

# National Solar Mission **Best Practices Guide**

Implementation of State-Level Solar Rooftop  
Photovoltaic Programs in India



सत्यमेव जयते

Government of India  
MINISTRY OF  
NEW AND RENEWABLE ENERGY

June 2016

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पीयूष गोयल  
PIYUSH GOYAL



विद्युत, कोयला एवं नवीन और नवीकरणीय ऊर्जा  
राज्य मंत्री (स्वतंत्र प्रभार)

भारत सरकार

Minister of State (Independent Charge)  
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Government of India



### Message

Solar has emerged as the fastest-growing Energy Generation technology globally, over the past decade. This has been largely due to its large-scale adoption by utilities and the private sector. A number of drivers have accelerated the development and deployment of solar energy generation projects across the globe. These range from increased awareness of climate change hazards, energy security considerations, presence of facilitating policy and regulatory frameworks, decline in solar energy generation costs and emergence of new and innovative business models.

Realizing its immense potential, Government of India has undertaken an ambitious target of 1,00,000 MW solar power. There is need to harness solar energy to reduce pollution from diesel, coal and other fossil fuels, to save precious resources and to usher in green and clean development.

Rooftop Solar (RTS) power has led the development of the solar sector across the globe with its ability to replicate rapidly. RTS projects provide an attractive opportunity for State Governments, utilities and cities, as they do not require pooling of land or separate transmission facilities. Rooftop Solar systems help utilities address critical issues such as high transmission and distribution losses, while simultaneously making the consumer an active investor and a participant in the energy sector.

Our Government has focused on speed, skill and scale to drive reforms in the renewable energy sector. Hence, a target of 40,000 MW capacity for RTS systems by 2022 has been set. Estimates show that nearly 70% of the building stock in India, which will be required in 2030, is yet to be constructed. This will further widen the avenues for solar PV rooftop installation. Ministry of New & Renewable Energy actively supports development of RTS projects through skill development programmes, financial assistance and incentives, concessional finance for developers and focused awareness programmes.

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We have actively engaged and supported State Governments to undertake key policy, regulatory and financial measures to promote RTS installations. However, it is important to encourage the market eco-system so as to provide further thrust to the sector. Stakeholders including regulators, distribution utilities, nodal implementing agencies at State/ UT level as well as investors need to address market-related constraints that hamper smooth implementation and capacity addition.

We must acknowledge that RTS projects need coordination across multiple stakeholders and are heavily dependent on local conditions. To ensure a consistent and robust eco-system across the country, we need to develop fast and learn from best practices. To fulfil this need the Ministry of New & Renewable Energy has developed this Best Practice Guide to provide key learnings from across the globe. It aims to fill the knowledge gap by providing information for enhancing quality and speed of implementation process at the Ministry / State / UT level.

I am confident that the Guide will show the way forward to State/ UT governments, distribution companies, investors, developers and other stakeholders for enabling large-scale deployment of RTS projects.



**Piyush Goyal**



सत्यमेव जयते

उपेन्द्र त्रिपाठी  
*Upendra Tripathy*



सचिव  
भारत सरकार  
नवीन और नवीकरणीय ऊर्जा मंत्रालय  
SECRETARY  
GOVERNMENT OF INDIA  
MINISTRY OF NEW AND RENEWABLE ENERGY

### Foreword

Solar has emerged as the fastest-growing energy generation technology globally over the past decade, largely due to large-scale adoption of the technology by utilities and the private sector. A number of drivers have accelerated the development and deployment of solar energy generation projects across the globe. These range from increased awareness of climate change hazards, energy security considerations, facilitating policy and regulatory frameworks, decline in solar energy generation costs, and emergence of new and innovative business models.

2. Solar rooftop has led the development of the solar photovoltaic sector across the globe with its ability to replicate rapidly. Solar rooftop systems help utilities address critical issues such as high transmission and distribution losses and offer long-term national as well as consumer level energy security, while at the same time making the consumer an active investor and a participant in the energy sector.

3. Realizing, its immense potential, the Government of India has set a target of 40 GW of capacity addition to come through solar PV rooftop systems. With this, India will emerge as a leading country to utilize “idle” rooftop space for solar generation. Estimates show that nearly 70 % of the building stock in India is yet to be constructed. This will further widen the avenues for continued solar PV rooftop installation. As per estimates, India is likely to have over 300 million solar rooftop installations by 2030.

4. The Central and State Governments have taken various initiatives, including policy, regulatory, fiscal and financial measures to promote solar PV rooftop installations. Some of the key initiatives /promotional measures taken by this Ministry are:

- Financial subsidy of 30% of project/bench mark cost for RTS projects in Residential/Institutional/Social sectors;
- Financial incentive upto 25% of project/bench mark cost for RTS projects in Government/PSU sector;
- Pursuing notification of Gross/Net metering policies in all States/UT;
- Development of Online Portal for RTS development programmes;
- Empanelment of agencies with capacity and expertise for installation of RTS systems;
- Developing Project Reports for various Solar Cities;
- Training of additional 10,000 Surya Mitra and staffs of DISCOMs/SNAs;
- Provision of concessional credit to project developers through multi-lateral support.

5. As a result, solar PV rooftop should be one of the fastest emerging market segments in the energy sector today. However, it is important to enable market eco-system to provide further thrust to the sector and ensure its scale up in an efficient manner. Stakeholders, including



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including regulators, distribution utilities, nodal implementing agencies as well as investors need to address certain critical technology, process and market-related constraints that hamper smooth implementation and capacity addition.

6. This Best Practice Guide provides learning's from across the globe and India, and other useful information required for deployment of large-scale solar PV rooftop. I am confident that the Guide will show the way to state governments, distribution companies, investors, developers and other organizations, not only in India but also in other countries. This Guide will also be useful for the corporate sector in developing business opportunities in this area.

7. I wish that all stakeholders involved in the journey of deployment of solar PV rooftop read, share and benefit from this Guide.

8. Let us all work together to make solar energy a norm rather than an exception.

27<sup>th</sup> May, 2016

( Upendra Tripathy )



**Santosh D. Vaidya, IAS**  
Joint Secretary

भारत सरकार  
नवीन और नवीकरणीय ऊर्जा मंत्रालय  
GOVERNMENT OF INDIA  
MINISTRY OF NEW AND RENEWABLE ENERGY



### Foreword

India has taken the challenge of developing 40 GW of rooftop solar (RTS) power capacity as part of its Green Commitments before UNFCCC. While most of the countries leading in solar energy have a substantial share of their solar power from rooftop projects, the RTS is still an emerging segment in India. Considering the clear advantages of RTS power (minimal distribution losses, no need of land & dedicated transmission, etc), Ministry of New & Renewable Energy (MNRE) is pursuing development of proactive eco-system for fast development of this segment.

This is crucial considering our immense RTS potential and that nearly 70 % of the building stock in India is yet to be constructed. Hence this Ministry and State Governments have initiated measures to provide financial subsidy in Residential/ Institutional/ Social sectors and financial incentive for RTS projects in Government/ PSU sector, to notify Gross/Net metering policies in 26 States/UTs, to develop RTS online portal and SPIN platform, to empanel channel partners, to assess RTS potential of buildings under all Ministries, to coordinate with Ministry of Urban Development of RTS projects in SMART cities and Solar Cities, to train Surya Mitras and staffs of DISCOMs/SNAs and of Banks through NISE and SETNET institutions and to provide concessional credit to project developers through multi-lateral support (World Bank, Asian Development Bank, KfW/ German Bank and New Development Bank).

Design and implementation of RTS project require substantial coordination of several agencies, viz. Regulatory Commission (Net metering regulation), Discom (net-metering & bill settlement), Ministry & State Nodal Agency (release of subsidy), Banks (housing/ improvement loan), Urban Local Body (IEC for public campaign), Rooftop owner (access to roofs), Developers/ Aggregators / EPC contractors (project implementation & operation), etc. For facilitating such coordination, MNRE has been working with USAID to develop this Best Practice Guide. By providing all best practices in developing business models, RTS promotion policies/ regulations, technical standards and capacity building at one place, this Guide will provide excellent foundation for all Stakeholders.

I am confident that it would help in accelerating speed of implementation process of RTS projects at the Ministry / State / UT level. Hence I would like to thank USAID and GERMI for developing this Guide that provides global learnings in collated fashion.

**Mr. Santosh D. Vaidya**  
Joint Secretary, Government of India



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## 1. Introduction to this “Guide”

### 1.1. Purpose of the Guide

The Ministry of New and Renewable Energy (MNRE), Government of India has announced an ambitious solar target of 100,000 megawatts (MW) installed capacity by 2022, of which 40,000 MW of solar photovoltaic (PV) systems are to be installed on rooftops.

There have been several efforts at the policy, regulatory and implementation levels for solar rooftop deployment in India. For a long time, the country witnessed solar installations with the help of Government funding, which has now started evolving to various public-private partnership (PPP) and private sector-based models. However, the net capacity of such projects has till now remained limited, especially compared to the regulatory and procedural efforts undertaken to realize such projects.

With dramatic reduction in PV prices over the last couple of years, we are entering an era of ‘grid-parity’, where the cost of solar electricity is competitive with retail electricity tariffs in many cases. This presents a whole new opportunity for the country, the sector and the market. However, in order to realize widespread solar rooftop deployment opportunities, the implementation process for each stakeholder needs to be clear and simple.

As many State nodal agencies (SNAs) and distribution companies (DISCOMs) embark on their journey of solar PV rooftop development, they will face challenges – most of these are teething troubles – which could include lack of clarity in policy or regulation to technical uncertainty to detailing and simplification of administrative procedures.

Implementing agencies can follow the ‘learn-as-you-go’ approach, but this approach would be costly and time consuming, as most of the issues would already been sorted out by someone else somewhere around the world or maybe even in India.

This Guide attempts to lay out a comprehensive and efficient solar PV rooftop implementation support process into a single document. It captures global and national best practices and learnings. The Guide primarily addresses grid-connected rooftop PV systems, under both net metering and gross metering connectivity.

### 1.2. Organization of this Guide

The Guide is organized to provide necessary and sufficient information to almost all stakeholders, especially administrative stakeholders including:

- State-level policy-makers and State Electricity Regulatory Commissions (SERCs).
- Implementing agency(s), usually the SNA or the local DISCOMs.
- Solar rooftop project developers, installers or even electrical inspectors.

- Financial institutions (FIs).

While it is recommended that all the stakeholders read the entire Guide, the Guide is designed to be also used as a reference, where one can read specific chapters or sections related to their role or responsibility. The chapters cover the following aspects:

**Chapter 2 (Business Models)** discusses the basis of the transaction structure of any solar rooftop programme – the relationship between different stakeholders and the prevailing business models in the space.

**Chapter 3 (Policy and Regulation)** is oriented towards policy-makers and regulators, addressing key considerations from the State's perspective towards its administration as well as the stakeholders.

**Chapter 4 (Technical Standards and Specifications)** is oriented towards the implementing agencies, primarily the DISCOMs and SNAs, as they are concerned with the safety, quality and performance of the solar installations. Relevant technical configurations in terms of system design and configuration; safety, performance and quality standards; documentation and compliance requirements are discussed in this chapter.

**Chapter 5 (Administrative Processes)** deals with specifics of administering a solar rooftop programme and details all critical preparatory, interconnection-related, and operation-related processes of the DISCOM.

### 1.3. Customization, Compliance and Revisions

The Guide addresses all necessary concerns, whether administrative or technical, to realize a simple, efficient and scalable solar PV rooftop programme. While it discusses many topics in detail, readers are suggested to ensure their applicability before directly applying them. Hence, it is envisioned that slight customization may happen from State to State based on the State's vision, budgets and even statutory provisions.

In case of any conflict between the provisions of the Guide with statutory provisions in the current scenario or in the future, the statutory provisions shall overrule the provisions of the Guide.

## 2. Business Models

### 2.1. Introduction

Design of appropriate business models assumes a greater significance in the case of solar PV rooftop market due to their relatively high cost of energy generation/high upfront investments coupled with distributed implementation and generation. Hence, appropriate design and packaging of a solar rooftop deployment programme in terms of a viable business models is key to its success, and should be the basis of any policy or regulation formulation.

### 2.2. Components and Design of Solar Rooftop Business Models

#### a. Building Blocks for a Solar Rooftop Business Model

The key determinants of any business model in the solar rooftop space are the ownership and revenue structures and other incentives. In most cases, the ownership structure or the revenue model are identified based on a number of factors such as the policy and regulatory framework in the market, the electricity market structure and tax policies. Revenue models depend on the manner in which the energy is generated and used/sold. This may also include other incentives which may be needed to ensure the financial viability of the business model.

#### b. Evolution of Solar Rooftop Business Models

The solar rooftop business model has evolved overtime based on the ownership of systems and external stakeholder participation as highlighted in Figure 2-1.

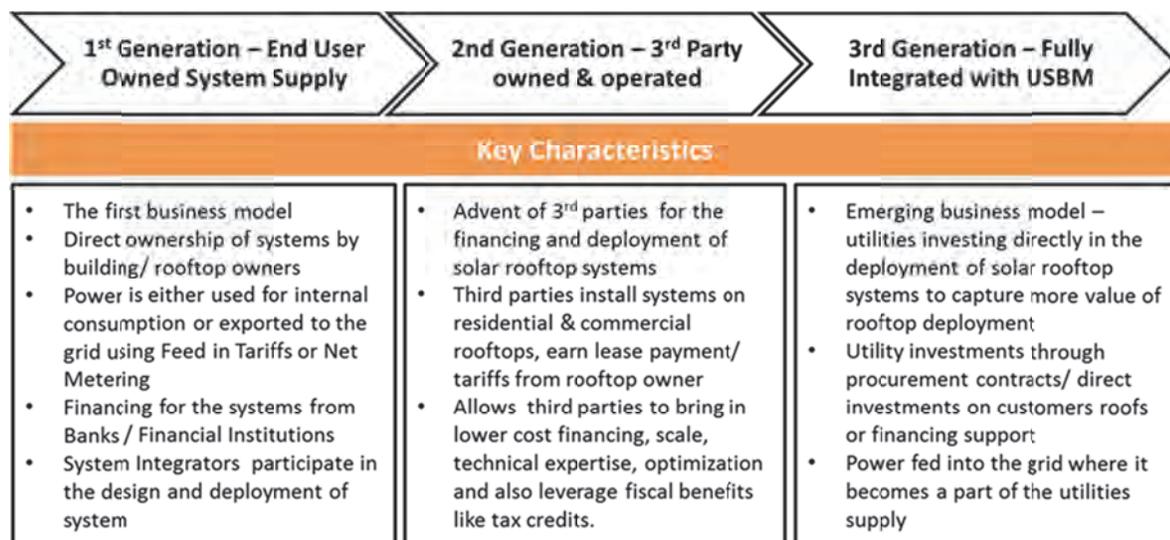


Figure 2-1: Evolution of Rooftop and Decentralized Solar PV Business Models (Source: IFC – Harnessing the Sun)

The first generation model is the most commonly found model globally. It was also the default model for the launch and scale-up of the German and Japanese solar programmes. The ownership of the systems under this generation lay with the rooftop owners or the end-users.

The second generation model evolved based on packaging a large number of smaller solar rooftop projects by a single project developer, known as a 'third party'. As this third party makes the investments, the consumer can avoid the burden of high upfront capital cost, and still benefit from the rooftop PV system by procuring that power and/or even leasing the rooftop system.

At present, the first two generation models dominate the market but a small shift can be seen in the way utilities are entering this market. As the utility is already in the business of supplying power and has been witnessing solar developers (consumers or third parties) take their share of the market, there is a perfectly justifiable case for utilities themselves to own the rooftop PV systems and supply the generated power.

### 2.3. Types of Solar Rooftop Business Models

#### 1. Self-Owned Business Models

Self-owned business models, as the name suggests, promote investment in solar rooftop systems by the consumers to either generate electricity for self-consumption or for export to the grid. For most of the self-owned business models, the rooftop owner invests the equity component of the rooftop system while the debt component is usually financed through a FI such as a commercial bank. Self-owned business models for grid-connected solar PV rooftop deployment have developed through the following three routes:

##### a. Captive (off-grid)

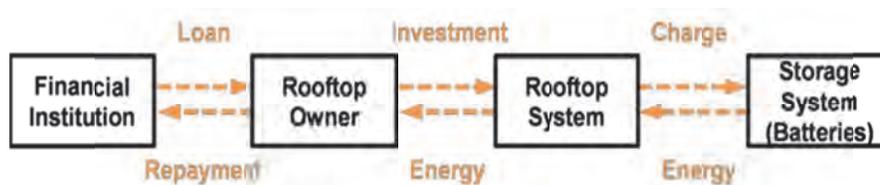


Figure 2-2: Captive (Off-Grid) Business Model

- (i) Application: Captive (off-grid) business models are prevalent in places where the grid is either absent or has very poor reliability. These rooftop systems have a huge application in rural, remote, isolated and semi-urban areas which have no or limited access to power. The consumer sets up the solar rooftop system with the intention of utilising all the power generated by the system onsite as shown in Figure 2-2.
- (ii) Advantages: Stand-alone captive rooftop systems are usually developed and deployed in energy deficient areas. These areas either lack clean and efficient lighting sources or

use alternate supply options such as diesel which are very expensive. These stand-alone captive solar rooftop systems, coupled with appropriate storage options, provide a more reliable and cheaper option.

- (iii) Disadvantages: Stand-alone captive rooftop systems need storage options coupled with them to service fluctuating demand requirements. The addition of storage options increases the cost of the energy to the user. Standalone captive systems have to be designed with a certain amount of redundancy in mind and this means that the sizing of the system always needs to be higher than what is optimally required, which in turn pushes up the cost of energy.

## b. Gross Feed

The gross feed model consists of grid-connected solar rooftop systems which feed all the energy generated to the grid. In lieu of the energy fed to the grid, they are paid feed-in-tariff (FiT). The FiT is approved by the regulator, and the owner/consumer enters into a long term power purchase agreement (PPA) with the utility. The FiT provides a minimum rate of return on the investment to the investor as shown in Figure 2-3.

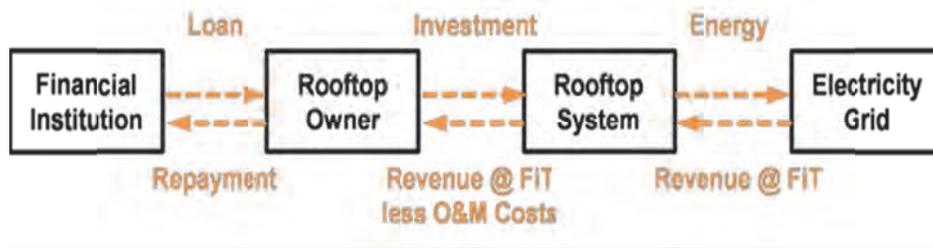


Figure 2-3: Gross Feed Business Model

- (i) Application: The key markets to adopt gross FiTs for solar rooftop systems have been Germany, Italy, France, other European Union nations, Japan and the Gandhinagar Solar Rooftop Pilot project in India.
- (ii) Advantages:
- These systems do not need to be coupled with stand-alone storage devices which bring down the cost.
  - This model allows entry of a number of new investors (consumers), resulting in the enhancement of the investment base.
  - Gross metering safeguards the utilities against migration of high paying consumers out of the utility ecosystem and the long-term viability of the grid.
  - The cost of solar is added to the Annual Revenue Requirements (ARR) of the utility and socialised across all consumer groups.
  - This model allows all consumer categories, regardless of their consumer tariffs, to participate in the solar rooftop programme and develop optimally-sized solar rooftop installations and earn a minimum rate of return on the investment made by them.

- (iii) Disadvantages: The FiT is usually higher than the average power purchase cost, and, creates an apparent short term cash flow burden on the utility's balance sheet. The higher cost of procurement also leads to increases in consumer tariffs.

### c. Net Metering

Under the net metered business model, solar energy is first consumed by the consumer for meeting the internal/captive requirement and the rest (surplus) is exported to the grid, where it is banked with the utility, and subsequently when the consumer imports power from the grid, the banked energy is adjusted against imports from the grid, leading to a lower bill for the consumer for grid based electricity services. It is amongst the most popular business model followed in the United States (U.S.).

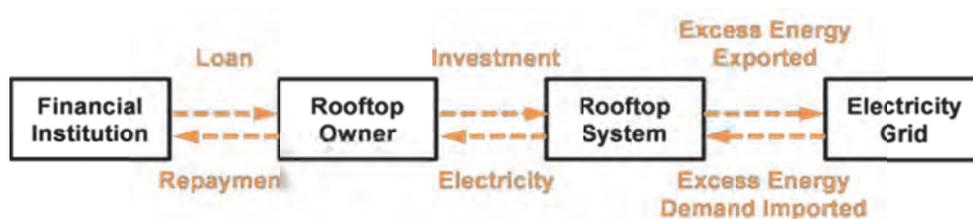


Figure 2-4: Net Metering Business Model.

- (i) Application: Net metering mechanism and the associated business models become attractive only when the consumer tariffs are higher than the cost of solar generation. In case tariffs are lower than the cost of generation, then installations do not take place or have to be incentivised through fiscal incentives as shown in Figure 2-4.
- (ii) Revenue Stream and Benefits: There are two revenue streams in this model. The first is the savings due to the avoided cost of power purchase from the grid, and the second is the sale of surplus power generated (at a rate determined by the regulator) over and above the consumer's own consumption within a settlement period.
- (iii) Advantages:
- It does not depend on FiT (which is usually higher than the average power purchase cost for the utility), and leads to limited outflow of funds from the utility.
  - It allows only those consumers to install solar rooftop who can afford to pay for solar and discourages socialisation of higher solar tariffs, thus bringing down the impact of high solar costs across the whole cross-section of consumers.
- (iv) Disadvantages:
- The net metering concept works only for consumers with high grid tariffs. It has a severe limitation in a market such as India where the cost of power for a large majority of the consumers is below the cost of solar power such as domestic or institutional consumers.

- It reduces the net quantum of power sold by utilities to consumers, especially for high tariff paying consumers.
- It leads to underutilisation of rooftop spaces as most utilities and regulators aim to regulate the size of the systems in such a way that the generation of the system is lower than the annual energy demand of the rooftop owner's energy requirements.

## 2. Third Party-Owned Business Models

Under the third party-owned model, a third party (separate from the consumer [rooftop owner] and the utility) is the owner of the rooftop systems. This third party may lease the rooftop from the rooftop owner and then generate power which may be sold to the utility or to the rooftop owner through a PPA or the third party may lease the system to the rooftop owner who may utilize power from the system.

### Case Study of Solar Leasing: Solar City

Solar City is one of the largest solar lease companies operating in the U.S. Solar City provides residential solar leases, which are financed by FIs and equity investors who claim the income tax credit and depreciation benefits. Solar City offers its customers a variety of lease structures including zero down-payment options. The lease payments cover the cost of the system and the cost of monitoring, maintenance, and repair, including inverter replacement, if necessary. Solar City also guarantees a minimum level of electricity output from the rooftop PV system.

Third party-owned models are emerging as a significant market force in the solar rooftop segment due to certain inherent capabilities that they bring to the business like access to low cost financing; greater ability to take on, understand and mitigate technical risks; aggregate projects and bring in economics of scale; effectively avail tax benefits; and the ability to make use of all Government incentives. Third party-owned rooftop systems have been developed through the following two main routes:

### a. Solar Leasing/Leasing of Solar Systems

- (i) **Design:** Solar leases were initially introduced in the U.S. market for financing residential PV systems where rooftop owners leased solar PV rooftop systems from large profit making investors. The lease agreement stipulates that the rooftop owner would make a monthly lease payment to the lessor over a specified period of time while enjoying the benefit of the electricity generated from the system and benefit from lower utility bills.
- (ii) **Ownership:** The ownership of the solar rooftop systems lie with the lessor. After a fixed period of time and at the end of the lease period, the rooftop owner has the option to (a) purchase the PV system, (b) extend the lease agreement, or (c) remove the system from the roof.
- (iii) **Revenue Streams and Benefits:** The third party investor earns steady cash flows in the form of lease rental payments while also benefiting from tax credits and depreciation benefits available to investors of solar rooftop equipment. The tax benefits help shore up

project internal rate of return (IRR) which in turn brings down the cost of leasing the systems to home owners.

(iv) Advantages:

- The rooftop owner is not required to make an upfront investment in solar rooftop systems but still benefits from use of these systems.
- The use of tax benefits makes these systems cheaper to the rooftop owner.

(v) Disadvantages:

- Leasing of capital equipment attracts a service tax, which makes leasing uncompetitive over the life of the project.
- There may be no relation between the lease rental paid by the consumer to the lessor and the quantum of energy generated from the systems, which could lead to low quality/performing installations.

**b. Solar Power Purchase Agreements**

The third party developer invests in solar rooftop asset, and the electricity is sold either to the building owner (also the utility consumer) or fed into the grid. Third party development models have the wherewithal to aggregate rooftops, structure large projects which bring economies of scale and also take maximum leverage of Government incentives, driving down the cost of solar power.

**Application and Revenue Arrangements:**

A number of commercial arrangements have come into the market where third party developers sell the power to either to the rooftop owner or to the grid through a PPA. Some of these arrangements have been highlighted below:

(i) Individual Rooftops With Third Party-Owned Systems With Grid Feed:

- **Gross Metering With Third Party Ownership of Systems:** Under the gross metering arrangement, the third party developer leases a rooftop and pays a rooftop lease/rental for the rooftop space. The developer exports the solar energy generated from the

**Case Study: 5 MW Gandhinagar Solar Rooftop Programme**

The 5 MW Gandhinagar Solar Rooftop Programme is a successful example of combined rooftop leased by a third-party with grid feed model via gross metering. This is among the first programmes to implement solar rooftop at a megawatt-scale in India, and that too as a PPP.

Here, two solar project developers, Azure Power and SunEdison, were selected through a tariff-based reverse bidding, and given a quota to install an aggregate of 2.5 MW of solar PV rooftop systems each. The two developers signed a PPA with Torrent Power Limited, the local distribution utility of Gandhinagar. Power generated by each solar rooftop system is fed into and accounted for using a dedicated feed-in meter. Rooftop lease agreements between the project developer and the rooftop owner (private residential or government), were designed.

rooftop installation to the utility at a predetermined FiT set by the regulator. The key challenge in this model lies in the availability of the rooftop for 25 years.

- **Net Metering With Third Party Ownership of Systems:** Under this arrangement, the rooftop owner signs a PPA with the third party developer (who is given the rooftop for the installation) and enters into a back to back net metering arrangement with the utility. The rooftop owner buys electricity generated by the third party developer at a fixed price under a long term PPA. This model is quite prevalent in the U.S.; especially with large energy consumers like retail chains or warehouses and logistics companies. This model has become quite successful in markets which have a high cost of electricity and time of day (ToD) tariffs.
- (ii) **Combined Rooftop Leased by Third Party with Grid Feed (Gross Metering):** Under this model, a project developer identifies and leases (through a lease agreement) a number of rooftops in an area and develops these together in the form of a single project. The project developer invests in the equipment, sets up the project and sells the energy generated to the utility. This model was followed for the pilot demonstration solar rooftop project under the Gandhinagar Solar Rooftop Program, where all the energy generated by the systems is being fed into the grid and the rooftop owners are entitled to a generation-based lease rental.

### 3. Utility-Based Business Models

Utility involvement in the solar rooftop market was initially limited to being a facilitator through a broad framework for interconnection. However, a growing number of investor-owned utilities have recently taken up a more pro-active stance in encouraging the development of solar rooftop projects due to 1) reduction in price of distributed clean energy technologies such as

Utility Ownership	Utility Financing	Customer Programs	Energy Purchases
<b>Southern California Edison</b> (250 MW on Customer Sites)	<b>APS</b> (special financing/refinancing to solar customers)	<b>Ellensburg Municipal (WA):</b> 136 kW available with customers for net metering	<b>We Energies</b> (Offered a feed-in tariff for 10 years contract)
<b>Western Massachusetts Electric Company</b> (6 MW on public and private high visibility sites)	<b>PSE&amp;G</b> (Lend capital to end-users & solar developers for 40%-50% of project cost)	<b>Sacramento Municipal (CA):</b> 1 MW - customers purchase share	
<b>Florida Power and Light</b> (110 MW on Customer Sites)		<b>Arizona Public Service (AZ):</b> Utility owned, customer sited, host customers receive fixed price contract, 2 MW	

*Figure 2-5: Utility-Based Business Model*

solar PV; 2) advent of a number of investors and developers who can implement systems which partially or wholly replace the grid; 3) maturing technology and easy financing options that allow

consumers to partially switch to these technologies; and 4) proactive policy and regulatory frameworks that allow these decentralised distributed technologies to come into play in the market.

Keeping in mind the impact of disruptive technologies such solar PV rooftop, the utilities have also started working towards active participation in these emerging segments through the use of new and innovative utility-based solar PV rooftop business models which aim to capture value of in these markets. The utilities involvement in the solar PV rooftop business model space has been limited to four broad areas which have been highlighted in Figure 2-5 with relevant examples.

#### **Case Study of Net Metering: SunEdison**

A well-known example for net metering on individual rooftops with third party-owned systems with grid feed is the SunEdison LLC's agreement to supply power to Walmart Stores using the latter's rooftops at several locations. These PPAs were sold to investors who then became the owners of the installation and could claim tax credits and rebates on the investments.

### **a. Utility Ownership**

Utilities are becoming more and more aggressive in owning rooftop systems as it allows them to claim tax credits, earn a healthy rate of return on the power generated from these installations while also ensuring that consumers with rooftops do not transit out of the utility's ecosystem.

#### **Case Study of Utility Financing: Powder River Energy Corporation**

On bill financing was offered by Powder River Energy Corporation, Wyoming to its residential customers - they could take loans up to USD 2,500 at a 0 percent rate of interest for up to 36 months. The Public Service Electric and Gas Company (PSE&G) of New Jersey also offers utility-based loans at 6.5 percent for up to 10 years and covers around 40 to 60 percent of the system cost.

A number of utilities ranging from San Diego Gas and Electric (SDG&E), Southern California Edison to Western Massachusetts Electric Company are aggressively developing rooftop installations on customer sites. The overriding reason behind the success of this model is the regulated rate of return that is available for these utilities for the capital investment in rooftop installations.

### **b. Utility Financing**

Another route in which utilities are encouraging the deployment of solar rooftop installations is by financing consumers. Utility and public financing programs have been launched by a number of utilities and local Governments across the U.S. to facilitate adoption of solar PV with two broad aims: (a) covering rooftop owners who do not have access to traditional financing options (self/third party), and (b) enhancing affordability of systems by reducing interest rates and upfront fees and relaxing lending guidelines. Two types of loans are typically available through utility-based financing:

- (i) **Utility Loans:** These are loans which are targeted at utility customers and administered by the utility at the local, municipal or the State level. These programmes are structured so as to be either cash-flow positive or neutral, in order to make electricity savings equal to or greater than the cost of the loan. Utility loans are either linked to the consumer (bill financing) or linked to the property (meter secured financing).
- (ii) **Revolving Loans:** Revolving loans finance rooftop owners directly through public sources such as public benefit funds, environmental non-compliance penalties, bond sales or tax revenues. Rooftop owners prefer these as they come at low interest rates, and have relaxed lending guidelines and extended tenors. The Montana Alternative Energy Revolving Loan Program is one such example.

### c. Community-Shared or Customer Programmes

Community-shared solar programmes provide energy consumers the option of utilizing the benefits of solar generation (through proportional benefits via virtual net metering) without actually installing on-site solar PV or making high upfront payments required for such projects.

#### Examples of Community-Shared Programmes Offered in the U.S.

**1. Tucson Electric Power’s (TEP) Bright Tucson Community Solar Program:** TEP, an investor-owned utility operating in Arizona, U.S., launched a third party-developed community-based solar programme for developing 1.6 MW of new solar capacity in three years. This programme allowed consumers to buy generating blocks of 150 kWh per month for a monthly fixed fee of USD 3 per month. The investments for the solar installations were made by a third party developer.

These plants are usually set up by community-owned utilities or third parties in partnership with investor-owned utilities.

The community-shared programme allows utilities to develop larger programmes and projects while providing expanded options to more customers at lower costs. The broad outline of a community-shared solar project model is highlighted in Figure 2-6.

The community members who sign up for these

#### 2. Colorado Springs Utility’s Community Solar Gardens Program:

In 2010, the Colorado Spring Utility offered its customers the chance to invest in community solar gardens. Under this scheme, the customers could lease panels from one of two community solar project developers, Sunshare or Clean Energy Collective, with a minimum solar garden interest of 0.4 kW. All customers who subscribed to the programme received a fixed credit of USD 0.09/kWh on their electric bill for their share of the power generated by the panels they had leased. The pilot run by the programme was for 2 MW of installations.

#### Case Study of Customer-Sited PV: San Diego Gas and Electric

SDG&E encourages development of solar rooftop installations owned by it and installed on leased rooftops of customers. The rooftops are leased by SDG&E, generally for 10 years, with a possibility of two five-year extensions. The rooftop systems are connected using a gross metering format.

projects receive solar benefits without paying upfront capital cost, installation cost or worry about the O&M.

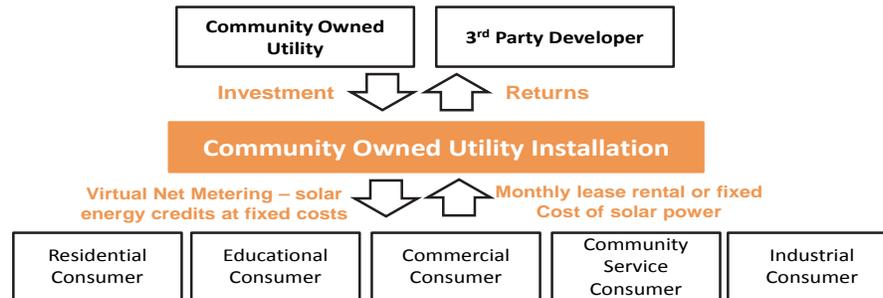


Figure 2-6: Community-Shared Utility-Based Business Model

#### d. Energy Purchases

A number of utilities are also entering the market with the objective of procuring energy directly from third party or rooftop owners by offering FiTs which allow utilities to buy all the energy generated by the rooftop at a flat price under a long term PPA, the cost of which is passed onto the consumers as part of its ARR, while at the same time retaining the customers on whose rooftops these systems have been set up.

#### 2.4. Key Challenges and Considerations

While the Indian solar PV rooftop market provides a number of opportunities for a host of developers/investors, the design and implementation of business models in India still remains a challenge, especially for third party developers who want to bring in greater scale and efficiency into the rooftop development market.

Solar rooftop projects suffer from a number of commercial, policy and regulatory, technical and financing challenges which need to be addressed as the market grows through a concerted effort from policy makers, regulators, financiers and above all the utilities. Some of these challenges have been highlighted below:

##### Two Examples of Energy Purchase by Utilities

**1. We Energies Feed-In Rate:** We Energies, a utility serving in Wisconsin and Michigan's Upper Peninsula, offers a FiT similar to the solar FiTs offered by European markets like Germany. The FiT offered by the utility is USD 0.225/kWh for 100 percent of the solar power generated, with the customer getting a credit on its bill or a check.

**2. Gainesville Regional Utilities' (GRU) FIT:** GRU, a municipal Utility in Florida, offers a FiT as an alternative to the rebate programme which allows it to retain utility customers, spread rebates over longer periods, and have a performance-based contract.

- a. **Contract Sanctity:** For long-term sustainability and investor confidence in the market, the contracts need to be easily enforceable, provide remedies for payment defaults, and buy out clauses/appropriate compensation framework in case of building redevelopment or relocation of projects.

- b. Availability of Financing and Capacity of FIs to Evaluate Rooftop Projects: Banks and FIs are still in the process of putting in place consumer financing products (loans) and guidelines which allow access to debt for rooftop owners. In case of third party developers, especially in the commercial and industrial space, banks and FIs still lack appropriate tools and expertise to evaluate these projects especially from a long-term risk perspective. As new business models come into the market, banks and FIs will also have to increase their capacity to analyse and finance these models.
- c. Solar Equipment Leasing: One of the key fiscal incentives used to bring down the cost of solar in markets like the U.S. is depreciation or accelerated depreciation (AD) in the case of India. This benefit is not available to new special purpose vehicles (SPVs), but can be utilised through investors who can buy the equipment and then the same equipment to developers. The key challenge here is that service tax is levied on the leased equipment which erodes most of the benefits that investors may have attained from AD.
- d. Rooftop Leasing: Access to rooftops for the life of the solar rooftop project remains another key challenge due to issues such as reconstruction of the building or expiry of the lease of tenets. Most private sector companies lease buildings (along with rooftops) for up to 10 years. Developing rooftop projects on buildings with leases up to 10 year becomes risky in case the next tenet or the building owner does not agree to extend either the lease or the PPA. Risk to rooftop projects also comes in when rooftop owners might want to construct more floors or reconstruct the whole building before the lease/PPA runs its natural life. Cases like these have come to light in New Delhi where institutions are not ready for solar rooftop despite a very competitive tariff and adequate space.
- e. Role of Utilities – Challenges and Facilitation Required: One of the biggest challenges faced by the solar rooftop sector is the limited capacity of the utilities in implementing solar PV rooftop projects. Interconnection processes are slowly being specified, and in some cases are long and cumbersome often allowing only a few contractors/developers to participate. There is a need to streamline the interconnection process, making it time bound and transparent with a focus on achieving the required performance standards and quality standards. One example is of the Bangalore Electric Supply Company Limited (BESCOM), which, using an open sourcing framework, specified the need to only adhere to national and international standards while deploying systems and interconnecting them to the grid.
- f. Match between Incentive Mechanisms and Needs of the Market: The policy makers and regulators have chosen the net metering framework for promoting solar PV rooftop development in India. While this framework has a number of advantages, it also suffers from the basic challenge of not allowing all consumer categories to develop solar rooftop projects. There is a need to evaluate a regulatory framework which targets rooftop utilization and penetration of solar rooftop systems on a large number of consumers such as schools, hospitals, and storage facilities, etc. which have huge rooftop space but do not have the financial justification for adopting net metered solar rooftop business models.

**In conclusion, this chapter describes various business models that can be implemented to boost and sustain the solar rooftop market. Several challenges related to these business models are also discussed. These challenges can be overcome with robust policy, regulatory and technical frameworks which are addressed in subsequent chapters of this Guide.**

### 3. Policy and Regulation

#### 3.1. Purpose and Introduction to Policy

The purpose of a policy is to make the intention of the Government known to the public and establish a framework of guiding rules for any given economic activity. Policy serves two key purposes:

1. Give clarity to various departments within the Government on the action plan and direction of the Government.
2. Give clarity to the general public, investors, developers and other public and private stakeholders on the intention of the Government in a particular field.

Framing a good policy is essential for any sector that is still dependent on Government subsidies and frameworks in order to become economically viable. A solar rooftop policy should ideally consider and address the following clauses:

##### a. Vision of the Government

The vision of the Government indicates the goals and aspirations of the Government for its people. A vision also helps align various departments within the Government and between the Centre and the State Government during times of differences.

##### b. Objectives/Goals/Targets

All goals should be measurable and time bound. Setting concrete goals helps the Government measure progress; and take corrective action in case the various departments are not on course to meet the targets. Goals are typically measured in GW or MW over a definite period of time.

The targets should be in line with the solar rooftop targets announced by the MNRE through its Notification No. 03/13/2015-16/GCRT dated June 30, 2015. The targets specified by the MNRE may be escalated slowly over time, reflecting three important facts:

- Falling Costs of PV: As PV prices fall over the target period, affordability of these systems increases, thereby increasing the uptake of these systems.
- Increasing Power Tariffs: Most consumers opt for solar PV rooftop systems as an effective way to hedge escalating power prices. As power prices increase steadily over time, many more consumers will begin to augment their current grid consumption with solar PV rooftop.
- Maturity in Ecosystems: As time progresses and various stakeholders in the solar PV rooftop value chain begin to get familiar with the technology and its risks, the ease of transactions and marginal risk costs begin to decrease. A good example of this is in the banking ecosystem. As banks familiarize themselves with lending to solar PV rooftop

systems from home and business owners, the costs of financing and timelines will reduce.

Another key determinant in setting goals for solar rooftop installation in the policy is the amount of subsidy available. Currently, there is a 30 percent capital subsidy from the MNRE for solar rooftop systems on homes, educational institutions, hospitals, etc. States might choose to provide an additional subsidy if required, especially for marginal groups and economically weaker sections of society. In such cases, the availability of funds earmarked in the State budget should be in line with the target for each year. This will ensure that the entire planned goals are met without compromising the subsidy.

It is however important to note that subsidies must be reduced gradually over time and this fact must be explicitly stated in the policy. The risk to State and Central Governments is that people may get used to the subsidy and demand entitlements.

### **c. Operative Period**

The operative period is the tenure of the policy. Most policies are extant for a period of three to five years. The following considerations must be kept in mind while determining the tenure of the policy:

- Changing Governments, and subsequent drastic changes in policy, are not good for the business environment as a whole. Governments must ensure that electoral transitions coincide with defined end-dates to policies.
- Drastically falling prices of solar PV have ensured that most of the earlier plans and policy direction have turned void. This has necessitated a revision in the policy and corresponding schemes under the policy. Such revisions take time since various departments and stakeholders within the Government have to be consulted. They also generally result in a dip in installation and can derail the roadmap to the target. It is, therefore, suggested to have policy tenures that are short enough to quickly adapt to the fast changing market.
- Policy tenure should be in line with the Government's national solar goal of 40 GW by 2022. In such a scenario, it might not be prudent for the State Government to set a policy end date as 2021.

### **d. Nodal Agency**

A nodal agency is the Government department that is responsible for the promotion of the policy. Clear demarcation of responsibility and a single point of contact for potential investors/consumers go a long way in improving the overall investment climate of the State.

Most States strive to adopt a single window clearance that helps investors obtain all clearances at a single office. This must be implemented in true spirit and a dedicated team

may be constituted for the rapid approvals and addressing of investor's grievances. The State energy development agency/authority is best suited for such a role.

#### **e. Implementing Agency**

While the nodal agency will be responsible for promotion of the policy and passing on benefits (e.g., subsidies) to stakeholders, it is the implementing agency that is responsible for implementing the solar rooftop programme.

As grid-connected solar rooftop plants have an implication on utility billing, grid safety and power quality, the DISCOM becomes the *de facto* implementing agency. While on the other hand, the SNA can become the implementing agency for stand-alone solar projects.

#### **f. Eligible Entities**

Eligible entities are usually the different categories of electricity consumers mentioned in the SERC orders. State Governments may decide to allow all the applicable schemes in the policy to all types of consumers or may choose to limit the schemes to certain consumers due to the financial implication on the State or one of its DISCOMs. A good example of this is incentives such as banking or net metering schemes. Such incentives may be restricted or reduced to commercial and industrial consumers while placing no restrictions for residential consumers.

It is recommended that such restrictions may not be placed during the initial phases of the policy. This is important to project that the Government is promoting solar PV rooftop. Financial implications may be considered while setting the targets of the policy. In case, the Government has financial constraints, then the target may correspondingly be reduced to a number that is comfortable to various stakeholders.

Another important aspect to this clause is the definition of 'eligible entity.' Various business models are in vogue due to the evolving solar PV rooftop financing ecosystem. An eligible entity may be an owner of the building, a tenant or even a third party investor.

#### **g. Schemes/Applicable Business Models**

A solar rooftop policy is implemented through various schemes. Schemes provide the necessary implementing framework for the policy and may change from time to time within the tenure of the policy. They may also include specific subsidies and incentives that are also time-bound, and may be applicable to a certain eligible entities and types of systems (e.g., off-grid versus on-grid).

Business models are critical from an investor/company's point of view in order to ensure return on their business. Revenue for these investors can come in different forms; for example, through a PPA with the rooftop owner/DISCOM/open access consumer or through

direct sale of equipment and engineering services (e.g., an engineering, procurement and construction (EPC) company). A good policy should take into account all these factors and promote various possibilities where investors may get involved. This will result in a vibrant and dynamic market.

The State shall encourage both net metering and gross metering systems. Net metering systems are primarily aimed at providing an opportunity to consumers to offset their electricity bills. Gross metering systems are aimed at third party investors who will like to sell energy to the DISCOMs by using roofs owned by another party.

Various incentives and exemptions applicable to a solar PV rooftop programme are summarized in Table 3-1.

**Table 3-1: Reference Incentives and Exemptions Applicable to a Solar PV Rooftop Policy**

Type of Incentive/ Exemption/ Parameter	Sale to Distribution Licensee		Sale to Third Party
	Net Metering	Gross Metering	Open Access
<b>PV System Capacity</b>	Limited to consumer's contract demand/sanctioned load.	Limited by the available rooftop area (or related to associated distribution transformer capacity) or as per the relevant terms of RFP, if applicable.	Based on mutual agreement between developer and off-taker.
<b>Ownership</b>	Self-owned.	Self-owned or third-party owned.	Third-party owned.
<b>Demand Cut</b>	50 percent of the consumer's current billing demand.	Not applicable	50 percent of the consumer's current billing demand.
<b>Billing Cycle</b>	As per consumer's current billing cycle.	Monthly	Solar energy to be adjusted on a 15 minute-basis.
<b>Banking</b>	Excess energy allowed to be banked during a financial year, at the end of which excess generation will be paid at an appropriate tariff determined by concerned SERC.	Not applicable as complete energy is sold to the distribution licensee at the tariff determined by concerned SERC.	No banking allowed for third party sale of power. Any excess, unadjusted energy shall be purchased by the distribution licensee at the tariff determined by concerned SERC.
<b>Tariff</b>	As determined by SERC from time to time.	As determined by SERC from time to time or based on competitive bidding using SERC's tariff as benchmark.	Mutually agreed between developer and consumer.

*(Continued on next page ...)*

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Type of Incentive/ Exemption/ Parameter	Sale to Distribution Licensee		Sale to Third Party
	Net Metering	Gross Metering	Open Access
<b>Wheeling Charges</b>	Not applicable	Not applicable	As per concerned SERC order
<b>Transmission Charges</b>	Not applicable	Not applicable	As per concerned SERC order
<b>Wheeling Losses</b>	Not applicable	Not applicable	As per concerned SERC order
<b>Transmission Losses</b>	Not applicable	Not applicable	As per concerned SERC order
<b>Cross Subsidy Surcharge (CSS)</b>	Not applicable	Not applicable	Exempted as a promotional measure
<b>Electricity Duty</b>	Not applicable	Exempted	Exempted
<b>Renewable Energy Certificate (REC)</b>	Consumer can claim REC for solar energy consumed by self and energy sold to distribution licensee at Average Power Procurement Cost (APPC). (In addition, the developer shall abide by all other provision as per the relevant REC regulations.)	Developer can claim REC if selling power to Distribution Licensee at APPC. (In addition, the developer shall abide by all other provision as per the relevant REC regulations.)	Developer can claim REC based on the provisions of relevant REC regulations.
<b>Renewable Purchase Obligation (RPO)</b>	Distribution licensee can claim RPO if (i) consumed solar energy is not credited towards the consumer's RPO and (ii) no REC is claimed for the generated solar energy.	Distribution Licensee can claim RPO if no REC is claimed for the generated solar energy.	Distribution Licensee can claim RPO if (i) consumed solar energy is not credited towards the consumer's RPO and (ii) no REC is claimed for the generated solar energy.
<b>Clean Development Mechanism (CDM)</b>	CDM is retained by the consumer.	CDM is retained by the developer.	CDM sharing is left to the developer and off taker.

## **h. Procedures**

Procedures and processes are not mandatory in a solar rooftop policy; however, if incorporated, they provide clarity to both companies/investors and to the Government departments themselves.

It is important that the procedures are framed by respective DISCOMs and publicized upon notification of the policy. Model procedures are indicated in Chapter 5 of the Guide.

## **i. Technical Requirements**

Technical requirements such as metering and issues concerning grid integration are covered by the Central Electricity Authority (CEA) standards. There are three specific regulations that are applicable to solar PV rooftop systems:

- The CEA “Technical Standards for Connectivity of the Distributed Generation Resources” Standards 2013
- The CEA “Measures Relating to Safety and Electricity Supply” Standards 2010
- The CEA “Installation and Operation of Meters” 2010

## **3.2. Purpose and Introduction to Regulation Regulations to Promote Solar Rooftop and Key Considerations**

The role of solar PV rooftop regulation is mainly three fold:

1. Determine benchmark capital costs and tariff for solar rooftop grid-connected systems.
2. Specify the grid code; ensure standards with respect to power quality and other electrical parameters that ensure that the functioning of the grid is not compromised.
3. Ensure the proper interpretation of the Electricity Act, 2003 and resolve any disputes between power producers, DISCOMs and consumers.

Regulations for solar rooftop systems are only applicable in case of grid-connected systems. The regulations may be either net/gross metering. The Electricity Act, 2003 provides the legal framework for setting up both the Central and the SERCs in the country.

The Central and State regulators are guided by the National Tariff Plan, National Electricity Policy and Tariff Policy (Section 79, 86). In case of any conflicts between the policy and the regulations, the Electricity Act, 2003 (Section 107 and 108) clearly states that the decision of the Central/State Government shall be final.

Any net/gross metering regulation should ideally consider the following clauses:

**a. Title, Scope and Application**

The regulation should clearly indicate the eligible consumer to whom and under what instances do the regulations apply. This clause is important to enable third party sale of power via solar rooftop systems. This term is also used in the State/Central solar rooftop policy. The key difference here is that the regulator assesses eligibility on a technical basis such as grid voltages, grid availability, etc. whereas the State/Central Government assesses eligibility on other financial and social criteria as well.

**b. Applicable Models**

All models for grid connectivity such as net metering, gross metering and other models such as Renewable Energy Certificate (REC) and ownership models can be addressed here. Although, there is significant overlap with the solar rooftop policy, it is good for the SERC and the State Government to be in line with each other on this topic.

**c. Capacity Limits and Interconnection Voltages**

Capacity limits specify the system size in kW (or MW) that can be connected to the grid at appropriate voltages. These are typically in line with the State grid/supply code. Example of capacity limits for different voltage sources are indicated in Section 4.1(c) of the Guide.

**d. Procedure and Process**

Regulations do not need to contain a detailed process flow pertaining to application and approval process. This is typically in the purview of the implementing DISCOM, and the same should be duly indicated in the regulation. In addition, the regulation can also specify time limits for specific steps of the process to ensure timely and efficient implementation by DISCOMs and avoid grievances from consumers. Procedures are discussed in detail in Chapter 5 of the Guide.

**e. Grid Connectivity, Standards and Safety**

The regulation must refer to the CEA “Technical Standards for Connectivity of the Distributed Generation Resources” Standards 2013 and the CEA “Measures Relating to Safety and Electricity Supply” Standards 2010. Safe solar PV penetration levels must be mentioned on a distribution transformer-basis.

**f. Metering**

The regulations must point to the CEA “Installation and Operation of Meters” 2010. The metering arrangement and jurisdiction (who shall procure and own the meter, etc.) must be clearly laid out in the regulations.

The type of meter should be specified (bi-directional meter, accuracy class, etc.) and the cost of the meter should be apportioned to the relevant stakeholder (consumer or DISCOM). The responsibility for charges for installation and testing of the meter should be also clearly apportioned.

The regulation may also specify different accuracy class of meters depending on the type of consumer (residential, commercial and industrial). The ToD-based meters are also usually specified for industrial consumers. It is recommended to maintain the same accuracy class of the gross/net meter as the consumer's earlier conventional meter.

#### **g. Energy Accounting, Billing and Banking**

Energy accounting, billing and banking that are essential for settlement of excess energy need to be considered. These include:

- Differentiation between residential, industrial, commercial and other types of consumers (if needed).
- Differentiation between open access consumers, captive, self-owned systems and third party-owned systems (if needed).
- What is the settlement period (one month/billing cycle/one year/15 minute)?
- What is the financial incentive in case the consumer is net positive in export of energy generated by the solar system in the specified settlement period?
- What are the charges for banking excess energy on the grid?
- What are the withdrawal charges (in INR/kWh) during peak load times?
- Applicability of open access charges (if needed) for third party-owned rooftop systems.

It must be noted that this section has potential overlap with specification of different business models and the charges under the policy. It is recommended that the policy and regulation are harmonized and that the policy includes all provisions mentioned in the regulations.

#### **h. Renewable Purchase Obligation (RPO), REC and other Green Attributes**

One of the main drivers of any solar programmes, whether on rooftop or on the ground, is the RPO. In addition to the (i) DISCOM, this RPO is also applicable to (ii) consumers with large captive power plants, usually greater than 1 MW, and (iii) open access consumers with large contract demands, usually greater than 1 MW. These 'obligated entities' are defined by the SERC from time to time.

Solar PV rooftop plants directly cater to the RPO. However, many consumers may not be obligated entities, and in this case, the DISCOMs may be encouraged by accounting all the generated solar energy towards the DISCOM's RPO. This concept is also indicated in the earlier policy-related sections of this chapter.

Green attributes include International Carbon Credits and India's National REC Mechanism. The applicability, and more importantly, the ownership of these attributes need to be addressed in a transparent manner. There can be a potential overlap in the jurisdiction of this clause with the State/Central Government policy in which case, the policy holds precedence. It is, therefore, recommended that the Government and the regulator converge to a similar stance on this matter.

**i. Powers to Direct/Relax/Amend**

This clause ensures that the provisions mentioned in the regulations may from time to time be reviewed and modified as it deems fit to the Commission.

**Thus, various key policy and regulatory considerations are discussed in this chapter. These policies and regulations have to be based on the business models that were discussed in Chapter 2, which becomes critical to the success of the solar rooftop programme. It is also important that the policy and regulation supplement each other, and bring out sufficient clarity to the DISCOMs and other stakeholders for implementing the programme.**

## 4. Technical Standards and Specifications

### 4.1. Types of Rooftop PV System

Rooftop PV systems are classified based on the following parameters:

#### a. Connectivity to the Grid:

- (i) Stand-alone PV systems are isolated from the distribution grid, and usually use stand-alone inverters with batteries.
- (ii) Grid-connected PV systems (also known as grid-tied systems) are directly connected to the distribution grid, use grid-connected inverters, and usually do not use batteries. Such systems are capable of exporting surplus power into the distribution grid and are designed to automatically shut down if it detects anomalies in grid parameters such as voltage, frequency, etc.
- (iii) Hybrid PV systems are connected to the grid and also have a battery backup. If a hybrid PV system observes anomalies in grid parameters, they are designed to work in an isolated mode.
- (iv) Other grid-interactive PV systems are also evolving in India wherein PV systems are directly connected with uninterruptible power supply systems. Such systems operate irrespective of grid conditions, but are usually not capable of feeding energy back into the grid.

#### b. Metering Arrangement:

The various metering arrangements are shown in Figure 4-1.

- (i) Net metering wherein a single meter records both import of conventional energy from distribution grid and export of solar energy into distribution grid. Grid-connected, hybrid and other grid-interactive PV systems can be net metered.
- (ii) Gross metering (also known as feed-in metering) wherein all the energy from the system is exported to the grid and is separately recorded through a different 'feed-in meter.' Only grid-connected PV systems can be gross-metered.

**c. Interconnection Voltage:** (i.e., voltage level at which the PV system is connected to the grid) - primarily governed by the regulation of the respective State. In case of direct interconnection with the grid, the following interconnection voltages are applicable:

- (i) For capacity less than 4 kW (or 5/6/7/10 kW in some States) - connected to the distribution grid at 240 V<sub>AC</sub>, 1 $\phi$ , 50 Hz.
- (ii) For capacity more than 4 kW (or 5/6/7/10 kW in some States) but less than 50 kW (or 75/100/112 kW in some States) - connected at 415 V<sub>AC</sub>, 3 $\phi$ , 50 Hz.
- (iii) For capacity more than 50 kW (or 75/100/112 kW in some States) but less than 1 MW (or 2/3/ 4/5 MW in some States) - connected at 11 kV<sub>AC</sub>, 3 $\phi$ , 50 Hz.

**IMPORTANT:** It should be noted that the same voltage ranges might not be applicable to net metering schemes as it is possible that PV plants with larger capacities can be interconnected at points at relatively lower voltages within the consumer's premises. Unnecessary stepping up of voltage and then stepping it down for utilization by the consumer can increase both cost and inefficiency.

## 4.2. Capacity Limitations

A solar PV rooftop system's capacity is typically limited by one or more of the following factors:

### a. Technical Reasons:

- (i) Limited requirement of energy or the lack of shadow-free rooftop area.
- (ii) Non-availability of distribution transformer capacity for evacuation (this can be enhanced through regulatory and/or DISCOM's intervention).
- (iii) Lack of a higher interconnection voltage (this can be enhanced through regulatory and/or DISCOM's intervention).

### b. Limitations Under Regulatory Provisions:

- (i) Capacity of the PV system limited to connected or sanctioned load of consumer.
- (ii) No substantial financial incentive/credit provided to consumer for surplus generation of energy at the end of the billing cycle or settlement period.
- (iii) Capacity of the PV system designed to meet a particular RPO or SPO.

## 4.3. Key Technical Considerations, Standards and Specifications

This section discusses key technical considerations from an administrative stakeholder's perspective, especially for the DISCOM, in terms of safety, quality and performance. DISCOMs should ensure compliance of these factors for PV systems connecting to the distribution grid through appropriate standards and specifications indicated here.

CEA's (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 primarily govern the standards and guidelines for rooftop PV systems in India. These regulations refer to relevant IS issued by the Bureau of Indian Standards (BIS). Further, in case of absence of relevant IS, equivalent international standard should be followed in the following order: (a) International Electro-technical Commission (IEC), (b) British Standard (BS), (c) American National Standard Institute (ANSI), or (d) any other equivalent international standard. In addition, the regulations state that industry best practices for installation, operation and maintenance should also be followed along with the relevant standards.

- IEC 60364, 1<sup>st</sup> Ed. (2002-05), "Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – PV power supply systems," is the

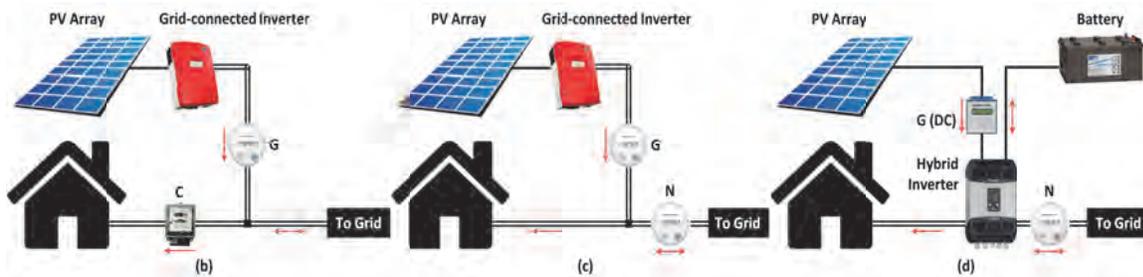
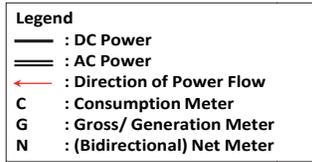


Figure 4-1: Metering Arrangement: (a) Conventional Metering, (b) Gross Metering or Feed-In Metering, (c) Net Metering, and (d) Net Metering Hybrid System

primary standard for PV installations, safety and fault protection, common rules regarding wiring, isolation, earthing, etc. This standard is applicable and commonly followed in India.

### a. Electrical Safety

- (i) General: All PV systems should comply with the CEA's (Measures Relating to Safety and Electricity Supply) Regulations, 2010.
- (ii) Anti-Islanding: All grid-connected and hybrid PV inverters are designed to shut-down when the grid parameters like voltage, frequency, rate of change of frequency, etc. change beyond the predefined range of the inverter.

Table 4-1: Trip Time in Response to Abnormal Voltages as per IEC 61727

Grid Voltage (at Interconnection)		Maximum Trip Time
$V < 50\% \text{ of } V_{\text{Nominal}}$	:	0.1 seconds
$50\% \leq V < 85\%$	:	2.0 seconds
$85\% \leq V \leq 110\%$	:	Continuous
$110\% < V < 135\%$	:	2.0 seconds
$135\% \leq V$	:	0.05 seconds

(Note:  $V_{\text{Nominal}}$  for India is 240 V (1 $\phi$ ) or 415 (3 $\phi$ ) V at LT.)

- IEC 61727, 2<sup>nd</sup> Ed. (2004), "Photovoltaic (PV) systems – Characteristics of the utility interface," is a standard for PV systems rated for 10 kVA or less. Section 5.2.1 indicates maximum trip time in response to grid voltage variation as given in Table 4-1. Section 5.2.2 specifies that the system should cease to energize the grid within 0.2 seconds if the grid frequency deviates beyond  $\pm 1$  Hz of nominal frequency.
- CEA's (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013, in its Section 11 (6) stipulates similar response times for disconnection of the distributed generation system. However, IEC 61727, being more stringent as well as widespread, is acceptable and more convenient to follow in India.

- IEC 62116, 2<sup>nd</sup> Ed. (2014-02), “Utility-interconnected photovoltaic inverters – Test procedure for islanding prevention measures,” provides a test procedure to evaluate the performance of islanding prevention measures for inverters that are connected to the utility grid. Inverters complying with this standard, for capacities both less than and greater than 10 kVA, are considered non-islanding as defined in IEC 61727.

(iii) Earthing (or Grounding):

While earthing practices in India are common and guided by IS: 3043-1987 (Reaffirmed 2006), but as a PV system contains both AC and DC equipment, earthing practices are often not obvious for such systems. Hence, clarification regarding earthing practices become critical from System Designer’s as well as the Electrical Inspector’s perspective.

- IS 3043-1987 (Reaffirmed 2006), “Code of practice for earthing,” governs the earthing practices of a PV system.

Earthing is required for PV module frames, array structures, (power, communication and protective) equipment and enclosures, AC conductors and lightning conductors. Although DC and AC systems are considered separate, they should be connected together during earthing. Earthing of DC cable is not required in most cases.

- IEC 62109-1, 1<sup>st</sup> Ed. (2010-04), “Safety of power converters for use in photovoltaic power systems – Part 1: General requirements,” defines the minimum requirements for the design and manufacture of Power Conversion Equipment (PCE) for protection against electric shock, energy, fire, mechanical and other hazards.
- IEC 62109-2, 1<sup>st</sup> Ed. (2011-06), “Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters,” defines the particular safety

What Is ‘Anti-Islanding?’

One of the foremost concerns among DISCOMs (and even transmission companies) engineers, when connecting a PV system to the grid is ***‘What if the distribution grid shuts down but the PV system remains ‘on’ and keeps on injecting power into the grid? Could this be a hazard to the technician who is unaware of this live PV system and comes in direct physical contact with the grid?’***

Another common question is ***‘If two PV systems are feeding solar power into the grid and if the grid shuts down, can the two inverters create a reference for each other and remain on?’***

**The answer to both these questions is ‘NO.’** The good news is that this problem has been sorted out a long time ago and is successfully being practiced around the world.

**All grid-connected PV inverters are designed to shut down when grid parameter change beyond the predefined range programmed in the inverter (including grid shut-down); thus, avoiding the PV system to act as an energized ‘island.’ This feature is called anti-islanding.**

Anti-islanding is ensured through various IEEE, IEC, UL, DIN VDE, etc. standards for such grid-connected inverters.

requirements relevant to DC to AC inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in PV power systems.

When earthing PV modules, all frames should be connected to one continuous earthing cable. Many installers use small pieces jumper cables to connect frames of consecutive modules, which is a wrong practice. Further, star-type washers should be used when bolting the lugs of earthing cable with the module frame that can scratch the anodization of the module frame to make contact with its aluminium.

The earthing conductor should be rated for 1.56 times the maximum short circuit current of the PV array. The factor 1.56 considers 25 percent as a safety factor and 25 percent as albedo factor to protect from any unaccounted external reflection onto the PV modules increasing its current.

In any case, the cross-section area of the earthing conductor for PV equipment should not be less than 6 mm<sup>2</sup> if copper, 10 mm<sup>2</sup> if aluminium or 70 mm<sup>2</sup> if hot-dipped galvanized iron. For the earthing of lightning arrester, cross-section of the earthing conductor should not be less than 16 mm<sup>2</sup> of copper or 70 mm<sup>2</sup> if hot-dipped galvanized iron.

Resistance between any point of the PV system and earth should not be greater than 5 Ω at any time. All earthing paths should be created using two parallel earth pits to protect the PV system against failure of one earth pit.

- (iv) DC Overcurrent Protection: The PV system is protected from overcurrent from the PV modules with the help of fuses at the string junction box. As PV modules are connected in series in a string, the short-circuit current of the string is equal to the short circuit current of the PV module. Each string should have two fuses, one connected to the positive and the other to the negative terminal of the string. The fuse should be rated at 156 percent of short-circuit current and 1,000 V<sub>DC</sub>; if the exact current rating is not available, the nearest available higher rating should be used.
- (v) DC Surge Protection: Several makes for DC surge arresters or SPD are available specifically for PV applications. The surge arrestors should be of Type 2 (with reference to Standard IEC 61643-1, “Low Voltage Surge Protective Devices”), rated at a continuous operating voltage of at least 125 percent of the open-circuit voltage of the PV string, and a flash current of more than 5 A. As the string inverters used for rooftop PV systems do not allow more than 800 V<sub>DC</sub>, surge arrestors rated for 1,000 V<sub>DC</sub> are commonly used. The surge arrestors should be connected to both positive and negative outgoing terminal of the string junction box (if the inverter already does not have an equivalent in-build DC surge arrester).

(vi) Lightning Protection: Lightning protection installations should follow IS 2309-1989 (Reaffirmed 2010).

- IS 2309-1989 (Reaffirmed 2010), “Code of practice for the protection of buildings and allied structures against lightning” govern all lightning protection-related practices of a PV system.

Large PV systems should have a dedicated lightning protection system including lightning rods, conductor and dedicated earth pits. For this, the existing lightning protection of a building may be used, provided it adequately protects the installation area and is assured of functioning throughout the life of the PV system.

(vii) Ingress Protection: All PV equipment, if installed outdoors, should have an ingress protection rating of at least IP65. This strictly applies to all junction boxes, inverters and connectors. Although many inverters are rated for operation up to a maximum ambient temperature of 60°C, it is highly recommended to make an additional shading arrangement to avoid exposure to direct sunlight and rain.

(viii) Labelling of PV System Equipment: Labelling of PV equipment is a crucial aspect of safety owing to the high DC voltages as well non-familiarity of technicians and laymen with such a system. The labelling of a PV system should conform to IEC 62446 standard.

- IEC 62446, 1<sup>st</sup> Ed. (2009-05), “Grid-connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection,” defines the minimal information and documentation required to be handed over to a customer following the installation of a grid-connected PV system. This standard also describes the minimum commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system.

IEC 62446 stipulates that:

- All circuits, protective devices, switches and terminals are suitably labelled.
- All DC junction boxes carry a warning label indicating active parts inside the boxes are fed from a PV array.
- Main AC isolating switch is clearly labelled, dual supply warning labels are fitted at point of interconnection and a single line wiring diagram is displayed.
- Inverter protection settings, installer details and emergency shutdown procedures are displayed on site.

## **b. Electrical Quality:**

(i) DC Power Injection: Most grid-connected inverters are transformer-less, and hence, utilities are concerned about DC power injection into the grid.

- IEC 61727, 2<sup>nd</sup> Ed. (2004), “Photovoltaic (PV) systems – characteristics of the utility interface,” in Section 4.4 stipulates that the PV system shall not inject DC current greater than 1 percent of the inverter rated output current into the grid.
- CEA’s (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2010, in its Section 11 (2) stipulates that the distributed generating resource shall not inject DC greater than 0.5 percent of the full rated output at the interconnection point.
  - (ii) Harmonic Injection: Most inverters are rated for THD of less than 3 percent of power injected into the grid, and hence, are suitable for interconnection from a harmonic injection standpoint in India.
- CEA’s (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2010, in its Section 11 (1) stipulate that harmonic current injections from a generating station shall not exceed the limits specified in (Standard) IEEE 519.
- IEEE 519 (2014), “Recommended practice and requirements for harmonic control in electric power systems,” stipulates the voltage and current harmonic injection limits as indicated Table 4-2: and Table 4-3, respectively.

(iii) Phase Imbalance (or Unbalance): Phase imbalance can occur due to varied loads and power injected into different phases of the distribution grid. The DISCOM should always limit its voltage imbalance to less than 3 percent. Phase imbalance can potentially arise from single-phase inverters feeding into the distribution grid. It is recommended that DISCOMS should keep track of the PV capacity connected to each phase for troubleshooting any extreme cases.

*Table 4-2: Voltage Distortion Limits as per IEEE 519 (2014)*

Bus Voltage (V) at PCC	Individual Harmonic	Total Harmonic Distortion (THD)
$V \leq 1.0$ kV	5.0 Percent	8.0 Percent
1 kV $< V \leq 69$ kV	3.0 Percent	5.0 Percent
69 kV $< V \leq 161$ kV	1.5 Percent	2.5 Percent
161 kV $< V$	1.0 Percent	1.5 Percent *

*(Notes:*

*PCC: Point of Common Coupling.*

*\*High-voltage systems can have up to 2.0 percent THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.)*

(iv) **Flicker:** IEC 61000 is a set of standards on electromagnetic compatibility, which are subdivided into sections that define:

- o The environment from the EMC viewpoint and establish the compatibility levels that the distributors must guarantee.
- o The emission levels into the networks and immunity levels of the appliances.

*Table 4-3: Current Distortion Limits as per IEEE 519 (2014)*

Maximum Harmonic Current Distortion in Percentage of $I_L$						
Individual Harmonic Order (Odd Harmonic)						
$I_{sc}/I_L$	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1,000	12.0	5.5	5.0	2.0	1.0	15.5
>1,000	15.0	7.0	6.0	2.5	1.4	20.0

*(Notes:*

*Even harmonics are limited to 25 percent of the odd harmonic limits.*

*Total Demand Distortion (TDD) is based on the average maximum demand current at the fundamental frequency, taken at the point of common coupling (PCC).*

*\*All power generation equipment is limited to these values of current distortion regardless of  $I_{sc}/I_L$ .*

The relevant IEC 61000 sections for electromagnetic compatibility including voltage fluctuation and flicker are shown in **Error! Reference source not found.**

*Table 4-4: IEC Standards and Scope for Electromagnetic Compatibility, Including Flicker*

- CEA's (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2010, in its Section 11 (3) stipulate that distributed generating resource shall not introduce flicker beyond the limits specified in IEC 61000.
- IEC 61727, 2<sup>nd</sup> Ed. (2004), "Photovoltaic (PV) systems – characteristics of the utility interface," in Section 4.3

Standard	Subject	Scope
IEC 61000-6-1	Immunity	Residential and Commercial
IEC 61000-6-3	Emission	
IEC 61000-6-2	Immunity	Industrial
IEC 61000-6-4	Emission	
IEC 61000-3-2	Harmonics	Inverter $\leq$ 16 A AC Current per Phase
<b>IEC 61000-3-3</b>	<b>Voltage Fluctuation and Flicker</b>	
IEC 61000-3-12	Harmonics	Inverter $>$ 16 A and $<$ 75 A AC Current per Phase
<b>IEC 61000-3-11</b>	<b>Voltage Fluctuation and Flicker</b>	
IEC 61000-3-4	Harmonics	Inverter $\geq$ 75 A AC Current per Phase
<b>IEC 61000-3-5</b>	<b>Voltage Fluctuation and Flicker</b>	

stipulates that the operation of the PV system should not cause voltage flicker in excess of limits stated in the relevant sections of IEC 61000-3-3 for systems less than 16 A or IEC 61000-3-5 for systems with the current of 16 A and above.

- (v) Power Factor: Grid-connected PV inverters are typically capable of injecting energy into the grid at unity power factor, and hence tend to have a positive impact on the grid.
- IEC 61215, 2<sup>nd</sup> Ed. (2005-04), “Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval,” outlines all the procedures for sampling, marking and testing of mono- and multi-crystalline silicon PV modules. The testing includes visual inspection, maximum power determination, insulation test, measurement of temperature coefficients, etc.
  - IEC 61646, 2<sup>nd</sup> Ed. (2008-05), “Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval,” outlines all the procedures for sampling, marking and testing of thin-film PV modules such as amorphous silicon, cadmium telluride (CdTe), copper indium gallium selenide (CIGS), micromorph and similar technologies.
  - IEC 62108, 1<sup>st</sup> Ed. (2007-12), “Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval,” outlines all the procedures for sampling, marking and testing of concentrator cell technologies and assemblies.

In addition to one of the above-mentioned three IEC certifications, all PV modules should also be certified for IEC 61730 as a part of their safety qualification.

- IEC 61730-1, Ed. 1.2 (2013-03), “Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction,” describes the fundamental construction requirements for PV modules in order to provide safe electrical and mechanical operation during their expected lifetime.
- IEC 61730-2, Ed. 1.1 (2012-11), “Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing,” describes the fundamental construction requirements for PV modules in order to provide safe electrical and mechanical operation during their expected lifetime.

One or both IEC certifications may be applicable if PV modules are intended for continuous outdoor exposure to highly corrosive wet environments.

- (i) Performance Warranty: The performance warranty of a PV module is one of the most critical considerations while procuring the module. The globally accepted performance warranty commits less than 10 percent performance degradation in power output during the first 10 years and less than 20 percent performance

degradation during the subsequent 15 years. Tier-I module manufacturers also back their performance warranty with bank guarantees as an added assurance.

- (ii) Workmanship Warranty: The typical workmanship warranty on a PV module is five years.

**c. Mechanical and Workmanship Considerations:**

- (i) Inclination of PV Modules: The optimal angle of inclination of a flat plate solar collector (which also includes a fixed PV module) is very close to the latitude of the location of installation facing south for India.
  - (ii) Area of a Rooftop PV System: A rooftop PV system can take anywhere from 10 to 15 m<sup>2</sup> of area per kilowatt of installation depending on the angle of inclination of the PV modules.
  - (iii) Weight of the Rooftop PV System: The weight of a PV system (including the PV module and structure) does not exceed 30 kg per m<sup>2</sup>. However, for mounting structures that are not anchored into the roof, the weight of the PV system can be deliberately increased. In any case, all terraces are designed to withstand the weight of PV systems.
  - (iv) Wind Loads: All MMS should be designed taking into consideration the wind loads at the location of installation and should consider the 'wind speed zone' of the location as per Indian Standard IS 875 (Part 3)-1987.
- IS 875 (Part 3)-1987, "Code for practice of design loads (other than earthquake) for buildings and structures," guide the design principles of wind loads to be considered when designing buildings, structures and its components. This standard is directly applicable to the design of PV module mounting structures.

The design document of a module mounting structure is a mandatory component of the overall design of the rooftop PV system and should be developed or approved by a chartered structural engineer. Readymade and modular mounting structures pre-certified for certain wind speeds are readily available in the market, and the same can be directly used.

- (v) Material of Mounting Structure: Galvanized iron (GI) or aluminium is the most common material used for module mounting structures. In case of GI structures, the quality of galvanization becomes very critical to ensure a rust-free life of at least 25 years.
- (vi) Penetration and Puncturing of Roof or Terrace: Penetration into or puncturing the roof or terrace for anchoring of MMS should be avoided as far as possible to avoid any water leakage-related issues.

**d. Other Considerations:**

- (i) Performance of a PV System: The quantum of energy output of a PV system depends on:

- System properties such as its capacity, internal losses, and tracking (if used), maintenance practices and frequency of cleaning.
  - Weather parameters such as incident radiation and temperature as well as ambient factors like fog and pollution.
  - Grid parameters such as fluctuations in voltage and frequency, and availability.
- (ii) Generation Guarantee: The generation guarantee sought by a utility (or in fact, any stakeholder) may depend on the nature of ownership of the PV system.
- If the utility intends to procure the PV system (i.e., bears the capital expenditure) from an EPC contractor, then the utility's motivation is to maximize the energy generation from the PV system. In this case, the utility should seek a generation guarantee from the contractor based on a reference GHI data specified at the time of inviting the bid.
  - If the utility intends to procure power (either through a PPA or net metering), then the generation guarantee does not need to be stringent. The project developer or the consumer itself will be motivated to generate maximum energy from the PV system. In such a case, the utility's interest in generation will be to meet its own RPO, hence, the utility may provide a range in terms of capacity utilization factor (CUF) within which the PV system should operate.
- (iii) Monitoring of a Rooftop PV System: A PV system can be monitored at various levels based on the capacity of the PV system and the type of involvement of the stakeholder. This is generally done at the following levels:
- *At PV Module-Level: done using micro-inverters or DC-DC converters/optimizers at each module. However, such micro-inverters/converters/optimizers increase the capital cost of the PV system.*
  - *At String-Level: This is done mainly using current sensors to each string in the string junction boxes which are connected to a supervisory control and data acquisition system. String monitoring systems compare the electrical output of each PV string with each other and also as a function of the ambient weather parameters.*
  - *At Inverter-Level: The data of the inverter can be either read from their display or be extracted by connecting USB or RJ45 cables, or wirelessly using Wi-Fi, ZigBee, Radio Frequency (RF) or Bluetooth. Inverters may also be monitored remotely using proprietary or third party equipment using GSM/GPRS.*
  - *At Meter-Level: Meter-level monitoring of a rooftop or any other PV is the most critical for utilities as well as investors, as the energy meter is directly linked to each stakeholder's revenue. Meter-level monitoring can be done either manually by the meter reader once during a billing cycle; or at another extreme, on a real-time-basis using remote wired or wireless communication.*

#### 4.4. Technical Documentation, Drawings and Inspection

##### a. Technical Documents of the Rooftop PV System

The inspection of a PV system may be guided by the IEC 62446 standard.

- **IEC 62446, 1<sup>st</sup> Ed. (2009-05), “Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection,” defines the minimal information and documentation required to be handed over to the customer following the installation of a grid-connected PV system.**

The critical documents of the rooftop PV system include:

- (i) Contact information of various stakeholders such as PV system owner, project developer, EPC contractor, designer, lending agency, etc.
- (ii) Datasheets of key equipment and the overall PV system.
- (iii) IEC certifications of the PV modules and inverters.
- (iv) Warranty documents of key equipment by Original Equipment Manufacturer.
- (v) Design document of the module mounting structure.
- (vi) Warranty document of the entire rooftop PV system as a whole by the installer.
- (vii) Generation estimation report based on realistic weather conditions.
- (viii) Operation and maintenance manual of the PV system.
- (ix) Test results and commissioning certificate.
- (x) Purchase bills and contracting documents.

##### b. Drawings of a Rooftop PV System

The critical drawings of the rooftop PV system include:

- (i) Single Line Diagram (SLD);
- (ii) Equipment layout diagram; and
- (iii) Wire and earthing layout diagram.

##### c. Inspection and Testing of a Rooftop PV System

The inspection of a PV system may be guided by the IEC 62446 standard.

- **IEC 62446, 1<sup>st</sup> Ed. (2009-05), “Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection,” defines the minimal inspection criteria to verify the safe installation and correct operation of the PV system, as well as periodic retesting.**

The overall objectives of rooftop PV system inspection are to:

- Visually inspect all equipment, component and connections, both electrical and structural;

- Verify the consistency of the overall installation with respect to its intended design;
- Ensure the necessary standard and safety compliance;
- Verify the performance of the PV system;
- Verify sufficiency of documents; and
- Identify remaining works of the project, if any.

The overall inspection activity of the rooftop PV system is divided into two parts: visual inspection and testing.

- (i) Visual inspection is done to verify:
  - Installation, interconnection, workmanship, warranty compliance, ratings of equipment, labelling, etc.
  - Safety via over-current/voltage protection devices, residual current devices, surge and lightning protection, disconnectors, earthing and other contingencies.
- (ii) Testing:
  - Performance testing of PV modules, strings, inverter, and overall system output.
  - Safety testing for continuity, short circuit and open circuit, polarity, earthing, insulation, islanding, and so on.

It is also highly recommended to undertake such inspections via third-party inspection and testing agencies that specialize in such work. Such inspection agencies should have well-trained manpower and equipment like I-V tester, weather monitoring equipment, infrared imager, megger, etc. It is important that such agencies are not EPC contractors or project developers in order to avoid any conflict of interest.

**In conclusion, this chapter describes key technical considerations including type, design, components, interconnection, standards, documentation and inspection of the rooftop PV system. These technical considerations are critical considering the fact that the PV system should safely and satisfactorily perform for at least 25 years.**

## 5. Administrative Processes

### 5.1. Significance of Administrative Processes

While policy, regulation and standards define the framework, it is the actual implementation which marks the success of the overall solar rooftop programme. Administrative processes define the manner in which implementation can happen and hence, the administrative processes are one of the most critical aspects of any solar rooftop programme at the State or the national level.

Overall, the development of the rooftop PV sector depends upon the concerted action of a number of key stakeholders. The roles and responsibilities of these stakeholders are highlighted in the following sections of this chapter.

### 5.2. Roles and Responsibilities of Key Stakeholders

#### a. The Policy-maker: State's Energy (or Power) Department

The rollout of a State's solar rooftop programme can be formally marked by the launch of the State's solar rooftop policy. This could also be a general solar policy with components addressing specific aspects and areas concerning solar rooftop systems and their development.

The State's Energy (or Power) Department is the proponent of the solar rooftop policy. Once the policy is launched, the Energy (or Power) Department should notify the other stakeholders including the SERC and the DISCOMs on their roles and responsibilities as well as the necessary action to be undertaken to implement the policy.

The Energy (or Power) Department should immediately set up a monitoring cell and instil it with sufficient powers to monitor the progress of activities under the policy, and also address concerns from stakeholders which would require amendments in the policy itself.

#### b. The Regulator: SERC

The regulator develops the necessary regulation addressing various provisions of the solar rooftop policy which has been captured in Chapter 3 of this Guide. Based upon the power instilled upon the regulator by the Electricity Act, 2003, the regulator may even develop the regulations required for solar rooftop systems in the absence of a relevant policy. Such a regulation would typically guide the interconnection process, tariff, banking, safety and similar concerns. The regulation may be developed *Suo Moto* or through the petition by any stakeholder.

#### c. DISCOM

The DISCOM interprets and implements the provisions of the policy and regulation, thereby

allowing consumers to interconnect their rooftop PV systems to the grid. In the process, they should ensure overall safety, adherence to the overall technical guidelines, and follow commercial processes. It should also be clarified here that the role of DISCOMs is only limited to PV systems interconnected to the grid (i.e. grid-connected and hybrid PV systems), and not stand-alone systems. The role of the DISCOM can be segregated based on the three phases of the overall solar PV rooftop programme implementation:

(i) Preparatory phase of the programme

- Delegation of powers and empowerment of committees
- Budgetary approvals
- Regulatory approval of process, systems and formats
- Integration with existing processes and changes to billing software
- Empanelment and procurement
- Capacity building, information dissipation and publicity

(ii) Application and approval phase of individual rooftop PV system

- Receipt of application from the consumer for PV capacity and interconnection
- Screening of application, and preliminary technical and commercial approval by DISCOM
- Post installation inspection of PV system and interconnection
- Verifying the results of the inspection by the Electrical Inspector and/or Third-Party Inspector (TPI)
- Inspection, meter replacement and commissioning of the PV system by DISCOM

(iii) Operation and billing of individual rooftop PV system

- Billing to the consumer and ensuring payment for energy sold to the grid, if any
- Ensuring safety of the distribution network
- Data collection

**d. SNA**

The SNAs can play a vital role in promoting solar rooftop programmes. Traditionally, SNAs have been the flag bearers of solar rooftop initiatives in India. Therefore, they have already developed:

- Technical capacities for solar rooftop PV systems, and
- Channels for promoting solar rooftop programmes through funds and subsidies.

The SNAs should ensure that their processes are well-integrated with the DISCOM's processes, which are described following sections of this chapter.

#### **e. The Chief Electrical Inspector (CEI)**

One of the main functions of the CEI is to ensure safe operation of the solar rooftop PV system as per the provisions laid out in the Electricity Act, 2003 and Indian Electricity Rules, 1956:

- Inspection and issue of statutory approvals for generator installations more than 10 kW and others under Rule 47-A of Indian Electricity Rules, 1956.
- Inspection and approval of electrical installation in high rise buildings (of more than 15 meters height) under Rule, 50-A of Indian Electricity Rules, 1956.

Hence, the CEI's involvement with respect to process is on two counts:

- First, during approvals of drawing and design documents, and
- Second, pre-commissioning inspection of the installed PV system for issue of the 'Charging Certificate'.

It is often debated as to what should be the minimum PV system capacity that is required to be approved by the CEI. While, it is commonly agreed that this minimum capacity can be around 10 kW (as has been decided by a number of states), it is highly recommended that smaller systems should be inspected by the DISCOM itself prior to commissioning or a TPI agency should be appointed to inspect PV systems, whether smaller or larger than 10 kW.

#### **f. The Consumer, Investor and Developer**

The consumer and developers (typically, third-party) are the key investors in the rooftop PV system. The consumers evaluate the information available to them from DISCOMs and system installers, and may only seldom refer to the policy and regulation.

The consumer would be responsible for the administrative paperwork for establishing and running the PV system including investment, availing loans, application to DISCOM, availing subsidies (if any), call for commissioning, operation, maintenance and other administrative and technical compliances.

#### **g. The System Installer**

The system installer is appointed by the consumer or the developer to design, procure and construct the rooftop PV system. The system installer should ensure that the system complies with all statutory and technical guidelines and best practices, as the consumer may not be technically well-informed. The system installer should install a robust PV system of good quality, so that it can perform safely and maximize energy generation.

System installers are often MNRE Channel Partners, and have direct access to subsidies from MNRE. It is recommended that the system installer should undertake the responsibility of availing subsidy, if applicable, on behalf of the consumer.

### 5.3. The Interconnection Process

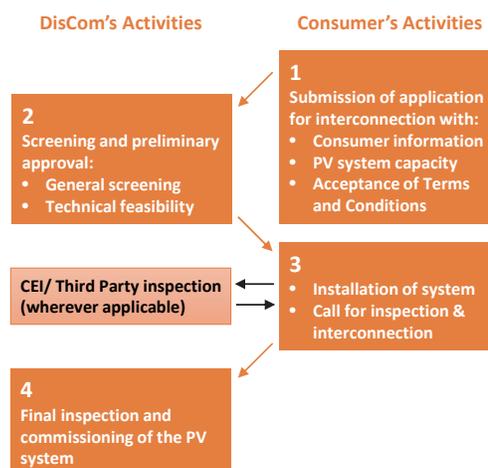
The interconnection process forms the heart of the engagement between the DISCOM and the consumer (or the solar rooftop PV developer). A simple and efficient interconnection process is the key to a successful solar rooftop programme as shown in Figure 5-1.

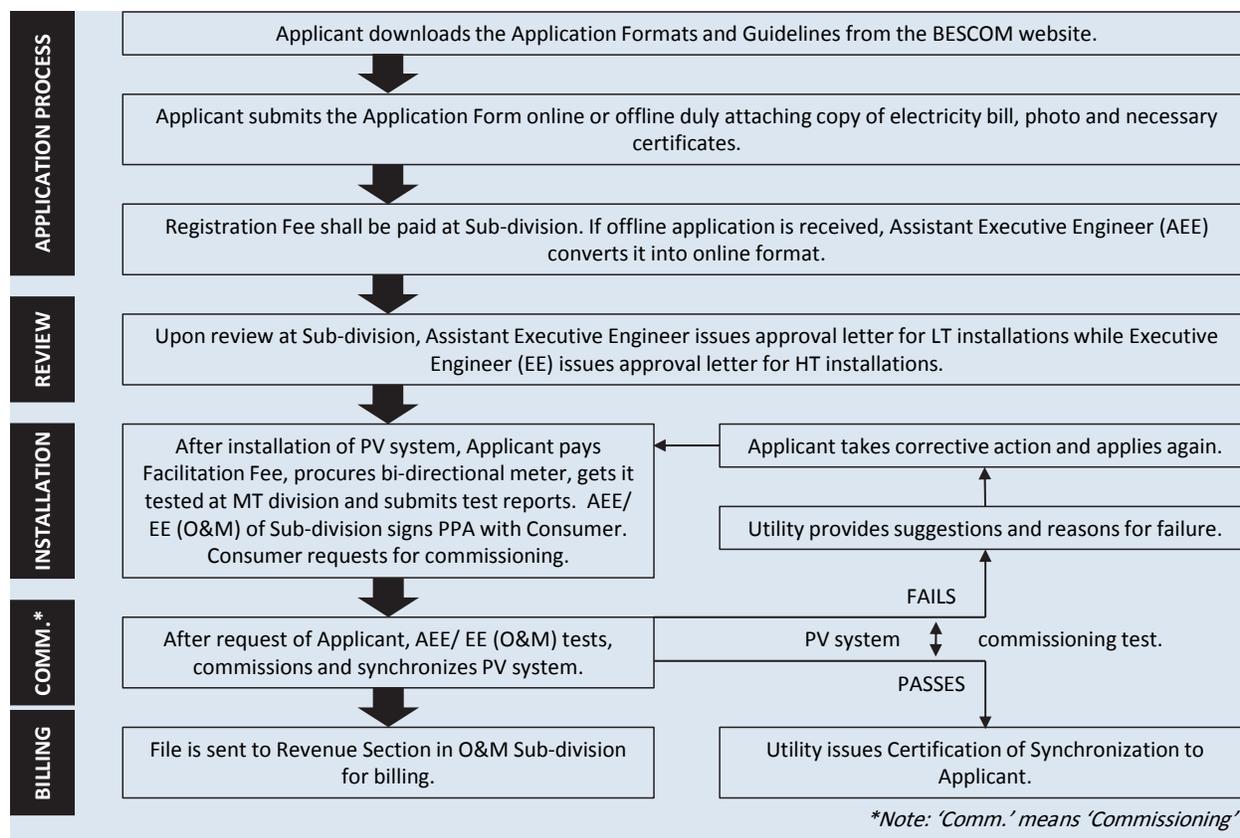
It is envisioned that net-metered PV systems would form a substantial part of the overall rooftop PV installations in India. The present section describes a model interconnection process to set up a net-metered rooftop PV system.

It is globally observed that DISCOMs often build in a number of checks and balances, which complicate the process by making it redundant and repetitive, adding additional conditions, paperwork and transactions; which usually happen due to lack of domain knowledge or an indirect intent to discourage solar rooftop deployment.

A simple yet effective interconnection process is recommended, which is broadly divided into the following four steps and can be directly adopted by DISCOMs:

*Figure 5-1: Overview of interconnection process.*





### a. Application Submission by Consumer:

The consumer initiates the process of interconnection by providing necessary details such as:

- Name and type of applicant, along with identity proof.
- Type of consumer, along with copy of latest electricity bill.
- Capacity of the intended solar rooftop PV system.

This application forms the basis of the consumer's interconnection agreement, and hence, should be treated with equivalent statutory weightage.

The state regulatory commissions allow the DISCOMs to charge an application fee to recover some of the transaction cost borne by the utility to interconnect solar rooftop systems. This application fee, openly publicized by the DISCOM should ideally be a nominal flat fee. (A fee of less than Rs. 500/- is recommended.)

### b. Screening of Application and Preliminary Approval by DISCOM

The preliminary screening of the consumer's application should take place within the local sub-division office itself. The DISCOM should undertake the preliminary screening based on the following:

### General Screening

- Verification of consumer details provided in the application form, and
- Receipt of application fee.

### Technical Feasibility

- Confirmation of the proposed capacity of the rooftop PV system based on the existing sanctioned load of the consumer and relevant regulatory guidelines. (For example, some regulation may stipulate that the PV system capacity should not exceed 50 percent of the consumer's sanctioned load.)
- Verification of technical feasibility of the proposed rooftop PV system based on the capacity of the relevant distribution transformer. (While most distribution transformers can safely facilitate 100 percent reverse power flow, some regulations or guidelines may stipulate that the total PV capacity should connected to a given distribution transformer should not exceed 30 percent capacity of that distribution transformer).

Upon successful screening, the DISCOM should intimate the consumer of Preliminary Approval within 7 (seven) days of acceptance of the application.

### What should be included in the DISCOM's Preliminary Approval?

The DISCOM's Preliminary Approval is important to the consumer as it not only formally confirms to the consumer to commence installation of the PV system, but this commitment by the DISCOM also enables the consumer to seek financial assistance such as loans, investments, etc. and undertake other formalities for the PV system.

The Preliminary Approval should consist of:

- Acknowledgment of receipt of the consumer's application, details, interconnection request fees and proposed rooftop PV system capacity,
- Sanctioned capacity of rooftop PV system by the DISCOM,
- Procedure and timeline for installation of the PV system by the consumer, and call for commissioning,
- Reference to the terms and conditions, standards and regulations to be followed by the consumer (which should be approved by SERC, and amended from time to time upon SERC's approvals).

### **c. Installation of PV System and Call for Inspection and Interconnection**

Once the consumer receives the Preliminary Approval, it can commence all its activities in a full-fledged manner including:

- Selection of a rooftop PV system installer (or developer), if not already selected, and awarding them the contract for installation (or project development);
- Application for bank loans; and

- Application for subsidies, which is usually through the system installer as they are also MNRE Channel Partners.

Additionally, when the construction of the rooftop PV system is completed, then the consumer, with the help of the system installer (or developer) should undertake the following activities:

- (If the PV system falls under the purview of the CEI, typically for capacities greater than 10 kW, then) Intimation to the Chief Electrical Inspector as per stipulated format for safety inspection and obtain a 'Charging Certificate' for the PV system. A DISCOM or CEI may also employ a TPI agency, which may inspect and certify the rooftop PV system at this point.
- (Once the Charging Certificate is obtained from the CEI, wherever applicable, then) Application to the DISCOM for interconnection and replacement from existing unidirectional meter to a bi-directional net-meter, i.e. commissioning.

This application should also consist of the necessary technical and administrative documents required by the DISCOM, such as:

- Covering letter with reference to DISCOM's Preliminary Approval and necessary undertakings;
- Drawings: SLD; equipment layout and wiring; earthing layout with specification;
- Datasheets/specification: inverter; PV module; module mounting structure; AC and DC junction boxes; surge protection devices; AC, DC and earthing cables/conductors; miniature circuit breaker (MCB)/ moulded case circuit breaker (MCCB)/ earth leakage circuit breaker (ELCB)/ residual current circuit breaker (RCCB)/ isolator;
- Certificates: IEC test certificates for PV modules and inverter(s); certificate from Licensed Structural engineer for compliance of module mounting structure as per relevant Indian Standards;
- Installer (or developer) information: contact information; (optional) contract information such as contract price or power purchase rate with terms; operation and maintenance terms; generation guarantee terms; etc.
- (Optional) Bank loan information

#### **d. Inspection and Commissioning of the PV System by DISCOM**

Once the DISCOM's sub-division office receives the consumer's call for inspection and commissioning, it should directly undertake the following activities:

- Site visit and inspection to verify the installed PV system as per documents submitted; and
- Replacement of the existing unidirectional meter with a bi-directional net-meter.

#### **e. Operation and Billing of Individual Rooftop PV System**

Once the rooftop PV system is successfully commissioned, the development phase of the rooftop PV system is complete. The DISCOM now has to focus on the following key activities:

- Billing to the consumer as per the DISCOM's net-metering terms, conditions and regulations;
- Ensuring safe operation of the rooftop PV system with respect to the grid as well as the consumer, which can be done by regular or random site inspections and audits;
- It is also recommended for the DISCOM to observe and gather data on the performance (generation) of the PV systems, as this data would be very useful for future techno-commercial planning as well as verification of the system data provided by the consumer.

#### 5.4. DISCOM's Preparatory Processes

Although the DISCOM's preparatory process for a solar rooftop programme are to be undertaken prior to the launch of interconnection process, in this chapter they are discussed after the description of the interconnection process so that the reader can appreciate why specific preparatory processes are required.

##### a. Delegation of Powers and Empowerment of Committee

As rooftop PV systems are decentralized in nature, it is very important to delegate appropriate powers to nodal offices in order to avoid any congestion in the administrative processes.

###### (i) Central Level:

- Administer the overall rooftop PV deployment for the DISCOM,
- Frame technical standards, administrative processes and relevant guidelines,
- Review and optimize technical standards and administrative processes based on stakeholder (consumer, engineers, etc.) feedback from time to time,
- Undertake centralized initiatives such as regulatory approvals, empanelment of equipment and contractors, publicity campaigns, staff and stakeholder training, etc.,
- Monitor multiple communication channels for consumers and other stakeholders, and
- Remove any difficulties that may arise anywhere throughout the rooftop PV programme.

(ii) Sub-Division Level: This DISCOM's local offices such as the sub-division office should be empowered to undertake all activities such as accept and process consumer's applications, undertake feasibility studies, commission rooftop PV systems, and resolve specific issues of the consumer.

##### b. Budgetary Approvals

Although any cost incurred by the DISCOM due to a solar rooftop programme can be passed through and loaded on the consumer, there will often be instances when it may cause a burden on DISCOM's balance sheet and also on the State's Exchequer. Hence, it is important to understand the financial implication of a solar rooftop programme on the DISCOM.

### **c. Regulatory Approval of Process and Formats**

Although the state may have a solar rooftop policy and regulation, the DISCOM should still get its administrative interconnection process, terms and conditions, schedules and formats approved by the SERC as there would be elements over and above those mentioned in the policy or regulation.

### **d. Integration with Existing Processes and Changes to Billing Software**

There would be some new process and some modification in existing processes within the DISCOM, which should be defined prior to the launch of the rooftop PV programme. The new processes to be established within the DISCOM include:

- Keeping record of consumer applications for interconnection and its status up to commissioning,
- Keeping record of rooftop PV capacity allotted to (and commissioned at) each distribution transformer and overall PV capacity within the DISCOM's network, and
- Accepting calls for inspection and interconnection, and assigning a team for the same.

### **e. Empanelment and Procurements**

Empanelment is a very important step for the DISCOM to ensure standardization and efficient implementation of not only the correct equipment and systems, but also the overall process and its compliance. Hence, it is recommended for the DISCOM to have some control over safety, quality and economics of the rooftop PV system through such empanelment.

Certain aspects and components are discussed herein, which may be empanelled based upon the DISCOM's involvement and comfort level with the solar technology.

(i) System Installers: A DISCOM may empanel system installers for the following activities:

- Install technically compliant and safe PV systems,
- Offer PV systems and services at a reasonable price and terms to the consumer,
- Follow all compliance norms of the DISCOM, and
- Educate and assist consumer with appropriate administrative processes.

The MNRE has already empanelled system installers, who are known as 'Channel Partners', through a certain amount of techno-commercial screening. These Channel Partners are already aware of the requisite technical standards and also the administrative processes to avail MNRE subsidies and other provisions (such as duty exemption, etc.). Hence, it is recommended that the DISCOM can directly empanel these Channel Partners.

- (ii) Inverters: The inverter is the brain of the PV system, which undertakes key functions such as synchronization of the PV system with the grid and ensures safety compliance for both, the grid as well as the PV system. There are several technical considerations for the interconnection of a PV system, including safety (e.g. anti-islanding) and power injection quality (e.g. harmonic distortion, surge protection, DC injection, etc.), which are taken care of through the inverter (as discussed in Section 4.4 of this Guide).

Hence, it is recommended to pre-approve and empanel inverter makes and models, so that system designs can be approved at the DISCOM's local (sub-division) office with more confidence. Moreover, inverter empanelment can be an ongoing process.

- (iii) Net-meters: Meters are one of the key equipment for the DISCOM, as they are directly linked to the DISCOM's revenue. The DISCOM needs to ensure purchase of appropriate bi-directional net-meters for different capacities. There is only a minor software change required from the meter-manufacturer's side.

It is also recommended to procure meters with communication ports such as RS-232/485 and standard protocols such as IEC 62056 or DLMS), so that such meters are also ready for functionalities that may be required in the near future such as remote meter reading and communication, energy prediction, energy audit, ToD tariff, etc.

## **f. Capacity Building**

Capacity building of both DISCOM engineers as well as system installers is important to ensure correct technical and procedural compliance under the solar rooftop programme. The DISCOM engineers should be trained on:

- Solar technology, safety, standards and performance,
- Administrative processes for interconnection and reporting issues, and
- Soft skills and customer relations.

The system installers should be trained on:

- Technical requirements of the DISCOM,
- Compliance with administrative processes of the DISCOM, and
- Providing honest and reliable services to the consumer.

## **g. Information Dissipation and Publicity**

As a solar rooftop programme is also social in nature, it is equally important to educate the consumer regarding:

- The solar technology, its possibilities and its limitation,
- Investing in a rooftop PV system and its payback,
- Selecting the right system installer, and with appropriate terms and conditions,
- Administrative processes for establishing a rooftop PV system, and

- Encouragement by the DISCOM to adopt rooftop PV systems.

**In conclusion, this chapter covers key administrative processes associated with a solar rooftop PV programme. These administrative processes are the keys to a successful rooftop programme. Once the rooftop PV programme commences, the administrative processes will automatically evolve based on sensible monitoring of the process and stakeholder feedback. Hence, these processes should also be governed by a competent and empowered authority of the DISCOM.**



