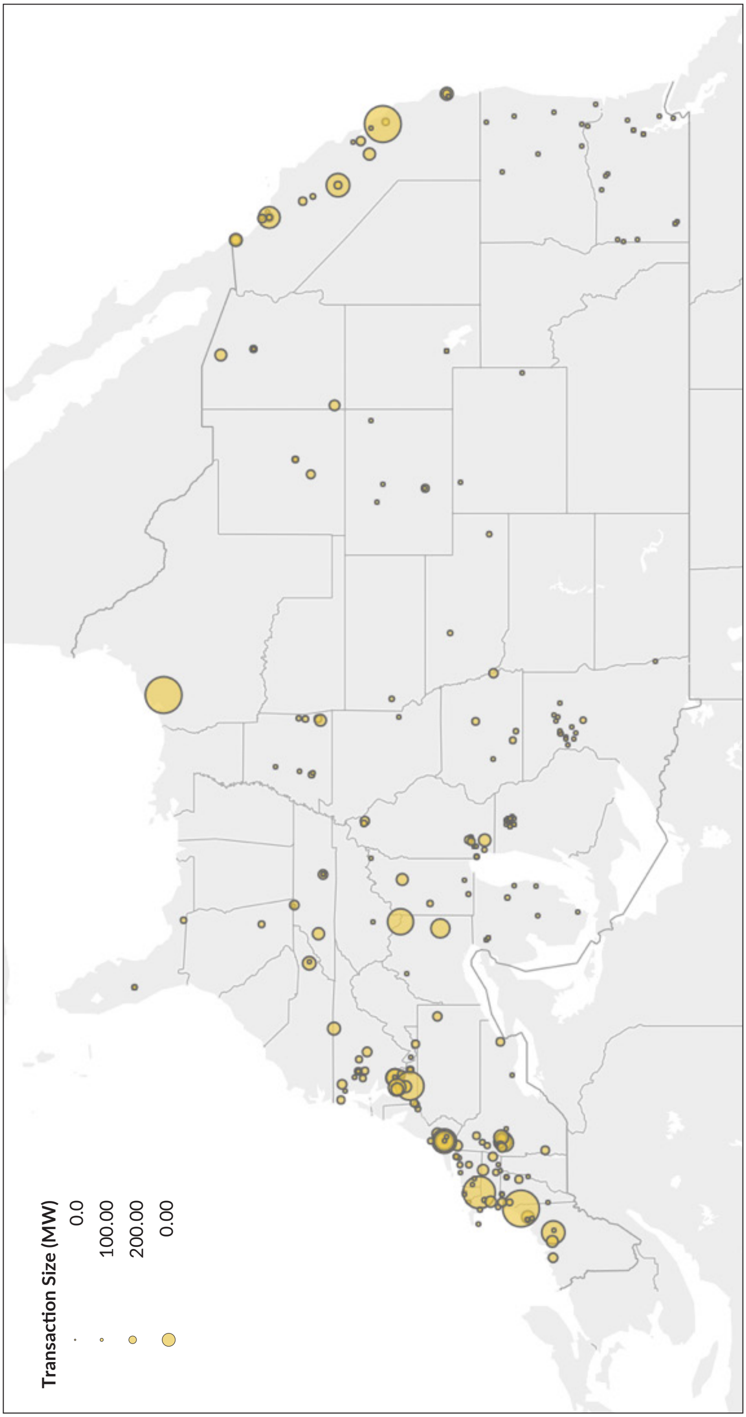
Albuquerque, New Mexico

- Installed 7 MW in 2017-2019 across 35 project sites
- Mostly financed using city clean renewable energy bonds
- Included rooftop and parking PV at fire and police stations, libraries, and community centers

Lowell, Massachusetts

- Installed 1.8 MW in 2014 on a capped landfill and three schools
- Included 23 energy conservation measures across 28 schools and 19 municipal facilities
- Expected to save Lowell $1.5 million per year over the 20-year contract

Figure 15 shows the 344 municipal on-site & rooftop solar projects in the U.S. since 2015



6

Next Steps

This manual aims to help potential users and city officials to develop a well-rounded understanding of the rooftop solar landscape in India, and encourage them to adopt the technology to increase the share of RE in their electricity use, as well as to move higher in the CSCAF progression levels. This sections outlines the operational takeaways or steps that city officials may undertake once they feel comfortable in moving ahead with procurement of RTS systems:

1. **Strategize:**
   i. Clarify your city's priorities: Identify, evaluate, and rank community priorities
   ii. Evaluate potential goals and how they compare to the goal of procuring RE
   iii. Develop final proposal for key decision makers; Zero in on appropriate technology
   iv. Finalize and set RE/ RTS goal for your city (in case none currently exist)

2. **Streamline (get administrative items in order):**
   i. Develop strategy/roadmap
   ii. Identify personnel requirement and build an RTS team if necessary
   iii. Seek and identify incentives and sources of funding
   iv. Create working groups comprising officials from regulators/ government departments/ discoms that can help fasten the process of RTS installation
   v. Enhance data management and data sharing

3. **Procure:**
    i. Evaluate Solar Potential
        a. Pre- screen all potential sites
        b. Request data and prioritize sites
        c. Estimate solar energy potential for prioritized sites

    ii. Assess Economics and Ownership
        a. Evaluate Project Economics
        b. Select an Ownership model

3. **Issue tender for procurement of RTS**
    a. Determine solicitation process
    b. Assist state nodal agency (discom) to issue/ release tender for call for bids
    c. Negotiate terms and award contract

4. **Monitor and Share**
    a. Monitor system performance
    b. Capture and document lessons
    c. Celebrate and share success story!

Glossary

1. Bank Guarantee: A guarantee offered by a lending institution to cover debt obligations of a debtor, in case the latter fails to settle the debt.

2. Behind the meter: Refers to on-site projects that connect to a customer's site behind a customer's electricity meter, thereby reducing the electricity that the customer needs to buy from the grid.

3. CAPEX model: CAPEX stands for Capital Expenditure

4. Generation based incentives (GBIs): Incentives availed on the basis of energy generation

5. Gross Metering: Under this form of metering, the electricity sold to the grid and the electricity bought by the customer is metered separately. The RTS owner pays for the electricity purchased at full retail tariff, but receives a feed-in-tariff usually lower than the retail tariff for the electricity sold to the grid.

6. KiloWatt (kW): A measure of power which is equal to 1,000 watts.

7. Killowatt-hour (kWh): A measure of energy which is equal to 1,000 watts being used or generated for one hour.

8. Megawatt (MW): A measure of power which is equal to 1,000,000 watts or 1,000 kilowatts.

9. Megawatt-hour (MWh): A measure of energy which is equal to 1,000,000 watts or 1,000 kilowatts being used or generated for one hour.

10. On-site solar: Solar project(s) built on local buildings or land, at the same location where the energy is consumed from the electricity grid.

11. OPEX model: OPEX stands for Operational Expenditure.

12. Net Metering: As the name suggest, under net metering, consumer has to pay only for the net electricity consumed. In case there is a surplus, the consumer can supply the excess to the grid at a feed-in tariff, or the number of units can get credited in the user's bill for next month.

13. Offtaker: An entity that is obligated to purchase power generated by a producer for a pre-decided period of time under a power purchase agreement (PPA).

14. Power Purchase Agreement (PPA): A contract with an energy project through which a customer agrees to purchase the energy produced by a generator over a specified period at a predetermined price per unit of energy. Types of PPAs include Physical PPAs, Financial PPAs and other structures.

15. Renewable Energy Certificates (RECs): A REC represents the clean energy attributes of 1 MWh of renewable electricity and conveys the environmental and social attributes of the generated electricity to customers.

16. Renewable Purchase Obligation (RPO): Renewable purchase obligation (RPO), is a mechanism by which the obligated entities are obliged to purchase certain percentage of electricity from Renewable Energy sources, as a percentage of the total consumption of electricity. RPOs are categorized as Solar and Non Solar RPO.

17. Rooftop solar (RTS): A photovoltaic system that generates electricity using solar energy, with panels typically mounted on rooftops of consumers' buildings.

18. Tariff: The conditions, such as pricing, charged to customers for the delivery and consumption of electric power, or the on-site generation of electricity.

List of Reference Materials

1. **Reports**:
    i. Report by IEEFA on *Vast Potential of Rooftop Solar in India*
    ii. Report by ADB on *Rooftop Solar Development in India* (Policies and Business Models)
    iii. Report by GIZ on *RTS Business Models with high replication potential* in India
    iv. Report by CPI on *potential for Municipal Bonds for scaling up RTS in India*
    v. Report by TERI on *Perspective of Discoms on Rooftop Solar*
    vi. *Operational Guidelines* for implementation of Phase II of GCRTS
    vii. *MNRE's portal for Solar PV Installation called SPIN* ('Solar Power in India') for monitoring and management of Grid Connected PV Rooftop Projects in India.
    viii. *Information Guide by MNRE* on Grid Connected Solar Rooftop Programme in India
    ix. Guidelines by USAID and MNRE on *RTS Adoption by Urban Local Bodies*
    x. *Concept note by MNRE* on bringing Discoms to the forefront of RTS implementation
    xi. Presentation from MNRE on *Unlocking economic potential of RTS in India*
    xii. Report by IEA-CEEW-MNRE on *Unlocking Economic Potential of RTS in India*
    xiii. Manual by MNRE and USAID on *best practices for implementation of state level RTS* programmes in India
    xiv. Report by CEEW on *Demystifying India's RTS policies* at the state level
    xv. Report by MNRE on the *RTS Process Flow across states* in India
    xvi. *Frequently Asked Questions* (FAQs) on Grid Connected RTS by MNRE

2. **Tools:**
    i. RMI's RTS siting excel tool - *https://niua.org/c-cube/content/screening-tool-roof-top-solar*
    ii. NREL's *PV Watts Calculator* for remote rooftop space assessment
    iii. MNRE's *Solar Calculator*
    iv. *Solar My Roof Calculator by Centre for Science and Environment*
    v. *MySun Solar Calculator*
    vi. *Solar Calculator by Renew Power*

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सत्यमेव जयते

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