



GOVERNMENT OF INDIA
**MINISTRY OF NEW
AND RENEWABLE ENERGY**



**BEST PRACTICES MANUAL FOR
IMPLEMENTATION OF STATE-LEVEL ROOFTOP SOLAR PHOTOVOLTAIC PROGRAMMES IN INDIA**

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Disclaimer

This Manual is prepared for the Ministry of New and Renewable Energy (MNRE), Government of India in order to assist in achieving the National Solar Mission's rooftop solar photovoltaic installation target of 40,000 megawatts by 2022. This Manual is prepared by the Gujarat Energy Research and Management Institute (GERMI) and the USAID's PACE-D Technical Assistance Programme. The Manual is prepared under MNRE's Administrative Approval No. 30/11/2012-12/NSM dated June 26, 2014 and Letter No. 03/21/2014-15/GCRT dated May 18, 2015.

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Foreword 1

The United States-India Partnership to Advance Clean Energy (PACE) Program was born out of our shared need to confront the threats of global climate change, increase energy security, and reduce greenhouse gas emissions. As part of this flagship program, the United States Agency for International Development (USAID) and India's Ministry of New and Renewable Energy have developed a robust partnership in the form of the PACE-D (Deployment) Technical Assistance (TA) Program that is accelerating India's transition to a high-performing, low-emissions and energy-secure economy through the development, deployment, and transfer of innovative clean energy technologies.

The five-year PACE-D TA Program, launched in July 2012, has aligned its core activities to support the Government of India (GOI) in achieving its ambitious target of 100 Gigawatt solar capacity by 2022 and is committed to work towards making the 40 Gigawatt rooftop solar target a success. In fact, thanks to the Program's focused interventions, there is already significant traction from stakeholders working on the policies, implementation frameworks, capacity constraints, and deployment of rooftop solar solutions.

The USAID-led PACE-D TA Program, in cooperation with the Gujarat Energy Research and Management Institute (GERMI), has developed this "Best Practices Manual" to raise awareness, disseminate knowledge, share learnings from the field, and provide key insights to accelerate solar rooftop deployment in the country. I am confident that this manual will address the gaps hindering the development of the solar rooftop market

by providing critical information related to business models, policies and regulations, technical standards, and specifications that will be of special interest to project developers. It will also help energy utilities across India implement sound administrative processes that are necessary to build the sector, adding to their understating of project financing as well as their ability to accurately assess and mitigate risks.

This Best Practices Manual will serve as a guide for policy makers, project developers, utility engineers, financiers, manufacturers, and new entrepreneurs working on building India's rooftop solar infrastructure.

I would like to express my sincere appreciation to our bilateral partner, the Ministry of New and Renewable Energy, and all other stakeholders for their continued support and guidance.

USAID is pleased to partner with India on its sustainable and inclusive growth path. The opportunities for cooperation between our two countries are immense. We at USAID welcome the opportunity to be part of this important partnership, one aimed at supporting India in its emergence as a global leader in renewable energy.

Ambassador Jonathan Addleton
USAID Mission Director to India

Foreword 2

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

This is crucial considering our immense rooftop solar power potential and that nearly 70 percent 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 rooftop solar power projects in Government/ PSU sector, to notify Gross/ Net-metering Policies in 26 States/ Union Territories (UTs), to develop rooftop solar power online portal and SPIN platform, to empanel Channel Partners, to assess rooftop solar power potential of buildings under all Ministries, to coordinate with Ministry of Urban Development for rooftop solar power projects in Smart Cities and Solar Cities, to train Suryamitras and staffs of Distribution Companies (DISCOMs)/ State Nodal Agencies (SNAs) and of Banks through NISE and SETNET institutions and to provide concessional credit to Project Developers through multilateral support (World Bank, Asian Development Bank, KfW/ German Bank and New Development Bank).

Design and implementation of rooftop solar power projects require substantial coordination of several agencies, viz. Regulatory Commissions (net-metering regulation), DISCOMs (net-metering and bill settlement), Ministry and SNAs (release of subsidy), Banks (housing/ improvement loans), Urban Local Bodies (IEC for public campaign), Rooftop Owners (access to roofs), Developers/ Aggregators/ EPC Contractors (project implementation and operation), etc. For facilitating such coordination, MNRE has been working with USAID to develop this Best Practices Guide. By providing all best practices in developing business models, rooftop solar power 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 rooftop solar power 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 Vaidya, IAS

*Joint Secretary to the Government of India
Ministry of New & Renewable Energy*

Foreword 3

We believe that rooftop solar is among the most mature models of sustainability in societal, environmental and energy terms. Rooftop solar provides an opportunity to an individual to directly invest towards its own self-reliance, in turn strengthening one's own sense of responsibility, and ultimately inching towards the greater good.

Gujarat has been in the forefront of promoting solar energy for a sustainable future, and we aspire to become a global rooftop solar capital. With this vision, we had launched the megawatt-scale Gandhinagar Rooftop Solar Programme as early as 2012, when rooftop solar was still being discussed in terms of kilowatts. Today, this programme has become a benchmark for many such programmes in India. We have also taken early-on steps to develop a skilled professional and technical workforce realizing its significance in this decentralized sector.

Our experience in rooftop solar has also highlighted a wide spectrum of matters, technical, administrative and social, that need to be synchronized in order to achieve its maximum potential. Every stakeholder will have to actively involve oneself towards simplifying the seemingly complex, voluminous, and hence, overwhelming ecosystem into a much simpler one that a common citizen can follow.

Leaders and administrators in Gujarat have always believed in 'ease of doing business', and with that notion in mind, are actively working to streamline the rooftop solar ecosystem starting from the recent solar policy itself, which clarifies all guidelines to deploy rooftop solar systems.

However, we also realize that several of our provisions would be different compared to our neighbouring states. Non-uniform technical standards, accounting methodologies and administrative procedures not only slow down deployment of a technology, but also increase its soft costs.

I am happy to see that this 'Best Practice Manual' has successfully, and without circumventing details, listed out all issues with respect to each stakeholder, and made very direct recommendations. If you are encountering a problem in your rooftop solar programme, I am sure that it will be addressed in this Manual. I also appreciate that the intention behind this Manual is to provide a uniform guideline to all State-level programmes, as well as other programmes of similar scale.

I am confident that this Manual would be helpful to agencies that are in the process or ramping up their rooftop solar programmes. I also encourage their suggestions and feedbacks, which would be highly valuable to subsequent editions of this Manual. I know the authors of this Manual personally, I encourage the readers to get in touch with them if in any doubt, and I am sure that you will benefit from their knowledge, enthusiasm and support. I wish you the very best and hope that you get the best out of your solar programme.

Mr. L. Chuaungo, IAS

Principal Secretary of the Government of Gujarat

Energy & Petrochemicals Department; and

Trustee, Gujarat Energy Research & Management Institute (GERMI)

Preface

The rooftop solar photovoltaic (PV) segment is one of the fastest growing clean energy segments across the globe due to its ability to provide reliable power for both rural and urban customers, scale up investments through entry of multiple investors, empower energy consumers and enhance their energy security while helping utilities address critical transmission and distribution losses.

The rooftop solar PV sector forms an important and critical part of Government of India's 100 gigawatt target by 2022. Over the last two years there has been a tremendous thrust from the central as well as state governments to promote solar PV rooftop installations. These thrusts have been in the form of policies, regulations, guidelines and even promotional subsidies at various levels. However, it is often observed that initiatives have not been able to address some critical technology, process and market related constraints, which have plagued implementation and capacity addition. This is primarily due to lack of understanding of the scope of the technology, the market, administrative setup and coordination required for rooftop solar PV deployment. Going forward, more and more government and private bodies aim to deploy rooftop solar PV programmes, but may have faced hindrances due to lack of experience and available resources.

If you are reading this Best Practices Manual for implementation of rooftop solar PV programmes, we assume that you have already decided to take up a rooftop solar PV programme for your state or distribution area. The purpose of this Manual is not to convince you to undertake a solar rooftop

programme, but to provide you the necessary resources to efficiently undertake the programme. While we have streamlined this Manual to provide you options to choose from, it also provides basic relevant knowledge to make your choice. This manual will give your programme a jump start and orient it in the right direction. We have attempted to address all preliminary issues.

This Manual is structured with the objective of taking the reader through all the critical elements required for deployment of a large-scale rooftop solar PV programme. This Manual addresses concerns of stakeholders including Policy-makers and Regulators, Distribution Utilities and State Nodal Agencies, and last but not the least, Bankers. Correspondingly and logically, this Manual addresses the key topics encompassing business models, policies and regulations, technological standards, administrative procedures and financing.

We hope this manual provides the apt and timely information to those seeking resources for undertaking their rooftop solar programmes. We also look forward to receiving comments and inputs from our readers, which will help this Manual evolve with newer developments and also in terms of relevance.

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We also take this opportunity to recognize allied projects that have enabled us to utilize their substantial insights into this manual. We thank Mr. Pankaj Pandey, IAS, Managing Director of BESCO, where the organizations of the authors serve on the technical and administrative committees for BESCO's rooftop solar programme. The discussions with

Mr. Rajesh Bansal, Vice President, BSES Rajdhani Power Limited, regarding metering and streamlining administrative processes have been very useful.

Our discussions with several technology and equipment suppliers have helped maintain this Manual as a very hands-on document. We owe our special gratitude to Shyam Sundar of Studer Innotec India Private Limited and Virag Satra of SMA Solar India Private Limited for sharing their insights on inverter intricacies as well as advance inverter functions.

Last but not the least, we express our heartfelt gratitude towards colleagues from GERMI, USAID and PACE-D TA Program who have supported us at each step, through technical inputs and administrative support.



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Abbreviations

η	:	Efficiency	CUF	:	Capacity Utilization Factor
Ω	:	Ohm	DISCOM	:	Distribution Company
1 ϕ	:	Single-phase	DLMS	:	Device Language Meter Specification
3 ϕ	:	Three-phase	DNI	:	Direct Normal Irradiance
ACB	:	Array Combiner Box	DSCR	:	Debt Service Coverage Ratio
ACDB	:	AC Distribution Box	EE	:	Executive Engineer
ADB	:	Asian Development Bank	EPC	:	Engineering, Procurement and Construction
A _{DC}	:	Ampere (direct current)	EVA	:	Ethyl Vinyl Acetate
AEE	:	Assistant Executive Engineer	FI	:	Financial Institution
AFD	:	Agence Française de Développement	FRT	:	Fault Ride-Through OR Frequency Ride-Through
AJB	:	Array Junction Box	GHI	:	Global Horizontal Irradiance
AM	:	Air Mass	GI	:	Galvanized Iron
ANSI	:	American National Standard Institute	GOI	:	Government of India
BIS	:	Bureau of Indian Standard	Govt.	:	Government
BoS	:	Balance of System	GW	:	Gigawatt
BS	:	British Standard	Hz	:	Hertz, unit of frequency
CAGR	:	Compound Annual Growth Rate	IBRD	:	International Bank for Reconstruction and Development
CdTe	:	Cadmium Telluride	IDA	:	International Development Agency
CEA	:	Central Electricity Authority	IEC	:	International Electrotechnical Commission
CFI	:	Commercial Financial Institution	IMD	:	Indian Meteorological Department
CIGS	:	Copper Indium Gallium Selenide			
CPV	:	Concentrator Photovoltaics			

I _{MP}	:	Current at Maximum Power Point	O&M	:	Operation and Maintenance
INR	:	Indian Rupees	OEM	:	Original Equipment Manufacturer
IP	:	Ingress Protection	PCC	:	Point of Common Coupling
IPP	:	Independent Power Producer	PCE	:	Power Conversion Equipment
IREDA	:	Indian Renewable Energy Development Agency	PFC	:	Power Finance Corporation
IRR	:	Internal Rate of Return	PID	:	Potential-Induced Degradation
IS	:	Indian Standard	P _{MAX}	:	Maximum Power
I _{sc}	:	Short-circuit Current	PPA	:	Power Purchase Agreement
JICA	:	Japan International Cooperation Agency	PPP	:	Public Private Partnership
kV	:	Kilo-volt	PSB	:	Public Sector Bank
kW	:	Kilowatt	PV	:	Photovoltaic(s)
kWh	:	Kilowatt-hour (i.e. Unit)	PVC	:	Polyvinylchloride
M	:	metre	PWM	:	Pulse Width Modulation
MCB	:	Miniature Circuit Breaker	RCCB	:	Residual Current Circuit Breaker
MCCB	:	Moulded Case Circuit Breaker	RE	:	Renewable Energy
MMS	:	Module Mounting Structure	RESCO	:	Renewable Energy Services Company
MNRE	:	Ministry of New and Renewable Energy	RF	:	Radio Frequency
MPPT	:	Maximum Power Point Tracking	RoW	:	Right of Way
MW	:	Megawatt	RPO	:	Renewable Purchase Obligation
mΩ	:	Milliohm	Rs.	:	Indian Rupees
NBFC	:	Non-banking Financial Company	SCADA	:	Supervisory Control and Data Acquisition
NOC	:	No Objection Certificate	SCB	:	String Combiner Box
NOCT	:	Nominal Operating Cell Temperature	SERC	:	State Electricity Regulatory Commission
			SJB	:	String Junction Box

SMF	:	Sealed Maintenance Free	USD	:	US Dollar
SNA	:	State Nodal Agency	V_{AC}	:	Volt (alternating current)
SPD	:	Surge Protection Device	V_{DC}	:	Volt (direct current)
SPO	:	Solar Purchase Obligation	V_{MP}	:	Voltage at Maximum Power Point
SPV	:	Special Purpose Vehicle	V_{OC}	:	Open-circuit Voltage
STC	:	Standard Testing Condition	VRT	:	Voltage Ride-Through
TDD	:	Total Demand Distortion	W	:	Watt
THD	:	Total Harmonic Distortion	W_P	:	Watt-Peak
ToD	:	Time of Day	XLPE	:	Cross-linked Polyethylene



1. Introduction to this “Manual”

1.1. Purpose of this Manual

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

There have been several isolated efforts at policy, regulatory and implementation-levels for rooftop solar 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) models. However, the net capacity of such PPP projects has also remain limited, especially compared to the regulatory and procedural efforts undertaken to realize such projects.

With the dramatic reduction in prices of photovoltaics 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. Henceforth, solar, a renewable energy, will witness more emphasis on ‘energy’ rather than ‘renewable’. Therefore, rather than focusing on government subsidies, this is the right time to shift focus on commercial aspects of implementation framework of solar programmes and improve their efficiencies.

In order to realize widespread rooftop solar deployment opportunities, the implementation process for each stakeholder needs to be clear and simple. It is envisioned that in the most mature form, rooftop solar systems would be deployed at scale by enabling individual ownership of such systems.

Many State Nodal Agencies (SNAs) and now even Distribution Companies (DISCOMs) are embarking on such rooftop solar deployment models driven by individual ownership, but are still facing teething trouble. Trouble faced by such implementing agencies range from clarity in policy or regulation to technical uncertainty to detailing and simplification of administrative procedures.

A brave approach by implementing agencies could be to ‘learn-as-you-go.’ But such an approach only means that one is reinventing the wheel, as most of the issues have already been sorted out by someone else somewhere around the world or maybe even in India. Moreover, a learn-as-you-go approach by individual organizations tends have a non-uniform development of the overall market (including standards), which further poses deployment inefficiency and cost-related issues to the sector.

This Manual attempts to lay out comprehensive and efficient rooftop solar photovoltaic implementation support process into a single document. The Manual captures global best practices and learnings, as well as those from within India.

This Manual primarily addresses grid-connected rooftop PV systems, under both net-metering and gross-metering connectivity. While the stress is more on individual ownership models, the Manual also recognizes other deployment models such as PPPs and third-party ownerships.

1.2. Organization of this Manual

This Manual is organized to provide necessary and sufficient information to each administrative stakeholder, including:

- State-level Policy-makers,
- State Electricity Regulatory Commissions (SERC),
- Implementing Agency, usually the SNA or the local Distribution Companies, and
- Financial Institution (FI).

This Manual can also be used by:

- The rooftop solar Project Developer, Installer or even Electrical Inspectors, as this Manual provides insights and guidelines for successful installation and procedural compliance.

While it is recommended that administrative stakeholder reads this entire Manual, this Manual is designed to also be used as a reference, where one can read specific chapters or sections related to their role or responsibility.

This first chapter (Introduction to this “Manual”) should be read by all stakeholders as it clarifies the overall purpose and instructions on how to use this Manual.

Chapter 2 (Business Models) discusses the basis of the transaction structure of any rooftop solar programme – the relationship between stakeholders. A good business model is the basis of the feasibility of an investment, whether by the Investor, DISCOM or the Government Exchequer; and rooftop solar is no exception. Hence, this chapter is a key read for Policy-makers, Regulators and Utility Heads.

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. Policies and regulations are discussed in lines with the business models described in Chapter 2. Reference clauses are also suggested for ease of understanding and utilization. Hence, this chapter is a key read for Policy-makers, Regulators and Utilities.

Chapter 4 (Technical Standards and Specifications) is oriented towards the implementing agencies, primarily the DISCOMs and SNA’s, 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. This chapter also converges between Indian (IS, CEA, etc.) standards and

international (primarily IEC) standards. Hence, this chapter can also serve as a guide to rooftop PV system installers.

Chapter 5 (Administrative Processes) deals with specifics of administering a rooftop solar programme. As global and also national experience indicates that DISCOMs are the key drivers of the rooftop solar programme, the chapter details all critical preparatory, interconnection-related, and operation-related processes of the DISCOM. Clarity and efficiency of the interconnection process between the DISCOM and the Consumer is one of the most critical processes to the success of the programme, and hence this chapter is a must-read for DISCOMs and SNAs.

Chapter 6 (Project Financing) discusses technical and commercial aspects of financing a rooftop solar project, including risk assessment and mitigation. Availability of finances for all stakeholders, whether residential, commercial or industrial, is an important driver for rooftop solar systems. On the other hand, such distributed energy systems are still a new topic for Financial Institutions in the country, which also overlaps between the energy and domestic sectors. Hence, this chapter is directed towards Financial Institutions to assist them in standardizing financing of rooftop PV systems and catering to a broader customer base in a secure manner.

1.3. Customization, Compliance and Revisions

This Manual addresses all necessary concerns, whether administrative or technical, to realize a simple, efficient and scalable rooftop solar photovoltaic programme. While this Manual 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 this Manual with statutory provisions in today's scenario or in the future, the statutory provisions shall overrule the provisions of the Manual.

It is also intended that this Manual will continually be revised based on developments and experiences from time to time and will incorporate technical, statutory and other relevant provisions in subsequent revisions.



2. Business Models

2.1. Introduction and Significance Business Models

A business model is a plan, implemented by a company or an organization, to deliver a value based proposition (product or a service or a combination of the two) to a Customer with the objective of earning revenues and profit. The business model formulates and communicates the logic behind the value created and delivered to the Consumers. In essence, a business model is a conceptual, rather than financial, model of a business. The company or the organization could be a Utility, Developer, financial institution or even the Consumer.

Design of appropriate business models assumes a greater significance in the case of solar PV rooftop systems due to their relatively high cost of energy generation/ high upfront investments coupled with distributed implementation and generation which in turn offer a number of benefits to society and the economy like high economic returns, energy security, ability to address climate change, reduced transmission and distribution losses, low gestation periods for development, and enhanced employment generation.

Hence, appropriate packaging of a rooftop solar 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 Rooftop Solar Business Models

a. Building blocks for a rooftop solar business model

The solar PV value chain extends from the production of polysilicon to final system installation and deployment of systems under specific commercial and technical conditions.

This Best Practices Manual focuses on the downstream portion of the value chain, i.e. activities related to the sale of the systems in the marketplace and their installation on rooftops, and the underlying arrangements related to these activities.

This segment of the value chain is seeing one of the most innovative periods with a number of permutations and combinations of ownership structures, revenue models and risk mitigation measures emerging with the main of reducing costs, reducing risks and mainstreaming installations.

While a business model may be simple or complex, the key variables for rooftop solar are very limited as shown in Figure 2-1.

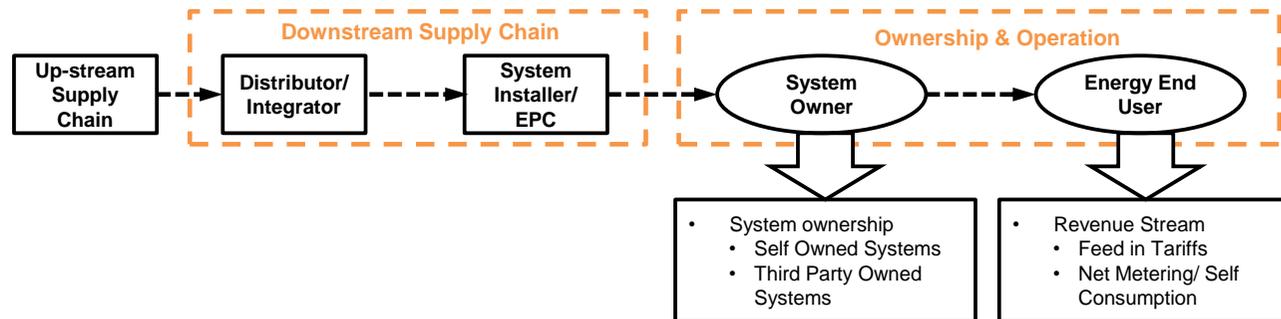


Figure 2-1: Downstream value chain for rooftop solar photovoltaics.

The key determinants of any business model in the solar space are the ownership structure as well as the revenue structure, i.e. how the energy generated by the solar plant is paid for. These two factors are the key variables across the design of solar rooftop business model the world over. Besides the owner of the rooftop PV system and the user or purchaser of the energy, there are also some additional stakeholders who provide inputs, services, regulations and incentives. These stakeholder also play an important role in the development of such projects.

b. Evolution of rooftop solar business models

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

The first generation model is the most commonly found one globally. This business model was the default business model used for the launch and scale-up of the German and Japanese solar programmes. The ownership of the systems under this generation of solar rooftop business model lay with the Rooftop Owners or the end-users (i.e. Consumers).

The second generation evolved based on packaging a large number of smaller rooftop solar projects by a single Project Developer, known as a 'Third Party' (wherein the Utility and the Consumer are the first two parties). As this Third Party makes the investments, the Consumer could 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 roof.

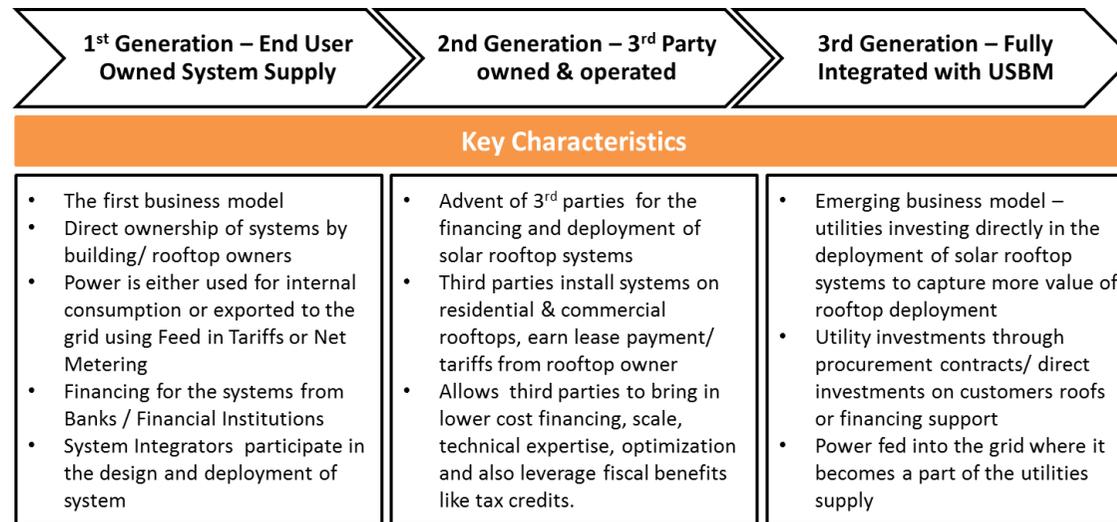


Figure 2-2: Evolution of rooftop and decentralized solar photovoltaic business models.

At present, the first two generations dominate the market but a small shift is being seen in the way Utilities are entering this market. As the Utility is already in the business of supplying power and are seeing Solar Developers (Consumers or Third Parties) starting to take their share, there is perfectly justifiable case for Utilities themselves to own the rooftop PV systems and supply the generated power.

With the evolution of the market, more innovation can be expected in the market as a number of intermediaries will enter the market and bring with them greater efficiency and ability to leverage scale.

c. Design of Rooftop Solar Business Models

Besides ownership structure and structure of revenue streams, in a number of cases, a third variable assumes importance in the design of business models – a variable which bridges the viability gap between the cost of ownership and the revenues through appropriate policy or fiscal incentives. Figure 2-3 highlights the key variables which have been used across the globe for the design of solar rooftop business models.

In most cases, either the ownership structure or the revenue model is identified first based on a number of

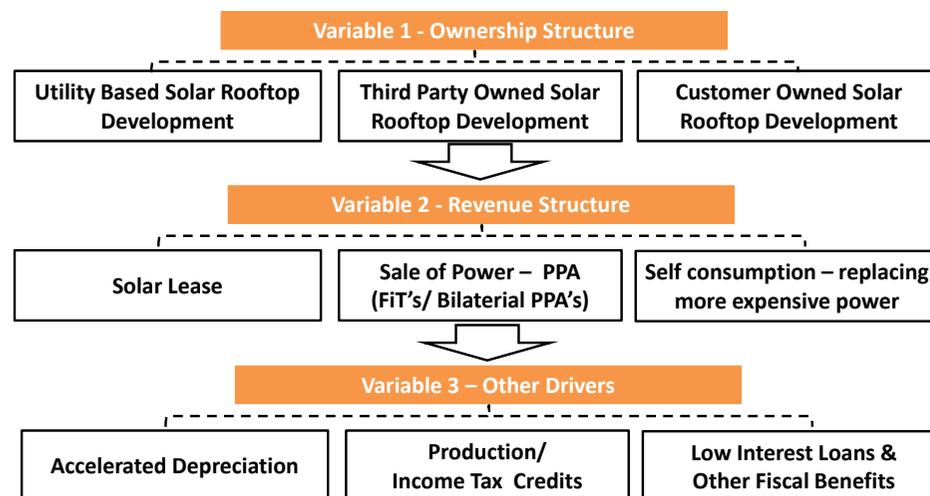


Figure 2-3: Solar Business Model Design Parameters.

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 is followed by other incentives which may be needed to ensure the financial viability of the business model.

2.3. Self-owned Business Models

Self-owned business models, as the name suggests, promote investment in solar rooftop systems by the end users of solar energy themselves. Self-owned business models have been developed through the following three routes:

1. Captive (off-grid mode)
2. Gross-metered
3. Net-metered

Systems developed under self-owned business models either generate electricity for onsite 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 financial institution like a commercial bank.

a. Captive (Off-grid Business Models)

- (i) Design and 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. The value proposition from these rooftop systems comes from either replacing the more costly diesel generators or providing grid quality electricity services. As the generation and consumption profiles vary significantly in these kinds of systems, storage systems like batteries need to be integrated with these systems.
- (ii) Ownership and Energy Consumption: As the name of model suggests, all of the systems are owned by the rooftop owners themselves who also consume all the power generated by the rooftop systems. To facilitate their establishment, the Ministry of New and Renewable Energy (MNRE), has over the years, been providing upfront capital subsidy for these systems.
- (iii) Revenue stream and benefits: As there is no sale of power, these systems have no specific revenue

stream, as the investment has been made for meeting the energy needs of the investor/ Rooftop Owner. However the returns to the investor can be determined by analysing the reduction in the cost of energy

- (iv) Advantages: Standalone 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 like diesel which are very expensive. These standalone captive solar rooftop systems, coupled with appropriate storage options provide a more reliable and cheaper option.
- (v) Disadvantages: Standalone 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

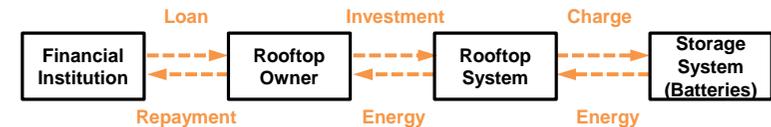


Figure 2-4: Design of captive (off-grid) business model.

always needs to be higher than what is optimally required, which in turn pushes up the cost of the energy.

b. Gross Feed

Gross feed based solar rooftop systems consist 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 a Feed in Tariff.

- (i) Design: Self-owned gross feed rooftop installations are amongst the most popular across the globe. The Gross Feed system was first adopted on a large scale by Germany. This model is prevalent in places where a feed-in-tariff (FiT) is applicable for solar rooftop installations under the assumption that this feed-in-tariff provides a minimum rate of return on the investment to the investor).

Under this model, the rooftop owner, who is also the consumer to the utility, installs a solar rooftop system with the intention of exporting (feeding in) all the power to the grid and earning a return in the form of a feed-in-tariff for each unit of power exported.

- (ii) Application: Gross feed rooftop solar systems have a huge application in areas with good grid reliability.

The key markets to adopt Gross Feed in Tariffs for solar rooftop systems have been Germany, Italy, France, other European Union nations, Japan and the Gandhinagar Solar Rooftop Pilot Project in India.

- (iii) Ownership: All the systems under this model are owned by the Consumers themselves. Rooftop Owners/ Consumers usually finance these systems through debt, equity and some fiscal incentives. In mature rooftop solar markets, most of these systems are eligible for project financing with no collateral from the Rooftop Owner. Most banks, especially in markets such as Germany, already have a set of Developers and Equipment Suppliers identified and the Consumer can go directly to these Developers and get the systems financed. The Rooftop Owner/ Consumer enter into a long term Power Purchase Agreement (PPA) with the Utility for the sale of power from the rooftop system.

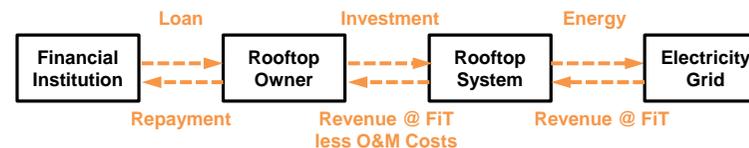


Figure 2-5: Design of gross feed business model.

- (iv) Revenue stream and benefits: These systems have a simple and well-defined revenue stream, which is linked to the energy generated and exported to the grid.
- (v) Advantages: The gross FiT model offers three main advantages:
- The biggest advantage of grid connected systems (whether Gross FiT or Net Metering based) is that these systems do not need to be coupled with stand-alone storage devices like captive systems (as the grid provides the necessary storage support), which in turn brings down the cost of energy generated from these systems.
 - The Gross Feed in Tariff model allows consumers to invest in renewable energy systems, resulting in the enhancement of the investment base for solar. The Gross Feed in Tariff mechanism also ensures that high paying consumers do not a) either migrate out of the utility eco-system or b) reduce their dependence on the utility (as is the case in Net Metered Solar Rooftop Systems). This safeguards the long term viability of the grid.
- Another advantage of the Gross Feed in Tariff Mechanism is that as the utility procures the solar rooftop power (mostly at a higher cost than what it pays for conventional sources of power), the higher cost of procurement is passed on as a part of the Annual Revenue Requirements (ARR) and socialised across all consumers being serviced by the utility.
 - The Gross FIT model allows all Consumer categories, regardless of their connected load and 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.
- (vi) Disadvantages: The FiT is usually higher than the average power purchase cost to the Utility, and hence, creates an apparent burden on the Utility's balance sheet due to the compulsion of buying expensive solar power, which in turn is passed onto the consumers as higher tariff.

c. Net Metering

- (i) Design: Self-owned net metering rooftop installations are amongst the most popular business model followed in several countries such as the United States and Japan. The net-metered solar rooftop business model promotes internal/ captive use of energy. It differs from the off-grid model as these systems are connected to the grid and allow the excess generation to be fed into the grid.

The connectivity to the grid allows these systems to do away with expensive storage devices, which in turn reduces the cost of power from the rooftop systems. Excess generation (when not required by the captive loads) is fed into the grid and captured as an export by a bi-directional meter. This energy is then netted out when an import takes place from the grid, say at night. Most Utilities and regulators aim to regulate the size of the systems in such a way

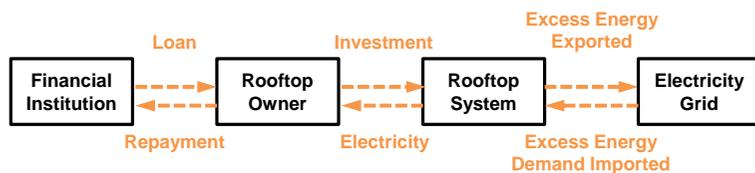


Figure 2-6: Design of net metering business model.

that the generation of the system is lower than the annual energy demand of the Rooftop Owner's energy requirements.

- (ii) Application: These rooftop systems have a huge application in all areas where grid reliability is good. The value proposition from this model comes from the difference between the Consumer tariffs and the cost of solar energy generation from solar rooftop installations. If the Consumer tariffs are higher than the cost of solar rooftop installations for specific Consumer categories, then the net metering mechanism and the associated business model become quite attractive for the Rooftop Owner. In case tariffs are lower than the cost of generation, then installations do not take place or have to be incentivised through fiscal incentives like capital subsidies.
- (iii) Ownership: All the systems under this model are owned by the Rooftop Owners/ Consumers themselves. Rooftop Owners/ Consumers usually finance these systems through debt, equity and some fiscal incentives. In mature solar rooftop markets, most of these systems are eligible for project financing with no collateral from the Rooftop Owner. Most banks, especially in markets like the United States, already have a set of Developers and Equipment Suppliers identified and

the Consumer can go directly to these Developers and get the systems financed.

(iv) Revenue stream and benefits: There are effectively two revenue streams in this model. The first is based on the savings due to avoided cost of power purchase from the grid. The second is the sale of surplus power generated over and above the Consumer's own consumption within a settlement period.

(v) Advantages: The net metering business model offers the following two main advantages:

- The net metering model does not depend on any high FiT (which is usually higher than the average power purchase cost for the Utility), and thus does not cause any significant outflow of funds from the Utility to Solar Rooftop Developers.
- The net metering model allows only those Consumers to install rooftop solar 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.

(vi) Disadvantage: The Net Metering framework works on the premise that solar power replaces more expensive grid power. Therefore the Net Metering concept works only for consumers with high grid tariffs. This framework has a severe limitation in a market like India where the cost of power for a large majority of the consumers is below the cost of solar power. The Net Metering framework also reduces the net quantum of power sold by Utilities to Consumers. As the net metering model is more attractive to Consumers paying a higher tariff to the Utility, this model tends to reduce sale of power to Consumers that account for higher returns to the Utility and who cross-subsidise the weaker sections of society.

2.4. 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. The Third Party may also lease out the entire system to the Rooftop Owner who may utilize power from the system to replace Utility-based power supply.

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 rooftop systems have been developed through the following two main routes:

- Solar Leasing
- Solar PPA

a. Solar Leasing

(i) Design: Leasing has been one of the key financing tools used across the capital equipment industry to finance equipment purchase and use. Solar leases were initially introduced in the U.S. market for financing residential PV systems. Under the leasing arrangements being followed in the U.S., the Rooftop Owner leases a solar PV rooftop system from a Lessor. The Rooftop Owner signs a lease agreement with the Lessor, under which, the Rooftop Owner agrees to make monthly lease payment to the lessor over a specified period of time while enjoying the benefit of the electricity generated from the system.

Case Study of Solar Leasing: SolarCity

SolarCity is one of the largest solar lease companies operating in the United States. SolarCity provides residential solar leases, which are financed by Financial Institutions like Morgan Stanley, Equity Investors who claim the Income Tax Credit (ITC) and depreciation benefits. SolarCity 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. SolarCity also guarantees a minimum level of electricity output (in kilowatt-hours) from the rooftop PV system.

(ii) Application: The electricity generated by the leased solar rooftop system is used by the consumer to reduce his/ her consumption from the grid leading to a reduced utility bill. The underlying requirement for this arrangement to work is that the savings from the reduced utility bill be higher than the cost of the monthly lease rental.

(iii) Ownership: The ownership of the solar rooftop systems lies with the lessor (who has leased out the systems). The leases are usually drafted for a fixed period of time and at the end of the lease period, the lessee (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. The lease arrangement provides an option for homeowners and other Consumers who wish to benefit from solar power but are unable or unwilling to make the large upfront investment in a solar PV system.

(iv) Revenue Streams and Benefits: The third party investor earns steady cash flows in the form of lease rental payments on a month to month basis while also benefiting from tax credits and depreciation benefits available to investors of solar rooftop equipment. The tax benefits available to the Lessor help shore up project IRRs which in turn bring down the cost of leasing the systems to homeowners. This has made solar leasing quite popular in the United States.

(v) Advantages: The key advantage of solar leasing solutions lies in a) the end user or the consumer not being required to make an investment in solar rooftop systems but still being able to obtain benefits available from these systems and b) cost reduction available to the consumers lessee's) leasing these systems. Lower cost of leasing these systems makes solar energy viable for a larger number of consumers.

(vi) Disadvantages: the two main disadvantages to the solar leasing framework are:

- Leasing of capital equipment like solar rooftop systems attracts a service tax by the Government of India, which makes leasing uncompetitive over the life of the project.
- There is no relation between the lease rental paid by the consumer to the Lessor and the quantum of energy generated from the systems. There is a need to benchmark lease payments with a minimum generation from leased systems.

The key challenge to this model in India is the service tax imposed on leases by the Government of India, which makes leasing uncompetitive over the life of the project

b. Solar PPA's

Design: Under the third party ownership model, third party developers invest in solar rooftop assets, which can then be sold either to the building owner (also the utility consumer) or fed into the grid. The basic reason why Third Party Development makes sense is that Third Party Developers have the wherewithal to aggregate rooftops and structure large projects which bring economies of scale and also

leverage a number of government incentives while developing these projects, 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 Power Purchase Agreement (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 and exports the solar energy generated from the rooftop installation to the Utility at a pre-determined FiT set by the regulator or a mutually agreed upon tariff. The key challenge in this model lies in the availability of the rooftop for 25 years as well as identifying locations for suitably large sizes of PV systems in order to keep the investment overheads as low as possible.

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 Wal-Mart Stores using the latter's rooftops at several locations. Often these PPAs are further sold to Investors who then become the owners of the installation and can claim tax credits and rebates on the investments. In its current form, this model is restricted in its application by factors like rooftop space, need for peak-differentiation in retail tariffs (e.g., through time-of-use tariff schemes, etc.) for viability and certain minimum day-time demand exceeding solar generation.

- Net Metering with Third Party Ownership of Systems: Under this arrangement the Rooftop Owner signs a Power Purchase Agreement 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. This model is quite prevalent in the United States; 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 tariffs. Under this sub-model the Rooftop Owners ask a Project Developer to build, own, and maintain

rooftop solar PV systems and sell the electricity generated to the host corporation (Rooftop Owner) at a fixed price over the long term using a PPA. Rooftop Owners, thus, avoid the large up-front costs of solar development while procuring clean green energy at a levelized tariff over the long term.

- (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 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.

2.5. Utility-based Business Models

Utility involvement in the solar rooftop market was initially limited to being a facilitator. The Utility mainly provides the broad framework for gross/ net metering and interconnections. Some Utilities also retail solar PV systems and provide system rebates, but this is limited to Municipal Utilities. However, a

Case Study: 5 MW Gandhinagar Rooftop Solar Programme

The 5 MW Gandhinagar Rooftop Solar Programme is a successful example of combined rooftop leased by Third Party with grid feed model via gross metering. This is among the first programmes to implement rooftop solar 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 power purchase agreement (PPA) with the local Distribution Utility of Gandhinagar, Torrent Power Limited. Power generated by each rooftop solar system is fed into and accounted for using a dedicated feed-in meter.

Rooftop lease agreements between the Project Developer and the Rooftop Owner, whether private residential or government, were designed at Rs. 3 per each kWh fed into the grid rather than a flat rent to ensure cooperation of the Rooftop Owner.

This programme has resulted into installations on 38 government buildings and 274 private residences. This programme is globally recognized and has become a benchmark for replication in several other cities of India.

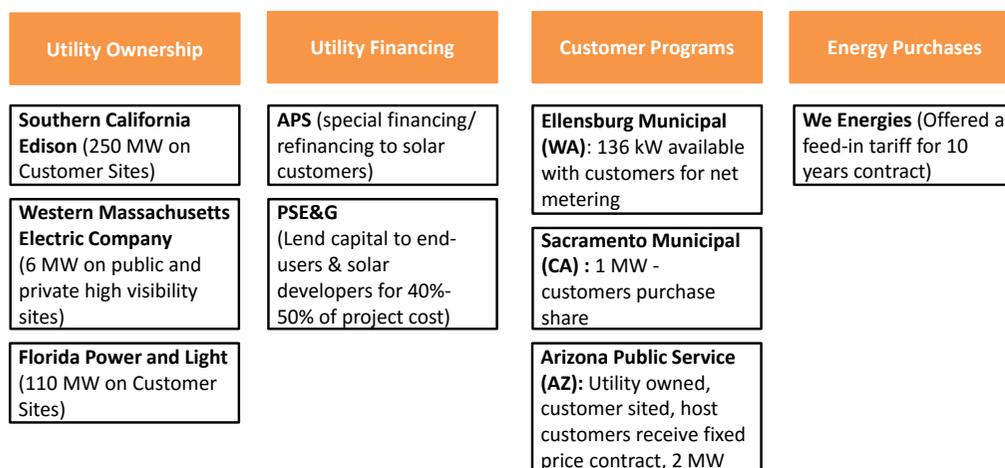


Figure 2-7: Utility-based business model.

growing number of Investor-owned Utilities have recently taken up a more active role in encouraging the development of solar rooftop installations due to a number of developments in the market.

The Utility business model is undergoing the most significant change since its development. Utilities, which were used to operating in a very benign environment have now had to face a more uncertain future due to a number of technological and economic developments like falling costs of distributed energy generation technologies; increasing Customer, regulatory, and political interest in demand side management (DSM) technologies and climate change considerations .

New disruptive technologies (solar PV, battery storage, fuel cells, etc.) are today becoming more and more competitive with Utility based energy services. As their cost curves improve, these technologies will force Utilities to change the way they deliver energy.

Keeping the impact of disruptive technologies like rooftop solar in mind, the Utilities have also started working towards active participation in these emerging segments.

Utility-based solar business models have started emerging wherein Utilities are now actively involved in innovating on the rooftop business model front in order to capture value from these solar markets. The Utilities involvement in the solar PV rooftop business model space has been limited to four broad

areas which have been highlighted in the figure below with relevant examples:

a. Utility Ownership

Utilities are becoming more and more aggressive in owning rooftop systems as it allows them to claim tax credits and at the same time ensure that they make a healthy rate of return on the power generated from these installations while also ensuring that Consumers with rooftops do not transit out (partially or fully) of the Utility's eco-system.

A number of Utilities ranging from San Diego Gas and Electric, Southern California Edison to Western Massachusetts Electric Company (WMECO) are aggressively developing rooftop installations on customer sites.

Ownership of solar PV assets by the Utilities has been pioneered by Utilities like Southern California Edison, Duke Energy and Arizona Public Service. The overriding reason behind 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

Case Study of Customer-sited PV: San Diego Gas & Electric

San Diego Gas & Electric's (SDG&E), under its Sustainable Communities Program encourages development of solar rooftop installations, owned by itself and installed on leased rooftops of Customers. The systems installed at Customer sited rooftops are installed, owned, maintained, and operated by SDG&E. SDG&E is also responsible for the design, installation, and maintenance work which is usually contracted out. The rooftops of the participating Consumers are leased by SDG&E, generally for 10 years, with a possibility of two five-year extensions. The rooftop systems are connected to the utility-side of the meter and the electricity flows right into the grid using a gross metering format. The Customer does not earn any energy credits nor is there a decrease in his/ her bill. However the Rooftop Owners can use the presence of the rooftop systems for obtaining Leadership in Energy and Environmental Design (LEED) credits. SDG&E obtained permission for a US\$ 4.3 Million investment from the regulators.

launched by a number of Utilities and Local Governments across the United States to facilitate adoption of solar PV. These financing options aim to address two broad aims of (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 broad types of loans are 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 appropriations, public benefit funds, alternative compliance payments, environmental non-compliance penalties, bond sales or tax revenues. Rooftop Owners prefer these as they come at low interest rates, 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 Share Solar Programmes provide Energy Consumers the option of utilizing the benefits of solar generation without actually installing on-site renewable

Case Study of Utility Financing: Powder River Energy Corporation

An on bill financing was offered by Powder River Energy Corporation of Wyoming to its Residential Customers wherein they could take loans up to US\$ 2500 at a zero percent rate of interest and repay the loan by 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 percent to 60 percent of the installed system cost. The solar system owner also has the option of repaying the loan by signing over solar renewable energy certificates to PSE&G.

generation or making high upfront payments required for the development of such projects. These plants are usually set up by Community-owned Utilities or Third Parties in partnership with Investor-owned Utilities.

They provide options for Customers to participate in and receive proportional benefits through virtual net metering or fixed price contracts. The Community Share Programme allows Utilities to develop larger programmes and projects while providing expanded options to more Customers at lower costs. The key challenge in this approach remains the need to ensure a compelling value proposition to Consumers. The broad outline of a community shared solar project model has been highlighted below.

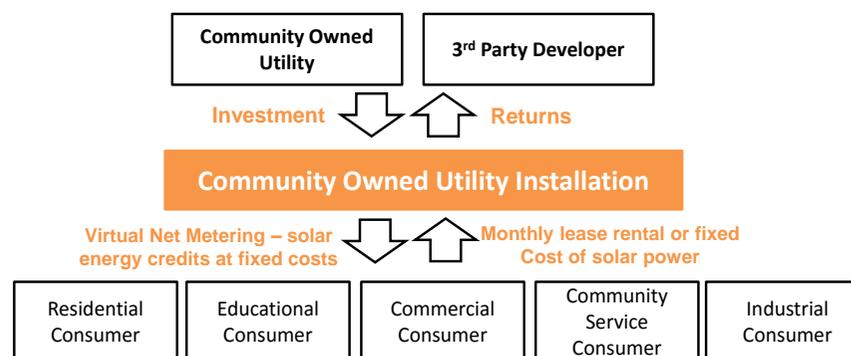


Figure 2-8: Community-shared Utility-based business model.

The advantage of community-based solar rooftop models for the communities is that they avoid the need to assess feasibility of solar rooftop installations, develop these installations and then monitor operation and maintenance. The community members who sign up for these projects receive solar benefits without paying upfront capital cost, installation or the O&M.

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 feed-in tariffs. The use of energy purchases allows the Utilities to buy all the energy generated by the rooftop at a flat price under a long term power purchase, the cost of which is passed onto the Consumers as part of its annual revenue requirements while

at the same time retaining the Customers on whose rooftops these systems have been set up.

2.6. Key Challenges and Considerations

While the Indian Power Sector provides a number of opportunities for a host of Developers/ Investors to come in and develop business models, however business model design and implementation 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.

Three Examples of Community Share Programmes offered in the United States

1. Tucson Electric Power: Bright Tucson Community Solar Program: Tucson Electric Power (TEP) is an Investor-owned Utility operating in the state of Arizona in the United States. In March 2011, TEP launched a Third Party developed community-based solar programme with the goal of developing 1.6 MW of new solar capacity in three years. This programme allowed the Community or the Consumers to buy generating blocks of 150 kWh per month for a monthly fixed fee of US\$ 3 per month. The investments for the solar installations were made by a Third Party Developer.

For every block purchased by the Consumer, a block charge of US\$ 3 per month is added to the Consumer's bill. In return the Consumer is allowed to consume 150 kWh per month per block and is exempt from future rate increases on the energy portion of the bill and two surcharges applied to other electric usage like the Renewable Energy Standard Tariff (REST) and the Purchased Power and Fuel Adjustment Clause (PPFAC). All of these factors combined result in a lower cost to the Consumer. Customers are also allowed to stop participating at in the programme at any time and do not incur a penalty.

The programme, which was launched initially in 2011 with the aim of developing 1.6 MW of solar power but the Consumer response received by the programme made it more successful than expected, and by July 2012, witnessed the development of 4.13 MW of solar power which included 777 Customers.

2. Colorado Springs Utilities' Community Solar Gardens Program: In 2010, the Colorado Utilities, the Municipal Utility serving the City of Colorado 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 \$0.09 /kWh on their electric bill for their share of the power generated by the panels they had leased. The Consumers could either lease or purchase panels at varying rates depending on the project. The pilot run by the programme was for 2 MW of installations.

As of October 2012, the Utility had 288 Residential and 1 Education Consumer participating in its programme and has a pipeline of another 51 Residential and 3 Educational Consumers waiting to be connected.

3. Sacramento Municipal Utility District's SolarShares Program:

The Sacramento Municipal Utility District (SMUD) SolarShares Program provides an opportunity to Customers who cannot or choose not to acquire PV systems on their own to purchase solar power directly from the installations under SMUD's SolarShares Program. The programme procures solar power from Third Party Developers or community based solar installations and passes these onto the Consumers. SMUD pays a fixed tariff for the power and then resells the solar power to participating Customers who get credits for the solar power using a virtual net metering scheme. The Customers pay a fixed monthly fee, based on the amount of PV to which they want to subscribe (from 0.5 to 4 kW). The Utility is now exploring moving from a fixed rental to a flat fixed fee per kWh, allowing Customers to purchase solar power in packets of 1,000 kWh/year. Initially Customers paid a premium for the solar energy they consumed, however as the rate at which they get power is locked and non-escalable, they gain as utility power costs increase.

Solar rooftop projects suffer from a number of commercial, policy and regulatory, technical and financing challenges which are being addressed as the market grows. However there is still a concerted effort required from Policy-makers, Regulators, Financers and above all the Utilities and the Developer community for all of these challenges to be appropriately addressed and the market to scale up.

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 feed-in tariff (FiT) similar to the solar FiT's offered by European markets like Germany. The FiT offered by the Utility is US\$ 0.225/kWh for 100 percent of the solar power generated, with the Customer getting a credit on its bill or a check when the accumulated amount exceeds \$100. The Company sets up a second meter, whose rent is around \$2.50 per month for time-of-use Customers and \$1.00 per month for all other Customers generating ≤ 40 kW. All PV systems between 1.5 kW and 100 kW are eligible for the programme and need to sign a 10-year contract and a standard interconnection agreement. Customers have the option of leaving the programme with a 60-day notice.

2. Gainesville Regional Utilities' (GRU) Feed in Tariff: GRU, a municipal Utility in Florida, offers a FiT as an alternative to the rebate programme. As a result of the FiT, GRU does not lose Utility Customers as it would have in a net metered programme, rebates can be spread over longer periods (five or ten years) instead of being offered up-front, the contracting is actually performance-based which in turn provides a greater leverage than the rebate programmes. These mechanisms provides a very transparent yet simple mechanism for the purchase of both solar generated power and the accompanying renewable energy credits.

Following are some of the key challenges associated with solar PV rooftop business model design:

- a. Contract Sanctity: One of the major challenges that Developers face in the Indian market are those related to contract sanctity. This essentially means according due recognition to the contractual framework which embodies the understandings between parties with appropriate legislative and legal back up in order that the protection of rights of any of the parties and enforceability are not eroded or taken away. Third Party Developers have to enter long term contracts with Rooftop Owners which are mostly backed up by Letters of Credit for one month's billing and with limited long term payment security.

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. The Developers as well as the financial institutions need to champion the development of these frameworks.

- b. Availability of Financing (especially project financing) and capacity of Financial Institutions to evaluate rooftop projects: Access to project financing and consumer financing is one of the key requirements for scale up the solar rooftop sector. Banks and Financial Institutions 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 financial institutions 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 Financial Institutions will have to also 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 United States is of depreciation or accelerated depreciation (AD) in the case of India. However many Developers use new Special Purpose Vehicles (SPV) for developing projects which in turn are unable to leverage this incentive mechanism due to no profits in new SPVs. The AD benefit can be utilised through Investors who have book profits and this would require these Investors owning the equipment and leasing the same to Rooftop Owners and Developers. These Investors would then be eligible for Accelerated Depreciation on the investment upfront.

While this does provide upfront relief in terms of lower costs, the Developers/ Rooftop Owners leasing the equipment needs to pay a service tax (14 percent) on the leased rental. The Net Present Value of the Service Tax paid by the Developer turns out to be higher than the tax savings from AD (for the Investor to make a 16 percent return on investment).

- d. Rooftop Leasing: Access to the rooftops for the life of the solar rooftop project remains another key challenge. A number of situations may arise where the Developer may not have access to the rooftop for the full life of the project due to either reconstruction or expiry of the lease. Most private sector institutions have leases which run up to 10 years and developing rooftop projects on buildings with 10 year leases becomes risky in case the building owner does not agree to become a part of the solar PV rooftop power sale and lease agreement and continue with the agreement with the new tenants once the building lease with the present ones is over.

In other cases Rooftop Owners are sceptical about leasing the rooftops for 25 years as they might want to construct more floors or in some cases reconstruct the whole building. This case has come to light in the New Delhi area where a number of institutions are not ready for rooftop solar despite a very competitive tariff and adequate space for rooftop systems have not agreed to the development of these systems.

- e. Role of Utilities – challenges and facilitation required: One of the biggest challenges facing the solar rooftop space is the limited capacity of the Utilities in understanding the solar PV rooftop space including the business models as well as developing a framework for their deployment. Interconnection processes are slowly being specified and in

some cases are long and cumbersome allowing only a few Contractors/ Developers to commission projects creating oligopolies.

A need exists for streamlining the interconnection process, making these time bound and transparent with a focus on achieving required quality standards. Utilities also need to be provided performance parameters for interconnection processes, which make them liable for ensuring time bound implementation. One example of where this is being attempted is the case of BESCO in Karnataka where an open sourcing framework has been developed and Developers need to 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, three basic disadvantages it suffers from are: (1) rooftop projects become attractive only for the commercial and industrial sector as these two pay the highest consumer tariffs, (2) Utilities end up losing their high-paying Customers, and (3) development of solar rooftop projects is not based on the optimal utilization of rooftop space.

The focus on Net Metered Consumers leaves out a large number of Consumers like schools, hospitals, and storage facilities etc. which have large rooftop space but do not have the financial justification of adopting net metered solar rooftop business models. A regulatory framework needs to evaluate the target market and reach of the business models which can work and aim for optimal rooftop utilization and penetration.

In conclusion, this chapter describes various business models that can be implemented to boost and sustain the rooftop solar 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 Manual.



3. Policy and Regulation

3.1. Purpose and Introduction to Policy

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

1. Give clarity to various departments within the Government on the action plan and direction of the Government, and
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, and more so for the solar sector that is still dependent on Government subsidies and frameworks in order to become economically viable.

3.2. Key Considerations and Components in Framing a Policy

A solar rooftop policy should ideally consider and address the following clauses:

Who frames the Policy: State or Centre?

Both the Central and State Governments are responsible for framing policy. The Electricity Act 2003, vests responsibility on both Governments to bring out policy for the power sector.

The Central Government has the key responsibility of preparing the National Electricity Policy, Plan and the Tariff Policy in consultation with the State Governments. This responsibility is laid out clearly in the Electricity Act, 2003. The relevant sections in the Electricity Act, 2003 are:

1. “The Central Government shall, from time to time, prepare the national electricity policy and tariff policy, in consultation with the State Governments and the Authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or materials, hydro and renewable sources of energy” (Section 3).
2. The Authority shall prepare a National Electricity Plan in accordance with the National Electricity Policy and notify such plan once in five years (Section 3).

a. Vision of the Government

The vision of the Government indicates the goals and aspiration of the Government for its people. All implementation programs and schemes stem from having a concrete vision. A vision also helps align various departments within the Government and between the Centre and the State Government during times of differences. The vision indicates the long-term objective of the government.

A model rooftop solar policy could consider the following as its vision statement:

In order to promote the effective use of solar energy in the state's contribution towards actions to arrest the effects of climate change, the state of [State Name] announces the [State Name] Rooftop Solar Policy [Year].

The state of [State Name] is endowed with high solar radiation with about [number] sunny days in a year. The state has ample radiation between [number] kWh per square meter per day".

While large scale solar projects present a possibility whereby a rapid scaling of solar energy in the electricity mix is possible in a short space of time, it is

also necessary to promote distributed energy generation for the following reasons:

- 1. Distributed solar energy is an effective way to distribute the impact over a larger geographical region and consequently a larger section of the grid.*
- 2. Distributed generation ensures that the transmission and distribution losses are minimized since the point of generation and consumption are located at the same premise.*
- 3. Distributed generation can stabilize the grid parameters such as frequency, phase and voltage due to the presence of advanced power electronics (inverters) at the tail end of the grid.*
- 4. Promote local employment and enable skill development along the different components of the solar rooftop value chain.*
- 5. Strive towards enhancing the distribution grid through technological aids such as smart-grid and energy storage.*
- 6. Promote local manufacturing and innovation, thus further driving down the cost of solar energy.*

7. Distributed generation results in people's participation in the transition to cleaner and an environmentally friendly source of electricity.

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.

Typical goals are measured in kW or MW over a definite period of time.

The targets can be in line with the rooftop solar targets announced by MNRE through its Notification No. 03/13/2015-16/GCRT dated 30th June 2015, which are summarized in Table 3-1.

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 increase, thereby increasing the uptake of these systems.
- Increasing Power Tariffs: Most consumers opt for rooftop solar PV systems as an effective way to hedge escalating power prices. As power prices increase

Table 3-1: State-wise rooftop PV targets specified by MNRE.

State	Target by 2022 (MW)
Andhra Pradesh	2,000
Bihar	1,000
Chhattisgarh	700
Delhi	1,100
Gujarat	3,200
Haryana	1,600
Himachal Pradesh	320
Jammu & Kashmir	450
Jharkhand	800
Karnataka	2,300
Kerala	800
Madhya Pradesh	2,200
Maharashtra	4,700
Odisha	1,000
Punjab	2,000
Rajasthan	2,300
Tamil Nadu	3,500
Telangana	2,000
Uttarakhand	350
Uttar Pradesh	4,300
West Bengal	2,100
North East	600
Union Territories	680
TOTAL	40,000

steadily over time, many more consumers would begin to augment their current grid consumption with rooftop solar PV.

- **Maturity in ecosystems:** As time progresses and various stakeholders in the rooftop solar PV 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 ecosystems. As banks familiarize themselves with lending to rooftop solar PV systems from home and business owners, the costs of financing and timelines will reduce.

Another key determinant in setting goals for rooftop solar installation in the policy is the amount of subsidy available. Currently, there is a 15 percent capital subsidy from the MNRE for rooftop solar 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.

A policy can consider the following objectives/ goals/ targets:

- 1. Greater community participation in rooftop solar energy generation**
- 2. Greater job creation and skill development in the solar PV sector**
- 3. Reduce the carbon emission of the state**
- 4. Promote the clean-tech sector as a whole in the state**
- 5. Reduce the utilization of land-based solar and other energy projects by using available roof space**
- 6. Reduce transmission and distribution losses by generating energy near the consumption centres**

In order to achieve these objectives, the State endeavours to meet a goal of [target] MW of both grid-connected and off-grid rooftop solar capacity during the operative period of this policy keeping in line with the goals of the National Solar Mission.

c. Operative Period

The operative period is the tenure of the policy. Typical policies are extant for a period of anywhere between 3-5 years. There are a few considerations while determining the tenure of the policy:

- The election cycle and the mandate of the people. Changing governments and subsequently any 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 earlier plans and policy direction have turned void. This has necessitated a revision in the policy and corresponding schemes under the policy. This takes time since various departments and stakeholders within the Government have to be consulted. This period generally results in a dip in installation and can derail the roadmap to the target. It is therefore suggested that the policy tenure might be short enough to quickly adapt to the fast changing market.
- Policy tenure should be in line with the Central Government's nation 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 of, for instance 2021.

The following clause can be considered for operative period:

The Policy shall come into effect from the date of its notification in the State Gazette and shall remain valid until [date / month / year].

d. Nodal Agency

A Nodal Agency is the responsible 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.

The following clause can be considered for Nodal Agencies:

The [State Energy Development Agency] shall act as the Nodal Agency to implement the rooftop solar projects and facilitate a single window for the benefit of Consumers, Investors and other Stakeholder.

e. Implementing Agency

While the Nodal Agency would 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 rooftop solar programme.

As grid-connected rooftop solar 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 State Nodal Agency can become the implementing agency for stand-alone solar projects.

The following clauses can be used for Implementing Agency:

The respective DISCOM shall be the Implementing Agency for grid-connected (including hybrid) rooftop solar PV projects within their distribution area. The Implementing Agency shall develop simple procedures for approvals and interconnection, and publicize them for efficient implementation of the projects; these procedures should be in accordance to the State Electricity Regulatory Commission's orders, as notified and amended from time to time.

f. Eligible Entities

Eligible entities are usually among the different categories of electricity Consumers mentioned the State Electricity Regulatory Commission 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 financial implication on the state or one of its distribution companies. 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 keep on promoting rooftop solar PV. 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'. With an evolving rooftop solar PV financing ecosystem, various business models are in vogue. An Eligible Entity may be an Owner of the building, a Tenant or even a Third-Party Investor.

The following clauses may be used for Eligible Entities:

The following category of Consumers shall be allowed to implement and integrate rooftop solar systems onto the grid:

- 1. Domestic Consumers***
- 2. Industrial Consumers***
- 3. Commercial Consumers***
- 4. [Add other types of Consumers]***

An Eligible Entity is a:

- 1. Person or Company that either own the system or lease the system from a Third-Party Financer/ Developer/ Investor,***
- 2. Legal Owner of the premise on which the rooftop solar system is to be installed OR a Tenant of the premises in case the building is leased, and***
- 3. Consumer of the Distribution Licensee for the area on which the building is located.***

g. Schemes/ Applicable Business Models

A Rooftop Solar 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, may include specific subsidies and incentives that are also time bound, 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 power purchase agreement with the Rooftop Owner/ DISCOM/ Open Access Consumer OR through direct sale of equipment and engineering services (example: an EPC company). A good policy should take in to account all these factors and promote various possibilities where investors may get involved. This would result in a vibrant and dynamic market.

The following clauses for schemes/ business models can be used:

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 would like to sell energy to the DISCOMs by using roofs owned by another party.

Various incentives and exemptions applicable to a rooftop solar PV programme are summarized in Table 3-2.

Table 3-2: Reference incentives and exemptions applicable to a rooftop solar PV policy.

Type of Incentive/ Exemption/ Parameter	Sale to Distribution Licensee		Sale to Third Party
	Net Metering	Gross Metering	Open Access
PV System Capacity	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.
Ownership	Self-Owned	Self-Owned or Third-Party Owned	Third Party-Owned
Demand Cut	50% of the Consumers current billing demand	Not applicable	50% of the Consumers current billing demand
Billing Cycle	As per consumer's current billing cycle	Monthly	Solar energy to be adjusted on a 15 minute-basis
Banking	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
Tariff	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

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Type of Incentive/ Exemption/ Parameter	Sale to Distribution Licensee		Sale to Third Party
	Net Metering	Gross Metering	Open Access
Wheeling Charges	Not applicable	Not applicable	As per concerned SERC order
Transmission Charges	Not applicable	Not applicable	As per concerned SERC order
Wheeling Losses	Not applicable	Not applicable	As per concerned SERC order
Transmission losses	Not Applicable	Not Applicable	As per SERC order
Cross Subsidy Surcharge (CSS)	Not Applicable	Not Applicable	Exempted as a promotional measure
Electricity Duty	Not Applicable	Exempted	Exempted
Renewable Energy Certificate (REC)	Consumer can claim REC for solar energy consumed by self and energy sold 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 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.
Renewable Purchase Obligation (RPO)	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.
Clean Development Mechanism (CDM)	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 rooftop solar policy; however if incorporated, provides clarity to both Companies/ Investors and to the Government Departments themselves.

However, it should be indicated that the procedures should be framed by respective DISCOMs and publicized upon notification of the policy. Model procedures are indicated in Chapter 5 of this Manual.

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 Rooftop Solar PV 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” 2006, 2010

The following clauses can be used for technical requirements:

All Rooftop solar PV systems in the State shall be governed by the Central Electricity Authority rules and regulations namely,

- ***Central Electricity Authority (CEA) “Technical Standards for connectivity of the Distributed Generation Resources) Standards 2013;***
- ***CEA “Measures relating to Safety and Electricity Supply” standards 2010; and***
- ***CEA “Installation and Operation of Meters” 2010; as amended from time to time.***

3.3. Purpose and Introduction to Regulation

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

1. Determine benchmark capital costs and tariff for rooftop solar 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; and
3. Ensure the proper interpretation of the Electricity Act, 2003 and resolve any disputes between Power Producers, DISCOMs and Consumers.

Regulations for rooftop solar 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 State Electricity Regulatory Commissions 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.

3.4. Key Considerations and Components in framing Regulations

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 rooftop solar systems. This term is also used in

the State/ Central Rooftop Solar 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 assess eligibility on other financial and social criteria as well.

The following clauses can be used for title, scope and application:

In exercise of powers conferred under Section 181 read with Sections 61 and 86(1) (e) of the Electricity Act, 2003 (Act 36 of 2003) and all other powers enabling it in this behalf, the [State] Electricity Regulatory Commission hereby makes the following regulations for grid connectivity of solar rooftop photovoltaic system.

These regulations may be called the [State] Electricity Regulatory Commission Net Metering Regulations, [Year].

These Regulations shall come into force from the date of their publication in the official gazette.

These regulations shall apply to all Consumers (residential, industrial, commercial and government) in the area of supply of the Distribution Licensee.

System Classification

These regulations are applicable to both distributed ground mounted and rooftop PV systems that are of capacity greater than 1kW and less than 1,000 kW.

Ownership

Both self-owned and third-party financed/ owned systems shall be eligible under this regulation.

Types of Metering

Both net metering and gross metering shall be allowed under this regulation.

b. Applicable Models

All models for grid connectivity such as net metering, gross metering and other models such as Renewable Energy Certificates (REC) and Ownership models can be addressed here. In fact, although there is significant overlap with the Rooftop Solar Policy, it is good for the SERC and the State Government to be in line with each other on this topic.

The following clause can be used to indicate applicable models:

Both gross metering and net metering shall come under the ambit of this regulation.

- 1. Gross Metering – Under gross metering, the system Owner (Consumer of Distribution Licensee OR Third Party Financer OR Developer) shall export energy into the grid irrespective of the consumption of the building on which the rooftop solar PV system is located. This can be considered as a direct sale to the Distribution Licensee.*
- 2. Net metering – Under net metering, the consumption of the building on which the rooftop solar PV system is installed is set off from the energy exported on to the grid. In this arrangement, the System Owner and the Consumer of power from the Distribution Licensee are typical the same. Any financial arrangement between a Third-Party Financer/ Developer and the Rooftop Owner are allowed, but do not fall under the gambit of this regulation. All agreements between the Financer/ Developer and the Consumer are independent. In all such cases, the DISCOM shall only enter into agreement with the Consumer.*

Renewable Purchase Obligations (RPO) and Renewable Energy Certificates (REC)

REC can be availed only under the following conditions:

- (i) ***If the quantum of energy injected into the grid does not fulfil any Obligated Entity's RPO requirement;***
- (ii) ***If the quantum of energy injected into the grid is not purchased at preferential tariff; and***
- (iii) ***The Developer abides by all other provision as per the relevant REC regulations.***

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 this Manual.

d. Procedure and Process

Regulations do not need to contain detailed process flows 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 this Manual. The following clauses can be used to highlight these procedures in the regulation:

The Distribution Licensee shall allow connectivity to the rooftop solar PV system, on first come first serve basis, subject to operational constraints.

Provided that the available capacity at a particular distribution transformer, to be allowed for connectivity under these Regulations, shall not be less than the limits as specified by the Commission from time to time.

The Distribution Licensee shall provide information regarding distribution transformer level capacity available for connecting rooftop solar PV system under net metering / gross metering arrangement within 1 (one) month from the date of notification of these regulations on its website and shall update the same within 7 working days of the subsequent financial year under intimation to the Commission.

The capacity of Renewable Energy System to be installed at any premises shall be subject to:

1. ***the feasibility of interconnection with the grid;***

2. ***the available capacity of the service line connection of the consumers of the premises; and***
3. ***the sanctioned load of the Consumer of the premises;***

The Distribution Licensee shall formulate a detailed, transparent online procedure for application, registration and grant of approvals for consumers who wish to install rooftop solar PV systems in the area of the Distribution Licensee.

e. Grid Connectivity, Standards and Safety

The regulation must point to the Central Electricity Authority (CEA) “Technical Standards for connectivity of the Distributed Generation Resources) Standards 2013

The regulation must also point to the Central Electricity Authority (CEA) “Measures relating to Safety and Electricity Supply” standards 2010.

Safe solar PV penetration levels must be mentioned on a Distribution Transformer-basis.

The following clauses can be used for grid connectivity, standards and safety:

The distribution licensee shall ensure that:

- (i) ***the interconnection of the rooftop solar PV system with the distribution system of the Distribution Licensee conforms to the specifications, standards and provisions as provided in the Central Electricity Authority (Technical Standards for connectivity of the Distributed Generation Resources) Regulations, 2013, as amended from time to time; and***
- (ii) ***the interconnection of the Renewable Energy System with the distribution system of the Distribution Licensee conforms to the relevant provisions of the Central Electricity Authority (Measures relating to Safety and Electric Supply), Regulations, 2010, as amended from time to time.***

The Solar rooftop PV generator shall be responsible for safe operation, maintenance and rectification of any defect of the PV system up to the point of tariff meter beyond which the responsibility of safe operation, maintenance and rectification of any defect in the

system, including the gross/ net meter, shall rest with the Distribution Licensee.

The Distribution Licensee shall have the right to disconnect the solar rooftop PV System at any time in the event of possible threat/ damage, from such Renewable Energy System to its distribution system, to prevent an accident or damage. Subject to Regulation 4 (2) above, the Distribution Licensee may call upon the Renewable Energy Generator to rectify the defect within a reasonable time.

The Distribution Licensee shall ensure that the cumulative installed capacity on any Distribution Transformer shall not exceed 100 percent of the transformer rating in kVA or MVA. Once this penetration limit has been reached, the Distribution Licensee must carry out a detailed load flow study before granting any further connection approvals.

f. Metering

The regulations must point to the Central Electricity Authority (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 cost for 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). Time of Day (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.

The following clauses concerning metering can be considered:

All the meters shall adhere to the standards as specified in CEA (Installation and Operation of meters) Regulations 2006 and (Installation and Operation of meters) Regulations, 2010 as amended from time to time.

The net/ gross meter shall be as per single phase or three-phase requirement. All the meters to be installed

for net/ gross metering shall be of the same Accuracy Class Index as the Consumer's existing meter.

The cost of the net/ gross meter shall be borne by the Consumer of the premises. The Consumer of the premises or the Distribution Licensee, who so ever if desires, may install check meter at their own cost.

The charges for the testing and installation of the net/ gross meters shall be borne by the Consumer of the premises.

The net/ gross meter at the premises of the Consumer shall be procured and installed by the Distribution Licensee. However, if the Consumer wishes to procure the net/ gross meter, it may procure such meter and present the same to the Distribution Licensee for testing and installation.

All meters, including the net/ gross meter and any other meters measuring renewable energy generation shall be installed at an accessible location of the premises to facilitate easy access for meter reading to the Distribution Licensee.

The net/ gross meter to be installed at the premises of the Consumer under the ambit of time of day tariff shall be time of day (ToD)-compliant.

g. Energy Accounting, Billing and Banking

Energy accounting, billing and banking are essential for settlement of excess energy are to be considered

Typical factors that need to be considered are:

- Differentiation between residential, industrial, commercial and other types of consumers (if needed),
- Differential between Open Access Consumers, Captive, Self-Owned Systems and Third Party Owned Systems (if needed),
- What is the settlement period (1 month / billing cycle / 1 year / 15 minute basis)?
- 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 charges for 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.

The following clauses can be considered for energy accounting, billing and banking:

The accounting of electricity generated, consumed and injected by the Consumer under these regulations shall become effective from the date of connectivity of rooftop PV system with the distribution system under these regulations.

The procedure for billing and energy accounting shall be applicable as directed by the Commission from time to time.

The Distribution Licensee shall show, separately, the energy units exported, the energy units imported, the net energy units billed and/ or the energy units carried forward, if any, to the consumer in their bill for the respective billing period.

If during any billing period, the export of units exceeds the import of units consumed, such surplus units injected by the Consumer shall be carried forward to the next billing period as energy credit and shown as energy exported by the Consumer for adjustment against the energy consumed in subsequent billing periods within the settlement period.

During any billing cycle, the Distribution Licensee shall raise invoice for the net electricity consumption, as per

applicable tariff, only after adjusting/ netting off of the unadjusted energy credits of the previous billing cycle(s).

The surplus energy measured in kilowatt-hour shall be utilized to offset the consumption measured in kilowatt-hour only unless otherwise allowed by the Commission from time to time. In case the Consumer is billed on kVAh, during injection of surplus energy to the grid, the Power Factor shall be assumed equal to unity.

At the end of the each Financial Year, the Distribution Licensee shall pay for any net energy credits, which remain unadjusted, to the consumers as per the rates notified by the Commission from time to time.

h. Renewable Purchase Obligation (RPO), Renewable Energy Certificates (REC) and other Green Attributes

One of the main drivers of any solar programme, whether on rooftop or on the ground, is the renewable purchase obligation (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.

Rooftop solar PV plants directly cater to the renewable purchase obligation. 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.

The following clause may be considered for renewable purchase obligation:

Distribution Licensee shall claim RPO if (i) consumed solar energy is not credited towards the RPO of the Consumer or any other Third Party, and (ii) no REC is claimed for the generated solar energy.

Green attributes include International Carbon Credits and India's National Renewable Energy Certificate Mechanism (REC). 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.

The following clauses can be considered towards green attributes:

Renewable Energy Certificates (REC)

RECs can be availed by the PV system Owner against 100 percent of generated solar energy provided:

- ***The generated solar energy is not accounted towards the RPO of the Consumer, Distribution Licensee or any other Third Party;***
- ***The generated solar energy is not procured by the Distribution Licensee at a preferential tariff; and***
- ***The rooftop PV systems abide by all relevant REC regulations.***

Clean Development Mechanism (CDM)

100 percent of all CDM shall accrue to the Owner of the solar PV system.

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.

The following clause may be considered:

The Commission may from time to time issue directions/ guidelines/ orders/ amendments or relax any of the above provisions in the regulations either in response to a petition from any stakeholder of Suo Moto as it may deem fit.

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 rooftop solar 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, which 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), which 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. A grid-connected PV systems is designed to automatically shut down if it detects anomalies in grid parameters such as voltage, frequency, rate of change of 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 isolate the Consumer from the grid and continue to supply power from the PV system and batteries. Batteries can be charged by the grid or by solar energy in such systems.

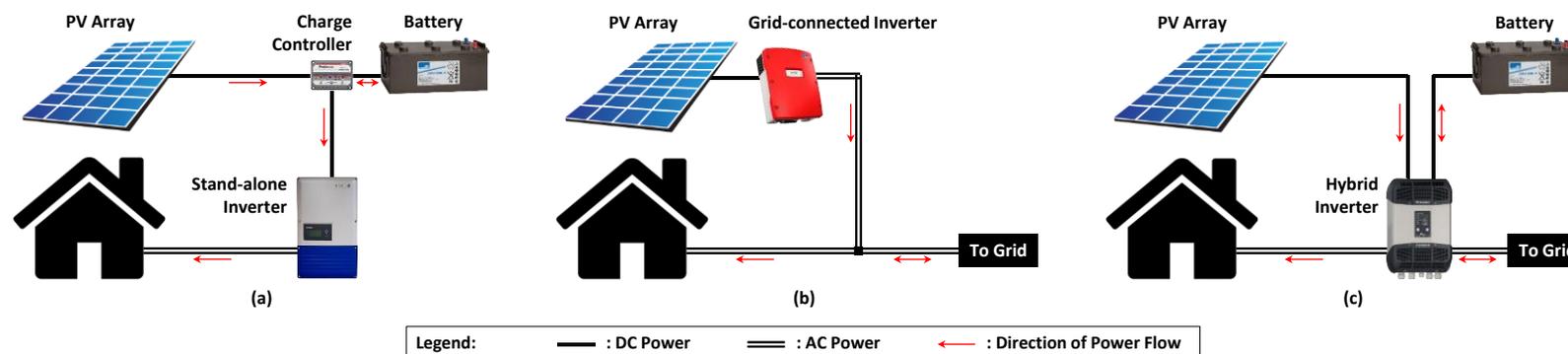


Figure 4-1: Options for connectivity to the grid: (a) stand-alone PV system, (b) grid-connected PV system, and (c) hybrid PV system.

- (iv) Other grid-interactive PV systems are also evolving in India wherein PV systems are directly connected with UPS systems. Such systems are functional of operating irrespective of grid conditions, but are usually not capable of feeding energy back into the grid.

b. Metering arrangement:

- (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 import of conventional energy from distribution grid is recorded by the usual 'consumption meter' and export of solar energy into the grid is separately recorded by a different 'feed-in meter.'

Grid-connected PV systems can be gross-metered.

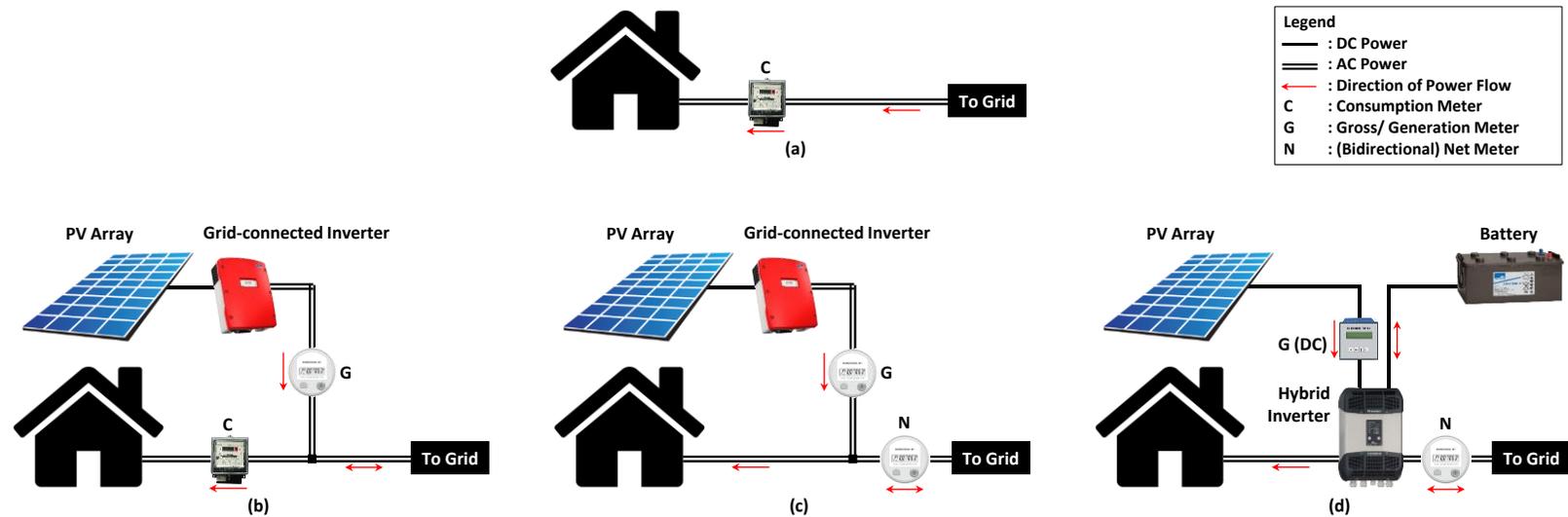


Figure 4-2: Metering arrangement: (a) conventional metering, (b) gross metering or feed-in metering, (c) net metering, and (d) net metering hybrid system.

c. **Interconnection voltage** (i.e. the voltage level at which the PV system is connected to the existing grid) is primarily governed by the regulation of the respective state. In case of direct interconnection with the distribution grid, the following interconnection voltages may be applicable:

- (i) For rooftop PV systems with capacity less than 4 kW (or 5/ 6/ 7/ 10 kW in some states) are connected to the distribution grid at 240 V_{AC}, 1 ϕ , 50 Hz.
- (ii) For rooftop PV systems with 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) are connected to the distribution grid at 415 V_{AC}, 3 ϕ , 50 Hz.
- (iii) For rooftop PV systems with 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) are connected to the distribution grid at 11 kV_{AC}, 3 ϕ , 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 could 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. Design of Grid-connected Rooftop PV Systems

a. General design of a net-metered rooftop PV system:

Rooftop PV systems can be designed based on multiple topologies, but the basic design philosophy remains uniform. This section briefly describes the main electrical components and topologies of a grid-connected rooftop PV system. Figure 4-2 shows various topologies of a net metering configuration, wherein the grid-connected PV system feeds power into the main AC distribution panel of a Consumer.

1. **PV Modules** convert sunlight directly into DC electricity. Solar cells (which are typically made of crystalline, polycrystalline or amorphous Silicon or other compound semiconductors like Cadmium Telluride-CdTe and Copper Indium Gallium Selenide-CIGS) are connected in series and encapsulated in a PV module.

PV modules are rated for a particular power capacity at standard testing conditions (STC), which is also indicated in its label. The number and capacity of PV modules primarily decide the capacity of the PV plant.

The safety and quality of the PV module is ensured through appropriate certifications, warranties and guarantees. PV modules typically carry a performance warranty of 90 percent for the first 10 years, and 80

percent for the next 15 years. Workmanship warranty on the PV module is typically for 5 years. Top tier PV module manufacturers also provide a back-to-back bank guarantee in addition to their manufacturer's warranty as an added assurance for their product.

- A number of PV modules connected in series is called a **String**. A string is designed such that it provides an output voltage in a range that is compatible with the solar inverter's input voltage range. Strings are then connected in parallel in a PV plant to achieve the desired DC capacity. The maximum allowable string voltage in India is $1000 V_{DC}$.

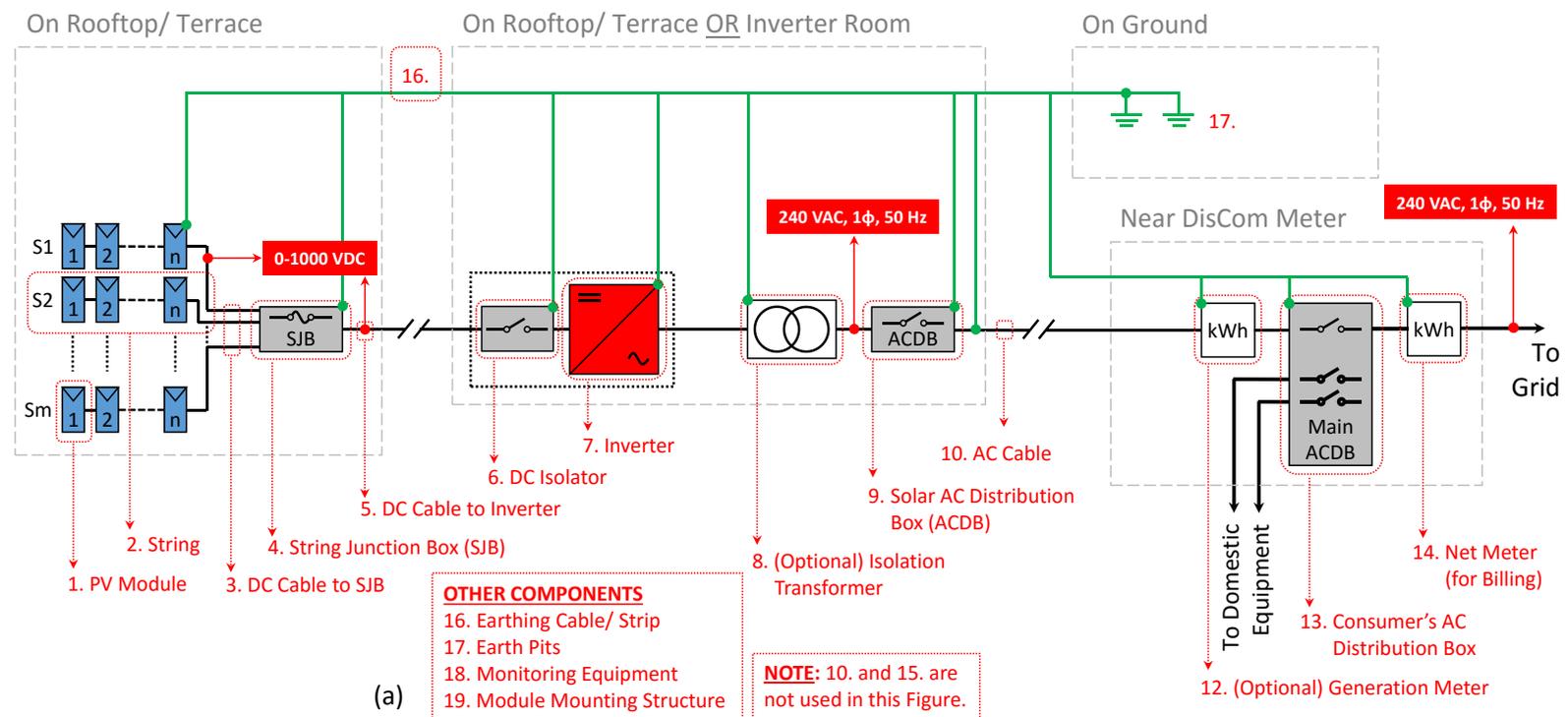
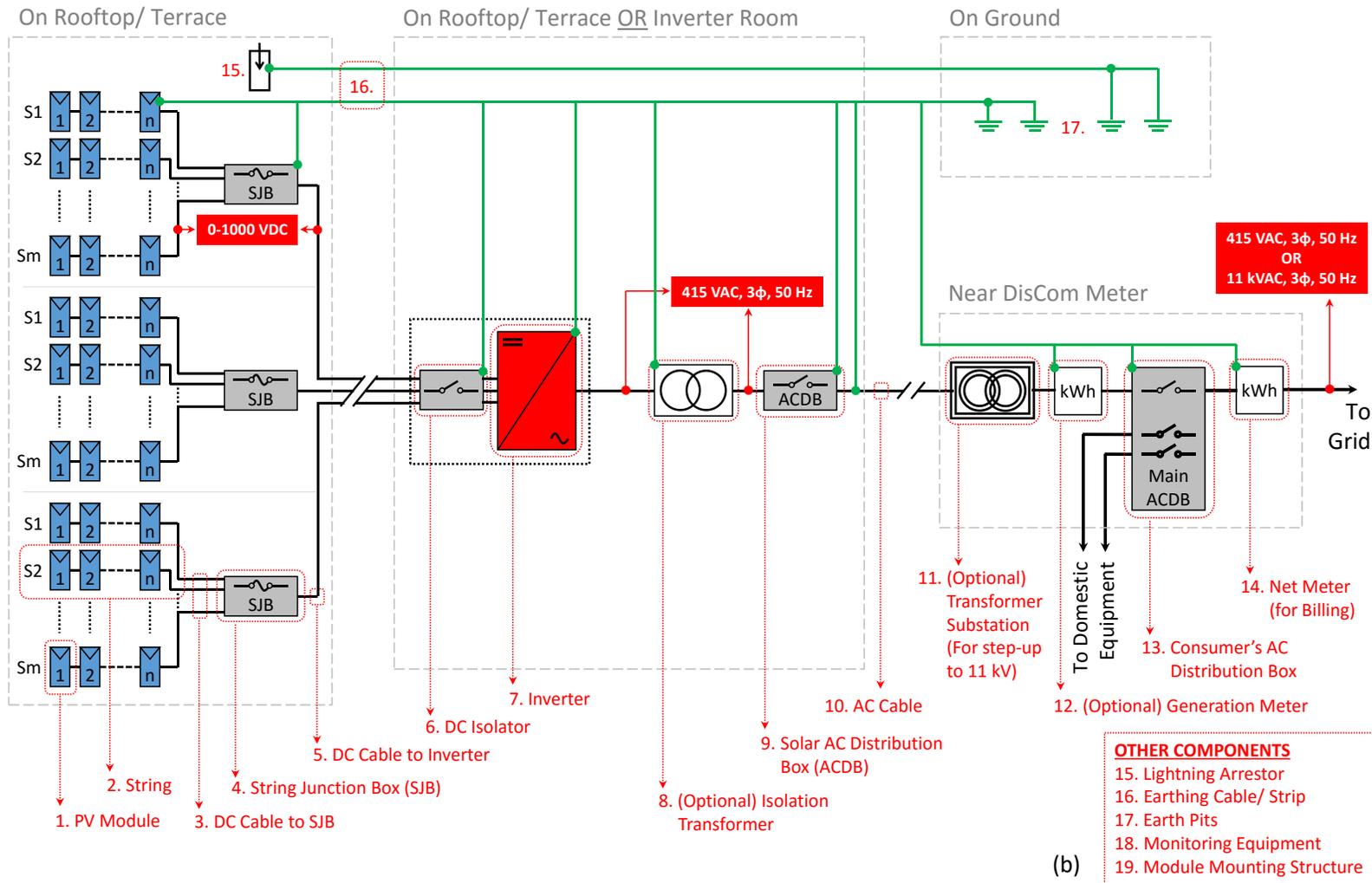
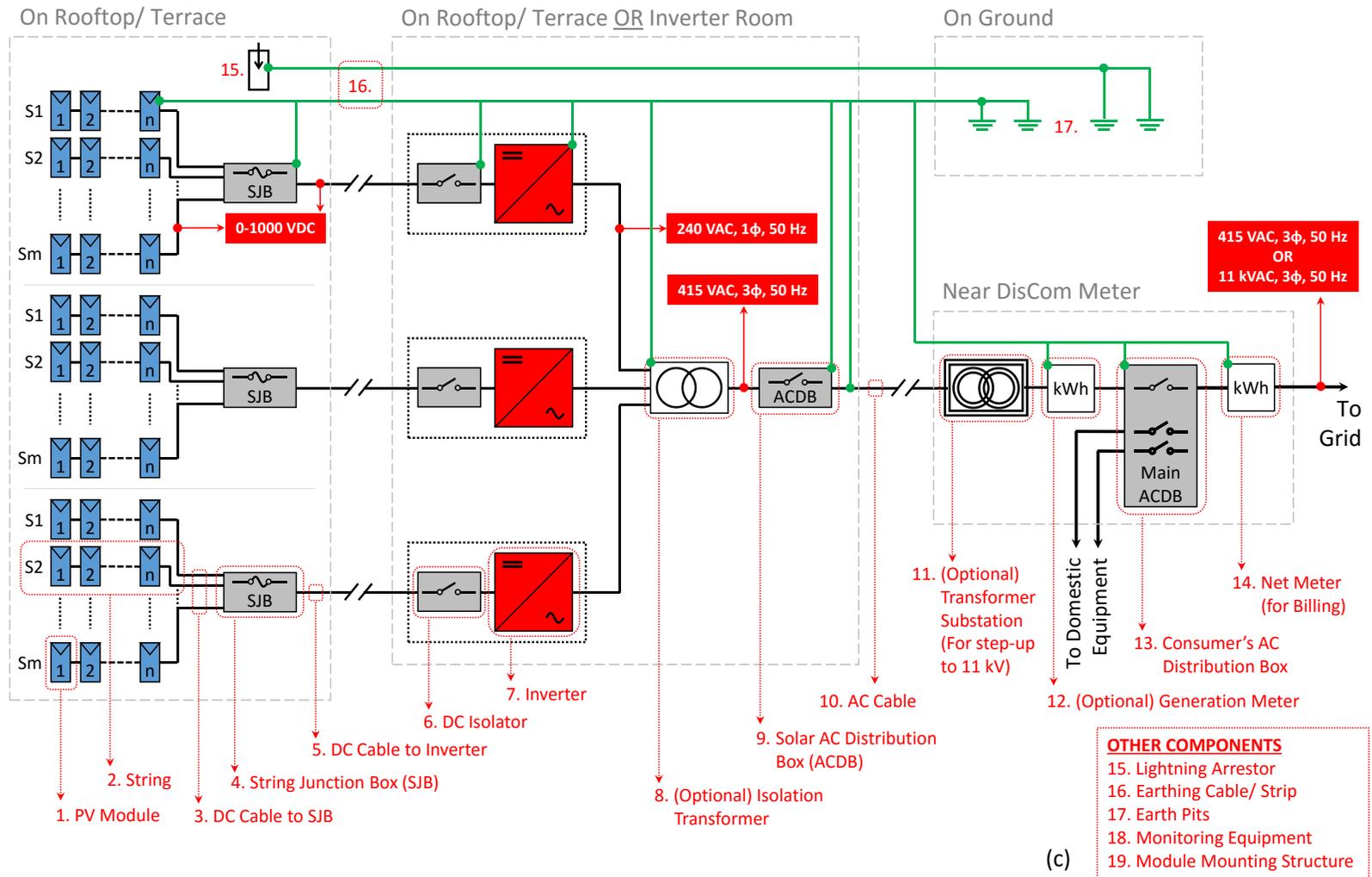


Figure 4-3: Topologies of PV system with net metering using (a) one single-phase inverter, (b) one three-phase inverter, and (c) three single-phase inverters.



[...(b) one three-phase inverter...]



[...(c) three single-phase inverters]

3. **DC Cables** conduct solar electricity from the string to the string junction box. The DC cable should be sized to carry the required current (along with necessary safety margins) and also limit the voltage drop (i.e. resistance losses).

Typically, single-core multi-stranded copper cables with cross section 4 or 6 mm² rated for a maximum voltage of 1.8 kV_{DC} are used for string connections of PV modules up to the string junction box. Halogen-free flame-retardant weather-resistant cross-linked polyethylene (XLPE) or UV-resistant polyvinylchloride (PVC) sheaths should be used. It is a common practice to use red-coloured sheath for positive terminal of the string and black-coloured sheath for negative terminal of the string.

The DC cables used in solar strings use specialized connectors. Such connectors are characterized by their electrical properties, mechanical properties and weather resistance. As these connectors are usually installed outdoors, they should be IP67-rated, UV and fire-resistant with a typical operating temperature of -40°C to +85°C. The contact resistance at the DC connectors should be minimal (typically less than 0.5 mΩ) and rated for at least 30 A_{DC} (but not less than the short-circuit current expected through that connector with necessary safety factors) and 1000 V_{DC}.

While MC4 connectors are the most common, other connectors such as H&S (Radox), Tyco, Amphenol Helios (H4) and SMK are also often used.

4. The **String Junction Box (SJB)** combines multiple DC strings in parallel. SJBs are also known as **String Combiner Box (SCB)** or **Array Junction Box (AJB)** or **PV Generator Junction Box**. SJBs should be weather resistant as they are typically installed outdoors.

SJBs should contain fuses and surge protection devices (SPD) to protect the PV modules as well as inverters. If the inverter has sufficient number of DC input terminals along with surge arrestor and overcurrent protection capabilities, then the SJB itself can be completely avoided in the PV system.

5. **DC Cables from SJB to inverter** are typically longer. They are sized to carry the required current and also limit the voltage drop. As a general practice, the DC wiring should not cause more than 2 percent power loss in the PV system.
6. **DC Isolators** are needed to disconnect the PV modules and strings from the rest of the PV system in cases of faults, fire or repair. Most PV inverters consist of a DC isolator, which should suffice the requirement. DC isolators are mandated globally; they should be clearly labelled and easily accessible.

7. **Inverters** are among the most critical components of the PV system that not only undertake power-related functions but are also responsible for the intelligence of the PV system. The functions of the grid-connected PV inverter are to:
- Extract maximum power from the PV modules (by optimizing the inverter's input impedance);
 - Convert the DC power into AC power;
 - Synchronize the output AC power with the phase, frequency and voltage of the available grid in order to feed the PV power into the grid;
 - Ensure anti-islanding by shutting itself down (and hence, PV generation) in case of grid failure;
 - Ensure protection of the PV system from DC-side (i.e. PV-side) for reverse polarity, overcurrent, overvoltage and surge. [Note: If these features are not available in the inverter, then they have to be externally provided in the PV system, typically SJB];
 - Ensure protection of the PV system from AC-side (i.e. grid-side) for grid-fault (e.g. over/ under-voltage, over/ under frequency, high rate of change of frequency, etc.), ground fault, residual current or fault conditions, etc. [Note: If these features are not available in the inverter, then they have to be externally provided in the PV system, typically AC Distribution Box-ACDB];
 - Log various PV system and grid-related performance parameters;
 - (Optional) Provide reactive power support if required, which is discussed in Section 4.5 (Advanced Inverter Functions); and
 - (Optional) Fault ride through such as Voltage Ride Through (VRT) and Frequency Ride Through (FRT), which is discussed in Section 4.5 (Advanced Inverter Functions).

Inverters can either be installed outdoors on the rooftop or terrace, or can be situated in a dedicated room nearby the PV modules and hence, should be rated for appropriate Ingress Protection (IP).

Single-phase string inverters, typically up to around 10 kW, give an output of 240 V_{AC}, 1 ϕ , 50 Hz; while three-phase string inverters give an output of 415 V_{AC}, 3 ϕ , 50 Hz. It is also a common practice to use three numbers of single-phase inverters to provide a net three-phase output. For bigger rooftop PV systems, central inverters of capacities more than 100 kW are often used, in which case the output voltage is stepped up to 11 kV or above using step-up transformers.

PV inverters are very efficient, generally 96-98 percent, and inject very minimal DC current, harmonics or reactive power into the grid, which are usually within the allowable range of the grid code.

8. **Isolation Transformers** are typically used to protect the inverters from grid-side surges as well as avoid any DC injection from the inverter into the grid. Many inverter models also have in-built isolation transformers. However, isolation transformers increase the cost and also decrease the efficiency of the inverter. Inverters available in the market today without such transformers have sufficient protective components and hence, such transformers are now optional.

However, isolation transformers also serve another purpose, which may be more relevant for certain grids or locations. If one regularly experiences lower voltages (especially at the tail ends of the grid) or higher voltages (especially near the substations), such voltages may not be a 'fault' but still may cause the inverter to shut down. In such cases, an isolation transformer with a slight tap change to marginally increase or decrease the grid voltage for the inverter can be used.

Isolation transformers are not required if the PV system is utilizing another transformer such as a step-up transformer to step up the voltage to 11 kV.

9. A **(Solar) AC Distribution Box (ACDB)** should be placed close to the inverter immediately after the inverter (or the isolation transformer, if used). The primary function of the ACDB is to isolate the PV system (including PV modules and inverters) from the grid. Additionally, the

ACDB should also contain Miniature Circuit Breakers to disconnect incoming and outgoing AC connections, Residual Current Circuit Breakers (RCCB) and SPD. [Note: RCCB and/ or SPD may not be required if the inverter has these components on the AC-side.]

10. **AC Cables** carry the AC power of the PV system from the top of the building to the metering point, which is typically at the bottom, and hence have to be selected critically to ensure safety as well as minimize power loss. While copper or aluminium cables can be used, it is highly recommended to use armoured cables. AC cabling practices are common in India, and appropriate standards and certifications should be adhered to. As a common practice, AC wiring loss of a PV system should not exceed 2 percent.

11. **Transformer Substations** would be required if the voltage of the PV system is to be stepped up to 11 kV (or sometimes even higher). All norms, standards and specifications of a conventional transformer, substation and switchyard would be applicable to PV systems.

However, if the PV system is sized such that all (or most) of the generated power is utilized within the Consumer's premises itself, then rather than stepping up the output voltage, it is highly recommended from a cost and efficiency standpoint to divide the PV system into smaller sub-systems and interconnect at one or

more ACDBs of the Consumer for direct use at lower voltages.

12. **Generation Meters** can be used if one specifically wants to record the solar energy generation. The specification of this generation meter depends on its purpose of use. For example, if a simple measurement of solar energy generation is desired, then a bidirectional panel meter would suffice; in fact, most inverters record performance parameters such as DC and AC energy generation and are able to display the same. However, if the solar energy generation has any legal, regulatory or contractual implications, then the standard and accuracy of the meter becomes important. For example, (i) if the DISCOM wants to use the generated solar energy to be credited towards its RPO, or (ii) if the PV system is owned by a third-party Developer and is selling solar energy to the Consumer through a private power purchase agreement, then the standard and accuracy class of the meter becomes critical.

While a unidirectional meter is often used for generation metering, it is highly recommended to use a bi-directional meter so that self-consumption (e.g. no load losses, auxiliary consumption, etc.) by the solar PV plant, if any, is recorded and automatically deducted.

Please refer to Annexure 1 for a brief note on net-meter specifications and standards.

In case of PV systems using hybrid inverters, the system topology may permit only DC measurement for solar energy generation. In such cases, either a separate DC meter can be used, or the internal measurement system of the inverter, if meeting accuracy requirements, itself can be used.

13. The net-metered PV system is interconnected to the distribution grid through the **(Consumer's) AC Distribution Box**. It should be ensured that the power capacity of the Consumer's ACDB and its components should be more than the capacity of the PV system.

It is very important to have an accessible and clearly labelled AC isolator (or circuit breaker) for the PV system. This isolator should be easily accessible by the DISCOM Engineer. If such accessibility to the Consumer's ACDB is not feasible, then a separate isolator should be installed and labelled in order for the DISCOM's Engineer to be able to disconnect the PV system.

14. The **Net Meter** is a very critical equipment from the DISCOM's perspective as it is the interface with the Consumer and pertains to the DISCOM's revenue through billing. The factors revolving around the net meter include bearing the cost of the meter, accuracy class, and remote communication (and billing) arrangements.

As net metering for PV systems is a new application in the Indian context, the volume of sale of such net meters is limited and it DISCOM's also tend to develop very stringent specifications for the same. As a result, the cost of the net meters increase, which increases the cost of the entire PV system, thus, hampering the financial viability of the system.

It is highly recommended that the accuracy class of the net meter for a particular Consumer should be the same as that for a Consumer with sanctioned load equivalent to the existing sanctioned load or capacity of the PV system, whichever is higher.

If the net meter is required to be capable of remote monitoring and communication, then it tends to be technically and financially more feasible to have the generation and net meter with similar communication specifications (such as ports, protocols, etc.).

Please refer to Annexure 1 for a brief note on net-meter specifications and standards.

15. While it is desired to protect all PV systems from lightning, **Lightning Arrestors** may not be mandated for PV systems with capacities less than 10 kW. It is highly recommended for PV systems to have their dedicated lightning arrestors rather than depending on foreign

rods and structures at greater heights that might exist at the time of installation.

16. Earthing, and hence **Earthing Cables/ Strips** are mandatory for all PV installations irrespective of size or capacity of the PV system. The lightning arrestor should have separate earthing system, while the rest of the PV system can have a common earthing system.
17. **Earth Pits** used in solar PV systems are the same as conventional earth pits used for electrical installations, and also follow the same overall standards. Each earthing system should have two earth pits, whether at the same end of the earthing system or each at the opposite end of the earthing system. This way, the risks from failure of the earthing system can be reduced and a lower earth resistance can be achieved.
18. **Monitoring** of the PV system performance as well as weather parameters are highly desirable. A performance of a PV system can be monitored through the inverter if the inverter has such capabilities. Most inverters also specify particular makes of weather monitoring equipment that can be readily integrated with the inverter.

However, if monitoring is to be done on a mass scale, especially with the intention of billing the Consumer, then such monitoring has to be done through the billing

meter, i.e. the net meter in the current case. Meter and remote monitoring specifications are discussed in detail in subsequent sections of this chapter.

19. **Module Mounting Structures (MMS)** are used to secure the PV modules in particular orientation to collect maximum sunlight. MMS are designed keeping several structural considerations such as:
- Load (weight) of the PV system;
 - Load bearing capacity of the terrace, rooftop or the structure on which the PV system is mounted;
 - Typical and maximum wind loads at that particular location, also factoring the height of the installation;
 - Seismic zone safety factors;
 - Other considerations such as saline or corrosive environments; and so on.

Most of the physical considerations are governed by Indian Standards.

PV modules are often mounted at a tilt angle lower than the optimum angle for maximum energy generation. Sometimes, the PV modules may also be aligned along the building structure, which might be non-optimal from a performance standpoint. This is a common and acceptable practice as such minor adjustments may drastically simplify the installation of the PV modules at a slight cost of performance. Lower tilt angles reduce the

wind loads encountered by the PV system, resulting into a lighter MMS and also avoid the need to puncture a terrace, which may cause water seepage problems in the future. The mounting of PV modules should be optimized from a techno-commercial standpoint rather than just a technical performance standpoint.

b. General design of a stand-alone PV system:

A stand-alone PV system is a very simple PV system configuration, wherein a charge controller connects the PV modules, batteries and the stand-alone inverter as shown in Figure 4-1 (a).

20. **Charge Controllers** perform the following specific functions:
- Extract maximum power from the PV modules either through an advanced 'Maximum Power Point Tracking' (MPPT) mechanism for larger PV systems, or through a simpler 'Pulse Width Modulation' (PWM) mechanism for smaller PV systems;
 - Regulate battery charging by controlling the charging voltage and/ or current, and also protect the battery from discharging below the specified limit; and
 - Provide a DC output at pre-specified voltage (e.g. 12/ 24/ 48V).

The DC output of a charge controller can either be used directly for DC equipment, or be connected to the input of a stand-alone inverter. A stand-alone inverter is simpler than a grid-connected or hybrid inverter, as it is not required to synchronize its AC output with the grid.

21. **Batteries** are used in PV systems to store energy and utilize it when available solar power may not be enough to power the desired load. While lead acid batteries such as flooded electrolyte, gel electrolyte, Sealed Maintenance Free (SMF), etc. are commonly used due to lower cost and high availability, other batteries such as lithium ion are also gaining popularity. Batteries are sized based on power and energy requirement of the load and often oversized to provide autonomy during cloudy days.

c. General design of a gross-metering PV system:

The gross metering PV system, as shown in Figure 4-2 (b), is one of the most popular and simplest configuration. The design of gross-metered PV system is very similar to that of a net-metered PV system. The only difference between the two systems lies in the location of the point of interconnection of the PV system with the grid. The gross-metered PV system is connected directly into the distribution grid via a feed-in meter used for billing, rather than interconnecting into the ACDB within the Consumer's premises (as in the net-metered system).

Hence, although the PV system is physically installed within a Consumer's premise and typically owned by the Consumer, it is electrically treated as separate system than the Consumers internal wiring. The DISCOM typically provides an interconnection point for such systems.

d. General design of a hybrid PV system:

A hybrid PV system, as shown in Figure 4-2 (c), is classified as a type of net-metered PV system, because it is interconnected within the Consumer's internal electrical network. In such a configuration, the hybrid inverter is connected in series with the incoming power cable from the grid and net meter, and the output of the hybrid inverter is connected to an ACDB through which power is then distributed to various AC loads of the Consumer.

A major advantage offered by hybrid PV systems is that during a power outage, the hybrid inverter can isolate the Consumers network from the grid and continue to provide power from the PV modules and batteries.

This section discussed the general design and components of common PV system configurations. **Detailed specifications of the PV system, which can be used for implementation or procurement, are given in Annexure 2.**

4.3. Capacity Limitations

The capacity of a rooftop PV system is typically limited by one or more of the following factors:

a. Technical reasons, through:

- (i) Limited requirement of energy.
- (ii) Lack of (especially shadow-free) available rooftop space.
- (iii) Non-availability of distribution transformer capacity for evacuation of solar energy (however, this can be enhanced through regulatory and/ or DISCOM's intervention).
- (iv) Lack of a higher interconnection voltage (however, this can be enhanced through regulatory and/ or DISCOM's intervention).

b. Limitations under regulatory provisions, wherein:

- (i) Capacity of the PV system is limited to the connected or sanctioned load of the Consumer.
- (ii) No substantial financial or other credit is provided the Consumer for surplus generation of energy at the end of the billing cycle or during a given

extended period of bill settlement, and hence, the Consumer would limit the installation capacity.

- (iii) Capacity of the PV system is designed to meet a particular Renewable Purchase Obligation (RPO) or Solar Purchase Obligation (SPO).

c. Financial reasons, through:

- (i) Lack of available investment funds by the Consumer or Developer.

4.4. 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.

Central Electricity Authority's (CEA) (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 Indian Standards (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 Electrotechnical Commission (IEC), (b) British Standard (BS), (c) American National Standard Institute (ANSI), or (d) any other equivalent international standard. The regulations also state that industry best practices for installation, operation and maintenance should also be followed along with the relevant standards.

- **IEC 60364, 1st Ed. (2002-05), “Electrical installations of buildings – Part 7-712, Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems,” is the 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. This standard is also equivalent to and/ or in conjunction with other standards around the world such as:**
 - *DIN VDE 0100-712:2006-06, Part 7-712: Requirements for special installations or locations solar photovoltaic (PV) power supply systems.*
 - *UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources.*
 - *IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems.*
 - *IEEE 929-2000: Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.*
 - *NEC 690: Solar Photovoltaic (PV) Systems*

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? Couldn’t 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.

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.
- **IEC 61727, 2nd 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**

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_{Nominal} for India is 240 V (1 ϕ) or 415 (3 ϕ) V at LT.]

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 ± 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, 2nd 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," govern 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. However, some inverters (usually with transformers) allow DC conductor earthing. In such cases, if allowed by the inverter, the negative DC cable should be connected to earth in order to reduce Potential-Induced Degradation (PID) of the PV modules. PID and methods to mitigate it are discussed in latter sections of this chapter.

Only earthing of the lightning conductor should be isolated from the earthing of the remaining PV system.

All inverters should have provision for earth fault monitoring, and shall disconnect from the grid and shut down in case of earth faults. The IEC 62109-2

standard includes earth fault protection requirement for PV circuits.

- **IEC 62109-1, 1st 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, 1st Ed. (2011-06), "Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters," defines the particular safety 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 photovoltaic power systems. Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage. This standard must be used jointly with IEC 62109-1.**

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 mm² if copper, 10 mm² if aluminium, or 70 mm² if hot-dipped galvanized iron. For the earthing of lightning arrester, cross-section area of the earthing conductor should not be less than 16 mm² of copper, or 70 mm² 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: As the output current of the PV module is limited by the amount of sunlight received, the maximum current on the DC side of

the PV system is calculated based on the rated short-circuit current of the PV module.

The PV system is protected from overcurrent from the PV modules with the help of fuses at the string junction box. As PV module 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 a 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 1000 V_{DC}; if the exact current rating is not available, the nearest available higher rating should be used. However, the rating of the fuse should not exceed 200 percent of the short-circuit current of the string. The fuse should be housed with dedicated fuse disconnectors.

DC Miniature Circuit Breakers (MCB) are an alternative option to fuses. They also provide an added advantage of allowing isolation of individual strings. However, this is a more expensive option compared to fuses, and there are also chances of accidental tripping of the MCB.

(v) DC surge protection: Several makes for DC surge arrestors (or surge protective devices-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_{DC}, surge arrestors rated for 1000 V_{DC} 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 doesn't have an equivalent in-build DC surge arrestor).

(vi) Lightning protection: Lightning can cause damage to a PV system either by a direct strike or through surge in the grid resulting from a nearby lightning strike. 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.***

Small rooftop PV systems pose minimal risk of lightning strike, and the cost impact of lightning protection system can be substantial. Hence, it may not be required to have a lightning protection

system for rooftop PV systems of capacity less than 10 kW.

It is recommended for larger PV systems to have a dedicated lightning protection system including lightning rods, conductor and dedicated earth pits. Already 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, 1st 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 (PV generator and PV array boxes) carry a warning label indicating that active parts inside the boxes are fed from a PV array and may still be live after isolation from the PV inverter and public supply.
- The main AC isolating switch is clearly labelled.
- Dual supply warning labels are fitted at point of interconnection.
- A single line wiring diagram is displayed on site.
- Inverter protection settings and installer details are displayed on site.
- Emergency shutdown procedures are displayed on site.
- All signs and labels are suitably affixed and durable.

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. DC power injection is restricted to either an absolute value or a minor fraction of the rated inverter output current.

- **IEC 61727, 2nd 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 Total Harmonic Distortion (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.

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 %	8.0 %
1 kV < $V \leq 69$ kV	3.0 %	5.0 %
69 kV < $V \leq 161$ kV	1.5 %	2.5 %
161 kV < V	1.0 %	1.5 %*

[Notes:

PCC: Point of Common Coupling.

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

- **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.**

Table 4-3: Current distortion limits as per IEEE 519 (2014).

Maximum harmonic Current Distortion in % of I_L						
Individual Harmonic Order (Odd Harmonic)						
I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤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% 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 .

I_{sc} : Maximum short circuit current at the PCC.

I_L : Maximum demand load current (Fundamental) at the PCC.

h: Harmonic number.]

- (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 typically observed that multiple rooftop PV interconnections tend to have an averaging effect on the grid and do not pose substantial unbalancing threats. However, it is recommended that DISCOMs should keep track of the PV capacity connected to each phase for troubleshooting any extreme cases.

Three-phase inverters (and PV systems) rather aid in minimizing the phase imbalance as they tend to uniformly feed power into all three phases.

- (iv) Flicker: IEC 61000 is a set of standards on electromagnetic compatibility, which are subdivided into sections that define:
- The environment from the EMC viewpoint and establish the compatibility levels that the distributors must guarantee.
 - The emission levels into the networks.
 - The immunity levels of the appliances.

The relevant IEC 61000 sections for electromagnetic compatibility, including voltage fluctuation and flicker are indicated in Table 4-4.

- **CEA's (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2010, in its Section 11 (3) stipulate that distributed generating**

Table 4-4: IEC standards and scope for electromagnetic compatibility, including flicker.

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
IEC 61000-3-3	Voltage Fluctuation and Flicker	
IEC 61000-3-12	Harmonics	Inverter $>$ 16 A and $<$ 75 A AC Current per phase
IEC 61000-3-11	Voltage Fluctuation and Flicker	
IEC 61000-3-4	Harmonics	Inverter \geq 75 A AC Current per phase
IEC 61000-3-5	Voltage Fluctuation and Flicker	

resource shall not introduce flicker beyond the limits specified in IEC 61000.

- **IEC 61727, 2nd Ed. (2004), "Photovoltaic (PV) systems – Characteristics of the utility interface," in Section 4.3 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 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.

Many inverters also provide a power factor range such as -0.8 (inductive) to +0.8 (capacitive), which can be pre-programmed or can be dynamically adjustable. This functionality of adjustable power factor is discussed in detail in Section 4.5 (Advanced Inverter Functions).

c. PV module considerations:

As the PV module is the most expensive component of the PV system, it is extremely critical to outline its specification. However, on the positive side, the PV module is a very robust component, and hence, satisfactory quality and performance can be ensured by ensuring key standards and specifications. One must also be sensitized that over-specification of the PV module can result into a substantial cost increase without any major gain in quality or performance of the module.

- (i) Components of a PV module: The main components of a polycrystalline silicon PV module are:

Standard Testing Condition (STC) and PV module efficiency

Standard Testing Conditions, or STC, implies a solar spectrum of Air Mass (AM) 1.5 at 1000 watts per square metre perpendicularly incident on a PV module, wherein the PV module temperature is fixed at 25°C. [Simply stated, AM1.5 implies a representative solar radiation and spectrum experienced on a typical sunny day on the Earth's surface.]

All PV modules are tested for their electrical outputs at STC using a solar simulator at the time of manufacturing. The resultant output power is called the 'rating' of that PV module, and denoted in watt (W) or watt-peak (Wp).

Hence, if a PV module is rated for 250 W or 250 Wp, then it would give an output of 250 W on the noon of a sunny day if the PV module is facing the sun and the temperature of the module is 25°C. However, as the Sun moves relatively to the PV module from this position and/ or the temperature of the PV module increases, then the power output of the PV module would decrease.

If the area of the 250 Wp PV module is 1 m x 1.6 m, then the efficiency (η) of that module is calculated as follows:

$$Efficiency = \frac{250W}{1000 \frac{W}{m^2} \times 1.6m^2} = 15.63\%$$

- *Solar Cell or PV Cell* is a device that directly converts sunlight into electricity. A standard polycrystalline silicon PV module has 60 or 72 solar cells connected in series. The area of each solar cell is 156 mm x 156 mm (6 inch x 6 inch), and gives an output current of around 8 A_{DC} and voltage of around 0.5 V_{DC}, resulting into an output power of approximately 4 Watts at Standard Testing Conditions (STC). It should be noted that the mentioned values of current, voltage and power vary from cell to cell, and hence, PV modules of varying ratings exist in the market. All cells in a PV module are connected in series.
- *Bus Ribbons* are soldered to the positive terminal of one solar cell and the negative terminal of the other solar cell, thus electrically connecting them in series.
- *Glass* provides mechanical strength to the PV module and also protects the internal components from the external harsh environment. This glass is tempered, low-iron, high in transmissivity and 3-4 mm thick.
- *Ethylene Vinyl Acetate (EVA)*, a transparent thermoplastic, is used above and below the

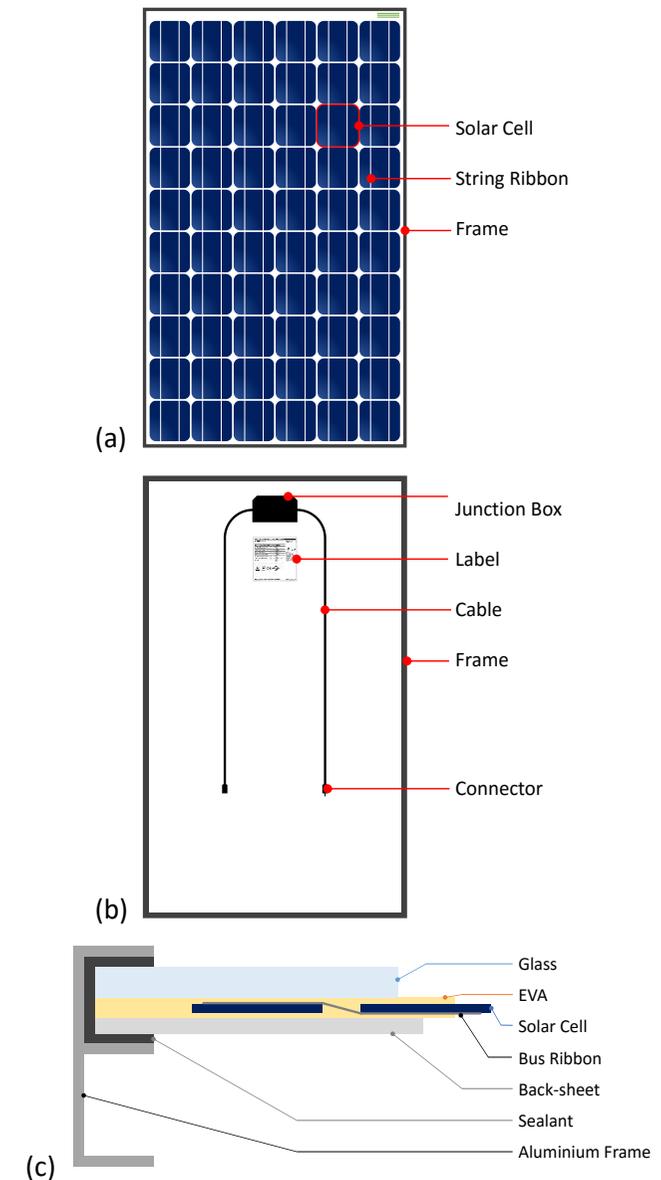


Figure 4-4: (a) Front, (b) back and (c) cross-sectional view of a PV module.

- solar cells to encapsulate them. EVA protects the solar cells from mechanical shocks while allowing the light to transmit through itself.
- *Tedlar®* or a similar back-sheet is used to protect the PV module from radiation, moisture and weather while also providing electrical insulation to the module. Some PV modules, especially for building integration or aesthetic purposes, may use a second glass layer instead of a back-sheet.
 - *Junction Box* affixed at the back-side of the PV module connects the internal conductors of the module to external cables for connection. Junction boxes also contain bypass diodes to provide an alternate path for current in case certain sections of the PV module are not able to conduct or generate power due to shading or damage.
 - *Cables and Connectors* are an integral part of the PV module and have to comply with the general standards of DC cables and connectors.
 - *Edge sealant* may be a silicone compound or a tape, and is used to protect the PV module from moisture and dust ingress from the sides, and also to hold the frame.
 - *Frames* are typically made of anodized aluminium and are used to protect the PV module, mount the module using clamps or bolts, and connect to the body earthing of the overall module.
- (ii) Rating of a PV module: A PV module is rated for its power output at STC. The PV module is also rated for its open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), voltage at maximum power point (V_{MP}) and current at maximum power point (I_{MP}). In addition to these, the temperature coefficient of power, voltage and current are also indicated in the datasheet of the PV module, which is important for designing as well as estimating the output of the PV system.
- (iii) Basic design and safety qualification: The design of the PV module is guided by one of the following three IEC standards depending on the type of the module, i.e. IEC 61215 for crystalline silicon, IEC 61646 for thin-film or IEC 62108 for concentrator PV modules.
- ***IEC 61215, 2nd 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, measurement of nominal operating cell temperature (NOCT), performance at STC and NOCT, performance at low irradiance, outdoor exposure test, hot-spot endurance test, UV preconditioning test, thermal cycling test, humidity-freeze test, damp-heat test, robustness of terminations test, wet leakage current test, mechanical load test, hail test, and bypass diode thermal test.

- *IEC 61646, 2nd 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. The testing includes visual inspection, maximum power determination, insulation test, measurement of temperature coefficients, measurement of nominal operating cell temperature (NOCT), performance at STC and NOCT, performance at low irradiance, outdoor exposure test, hot-spot endurance test, UV preconditioning test, thermal cycling test, humidity-freeze test, damp-heat test, robustness of terminations test, wet leakage current test, mechanical load test, hail test, bypass diode thermal test, and light soaking.*

- *IEC 62108, 1st 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. The testing includes visual inspection, electrical performance measurement, ground path continuity test, electrical insulation test, wet insulation test, thermal cycling test, damp heat test, humidity freeze test, hail impact test, water spray test, bypass/ blocking diode thermal test, robustness of terminations test, mechanical load test, off-axis beam damage test, ultraviolet conditioning test, outdoor exposure test, and hot-spot endurance test.*

In addition to one of the above-mentioned three IEC certifications, all photovoltaic 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. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. This part pertains to the particular requirements of construction.*

- **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. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. This part pertains to the particular requirements of testing.**

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

- **IEC 61701, 2nd Ed. (2011-12), “Salt mist corrosion testing of photovoltaic (PV) modules,” describes the test sequence useful to determine the resistance of different PV modules to corrosion from salt mist containing Cl⁻ (NaCl, MgCl₂, etc.). This standard is applicable to PV modules intended for continuous outdoor exposure to highly corrosive wet environments such as marine environments or temporary corrosive environments such as where salt is used in winter periods to melt ice formations on roads.**
- **IEC 62716, 1st Ed. (2013-06), “Photovoltaic (PV) modules – Ammonia corrosion testing,” describes the test sequence useful to determine the resistance of different PV modules to ammonia (NH₃). This standard is applicable to PV**

modules intended for continuous outdoor exposure to wet atmospheres having high concentration of dissolved ammonia such as stables of agricultural companies.

- (iv) 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.
- (v) Workmanship warranty: The typical workmanship warranty on a PV module is 5 years.
- (vi) Potential-induced degradation (PID): The high potential difference between the solar cell and module frame (which is grounded) drives ion mobility between them, which is further accelerated by humidity and temperature; all these phenomena causes degradation in the output power of the PV module.

Hence, it is recommended to use PID-resistant PV modules, which resist the transportation of causative ions such as Na⁺ leaking from the glass,

EVA or even the anti-reflective coating of the solar cell. PID-resistant modules use highly insulating EVA with Na⁺ blocking capabilities, low conducting glass cover, higher distances of the cell strings to the frame, insulating frame, and so on.

PID can also be eliminated by grounding the negative terminal of the PV string if inverters with transformers are used. Alternatively, PID can also be eliminated or reversed via the application of a reverse voltage (using an external power supply, often called “PID-box”) during night-time to the module strings or to specific modules.

d. 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. Further, the PV modules installed in the northern hemisphere (as is the case for India) should be inclined such that they face south.

However, it is also a common practice to reduce the inclination angle in the range of 10-15° (irrespective of the latitude of location) on flat roofs or terraces. Such a reduction in inclination results into simpler, quick and cost-effective installation owing to lesser

wind resistance of the low profile, lighter mounting structure and avoided penetration or anchoring into the terrace. The reduction in solar energy generation can be relatively up to 5 percent, but the commercial and other benefits tend to outweigh this loss.

- (ii) Area of a rooftop PV system: A rooftop PV system can take anywhere from 10 to 15 m² of area per kilowatt of installation depending on the angle of inclination of the PV modules. This area also includes the spacing between two rows of PV modules.
- (iii) Weight of the rooftop PV system: The weight of a PV system (including the PV module and structures) does not exceed 30 kg per m². However, for mounting structures that are not anchored into the roof, the weight of the PV system is deliberately increased using bricks to counter the uplift or drag forces created by wind pressures. In any case, all terraces are designed to withstand the weight of PV systems.
- (iv) Wind loads: All module mounting structures (MMS) should be designed taking into consideration the wind loads at the location of installation. The design 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. This design should be developed or approved by a chartered structural engineer. This design should also be a part of the submission for drawing and design approval to the concerned electrical inspector or inspection agency.

Readymade and modular mounting structures pre-certified for certain wind speeds are readily available in the market, and the same can be directly used.

For PV installations on tall buildings, the design should consider the ‘height factor’ as per IS:875 (Part 3)-1987, which quantifies higher wind loads on tall structures within the same wind zone.

- (v) Material of mounting structure: Galvanized iron (GI) or aluminium are the most common materials 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.

It is highly recommended to use stainless steel fasteners due to their weather-resistant properties. If stainless steel is not possible due to any reason, then GI fasteners can be used.

- (vi) Penetration and puncturing of roof or terrace: Penetration into or puncturing the roof or terrace for anchoring of module mounting structure should be avoided as far as possible to avoid any water leakage-related issues.

However, if puncturing the roof is unavoidable, sufficient care should be taken for waterproofing the roof or terrace as a part of the installation itself.

e. 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.

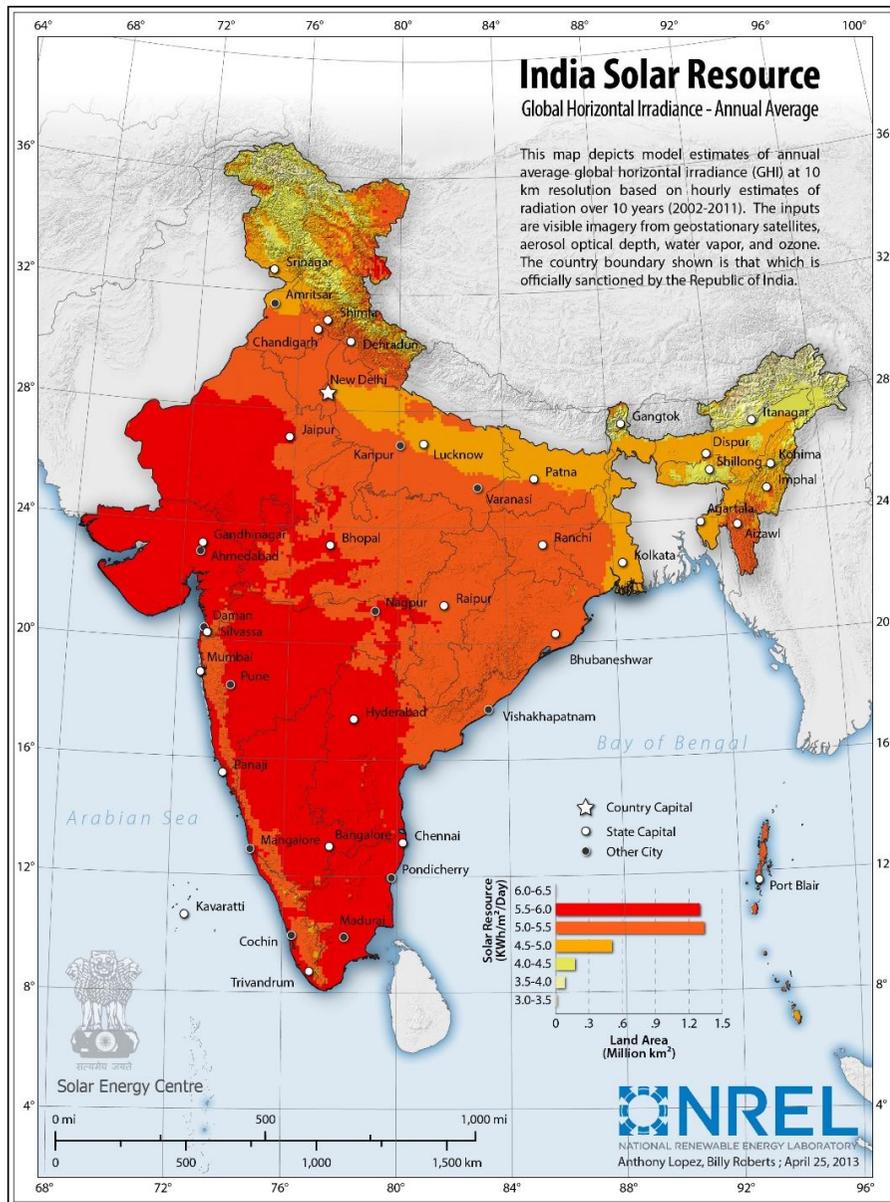


Figure 4-5: GHI map of India.

What is GHI and DNI, and what do the maps mean?

Sunlight can broadly be classified into its 'direct' and 'diffused' component. The direct component is the solar radiation travelling on a straight line from the Sun. The diffused component, on the other hand, is the solar radiation reaching the Earth's surface after being scattered by molecules and particles in the Earth's atmosphere. Both these direct and diffused components sum up to be known as the 'global' radiation.

'Global Horizontal Irradiance (GHI)' is the measure of incident solar energy per horizontal unit area (typically square metre) per given period of time (either day or year). Hence, GHI is denoted in kilowatt hours per square metre per day (kWh/m²/day) or per year (kWh/m²/year). GHI is measured using instruments like a pyranometer or a radiation sensor placed horizontally on the ground.

The incident solar radiation energy, also known as 'insolation', is not constant and follows a bell-shaped curve; it starts at sunrise, peaks at noon, and then diminishes to zero at sunset.

(Continued on next page...)

The integration of this bell-shape curve yields the total net solar energy i.e. insolation for that day in kWh/m²/day. The same value is also equivalent to the number of hours of irradiance if the Sun was shining at a constant irradiance of 1 kW/ m². This value (i.e. number of hours) is known as “Peak Sun Hours”.

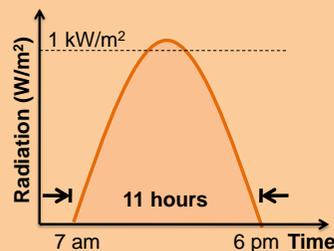


Fig. Actual Irradiance on a particular day.

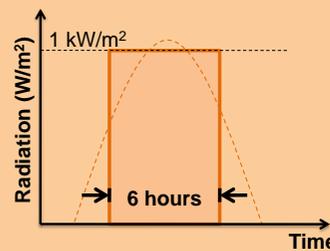


Fig. Normalized Irradiance (with same energy content).

For example, it is seen in the figure above (left) that the Sun shines from 7 am to 6 pm and as a result yielded an insolation of 6 kWh/m² for that day (determined by integrating the bell curve). This insolation is equivalent to that resulting from the Sun shining at an intensity of 1 kW/m² for 6 hours. Hence, it can be said that the insolation received was for “6 Peak Sun Hours”.

GHI data or maps indicating monthly or annual average values are widely available through various open sources (e.g. NASA, NREL, MNRE, etc.) or by paying a license fee (e.g. SolarGIS, 3Tier, IMD, etc.).

GHI is one of the primary data required to calculate the output of a typical (non-tracking) PV system, whether on ground or on a rooftop.

For example, to calculate the average daily output of a 10 kW PV system located in Ahmedabad, we first identify the GHI at that location. Say, the average daily GHI of Ahmedabad indicated in a GHI map is 5.5 kWh/m²/day (which is the same as 5.5 Peak Sun Hours).

Assuming that the PV system is (near-) optimally tilted, and also assuming standard losses, the energy output can be calculated as follows:

$$E = 10 \text{ (kW)} \times 5.5 \left(\frac{\text{hours}}{\text{day}} \right) \times 1.1 \times 75\% = 45.4 \left(\frac{\text{kWh}}{\text{day}} \right)$$

Where,

- ‘1.1’ is the ‘Tilt Factor’ resulting from an optimal orientation of the PV collector (i.e. PV module), and
- 75% is the ‘Performance Ratio’, which takes into account the various losses in a PV system.

These factors are described in detail in the current section of the chapter.

(Continued on next page...)

Concentrator solar technologies can only utilize the direct component of sunlight and need a mechanical tracking assembly to align themselves perpendicular (normal) to the incident radiation.

Although concentration of sunlight was earlier only adopted by solar thermal technologies to achieve very high temperatures, lately several PV technologies using both silicon and high-efficiency cells have also started adopting low and high concentration techniques to achieve higher efficiencies and reduced the cost of electricity generation.

Hence, when we talk about the available solar resource, there is also a need to measure only the direct and normal component of sunlight, i.e. 'Direct Normal Irradiance (DNI)' for estimating the output generation of such tracking concentrator systems.

DNI is measured using an instrument known as pyrliometer, which tracks the Sun and measures only the direct 'beam' component of sunlight by blocking away the diffused light.

It should be noted that if a tracking system is used without any concentrator, then in addition to DNI, the diffused component of sunlight (which is about 10-15% of GHI) should also be considered as input.

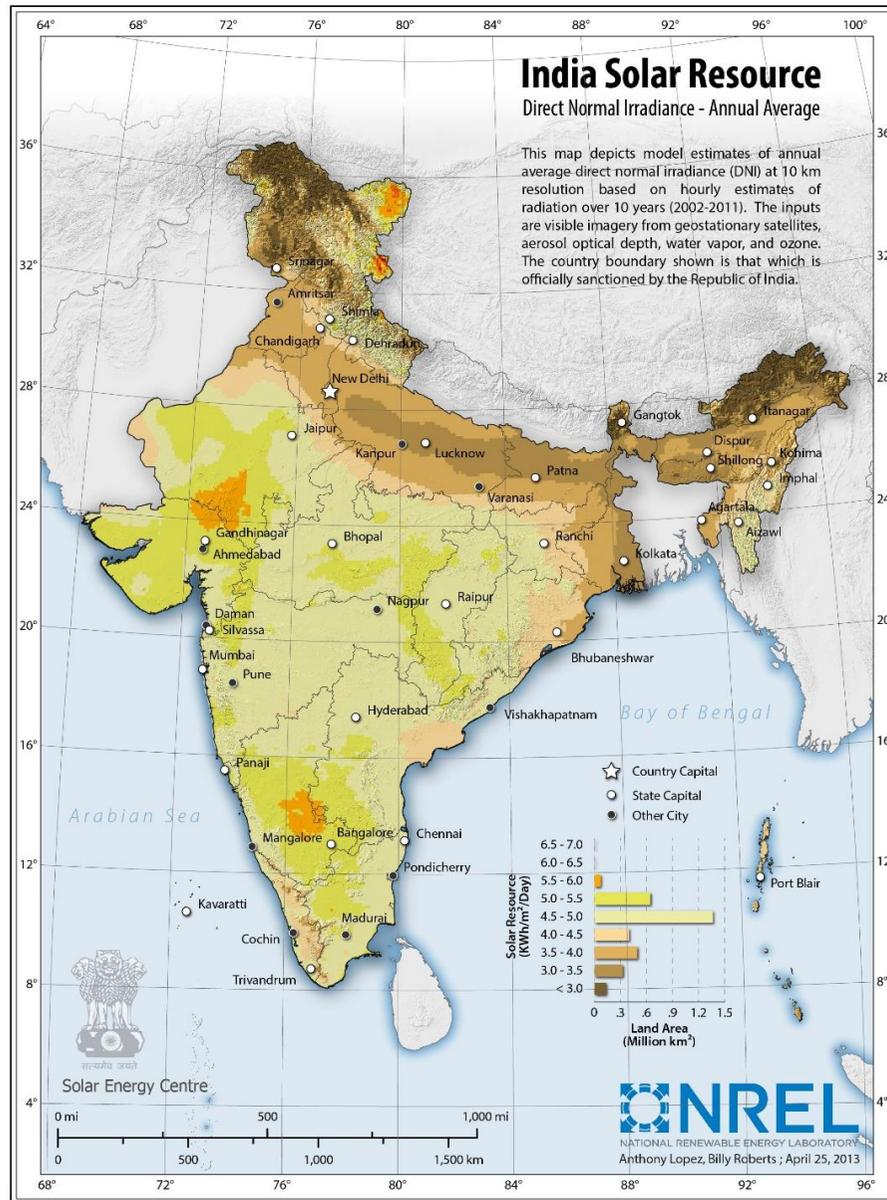


Figure 4-6: DNI map of India.

A PV system starts generating energy shortly after sunrise, reaches the peak of its production around noon, and thereafter progressively decreases and ceases generation around sunset. The system typically reaches around 75-80 percent of its peak capacity around noon. (For example, a 10 kW PV system will generate about 7.5-8 kW power around noon).

The average daily energy output of a PV system at a particular location can be roughly calculated as follows:

$$E = C \times GHI \times TF \times PR$$

Where,

E : 'Energy Output' of the PV plant in 'kWh/day.'

C : 'Capacity' of the PV plant in 'kW.'

GHI: 'Global Horizontal Irradiance' in 'kWh/m²/day.' Note that this is equivalent to 'peak sun hours,' the units for which is 'hours.' GHI can be easily identified from readily available GHI maps or datasets such as that from MNRE and NREL as shown in Figure 4-5.

TF : 'Tilt Factor' indicating the increase in energy generation due to optimized orientation of the PV modules. This is a dimension-less

quantity can be roughly estimated around 1.1 for India.

PR : 'Performance Ratio' indicates the 'quality factor' of the PV system and discounts all internal losses due to temperature, equipment, wiring and so on. While PR can vary between 70 percent and 80 percent, a value of 75 percent can be considered for primary calculation.

For rooftop PV system with seasonal tracking, i.e. an assembly where the tilt angle can be optimized for each season, the output can further increase by 3-5 percent.

Complex tracking mechanisms are typically not used for rooftop PV systems, as they result into heavier and more complex systems, where the capital cost may also substantially increase.

(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 Engineering, Procurement and Construction

(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.

This is a win-win scenario for both the Utility and the Contractor, because in case of a lower radiation during a year, the effective generation guarantee will be lower and the Contractor will be protected. While during a year with a higher radiation, the effective generation guarantee will be higher and the Utility will benefit from the same. Such a generation guarantee also discourages the Contractor from installing PV systems at locations where shadows are cast regularly.

- If the Utility intends to procure power (either through a power purchase agreement (PPA) or net metering), then the generation guarantee does not need to be stringent. The Project Developer or the Consumer itself would be motivated to generate maximum energy from the PV system.

In such a case, the Utility’s interest in generation would be to meet its own renewable

Example of evaluation of bids with capital cost and generation guarantee.

Consider an example where a Utility in Bhubaneswar, Odisha intends to procure a 10 kW rooftop PV system. In this case, the Utility may seek:

- (i) Capital cost in INR, and
- (ii) Generation guarantee based on an annual GHI of 1,758 kWh/ m².

Assume it receives 3 bids as follows:

	Bidder 1	Bidder 2	Bidder 3
Capital Cost (in Rs.)...	7,80,000/-	8,00,000/-	8,50,000/-
Generation Guarantee (in kWh)...	14,892.00	15,768.00	16,644.00

Taking the ratio (i.e. capital cost / generation guarantee), the standings are evaluated as follows:

	Bidder 1	Bidder 2	Bidder 3
Ratio...	52.38	50.74	51.07
Standing...	L3	L1	L2

Interpretation:

- Bidder 1 has quoted low, but is also guaranteeing less.
- Bidder 3 is guaranteeing high, but is expensive.
- **Hence, Bidder 2 emerges as the Successful Bidder with the right combination of quoted price and guarantee.**

purchase obligation (RPO), efficiently forecast solar generation, and avoid any stress on its assets due to over-injection of solar power into the grid. Here, the Utility may provide a range in terms of capacity utilization factor (CUF) within which the PV system should operate. The range may be broad enough to accommodate down-times and minor under- or over-performance of the PV systems. For example, at a location with 18 percent nominal CUF, an actual CUF between 15 percent and 21 percent may be allowed.

Also a decrease in the guaranteed generation at the rate of 1 percent (relative over the previous year) may be allowed owing to degradation of the PV modules.

(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 type of involvement of the stakeholder generally as follows:

- *At PV module-level*: This is done using either micro-inverters or DC-DC converters/optimizers at each module, where monitoring is provided as an added functionality. However, such micro-inverters/ converters/ optimizers

increase the capital cost of the PV system, and hence, are not popularly used.

- *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 (SCADA) 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. Hence, any underperforming string can easily be identified and the underperformance can be pinpointed only to a few PV modules. However, the cost of such systems are justified in bigger PV plants.
- *At inverter-level*: Most PV inverters come with a monitoring functionality indicating critical parameters such as instantaneous currents and voltages, input DC and output AC power, energy generated during the day or during a given timeframe, etc. In addition, most inverters also allow connectivity to their proprietary or third-party weather monitoring equipment.

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 or even locally available Wi-Fi. Some such third-party monitoring solution providers are Solar-Log™ by Solare Datensysteme GmbH, Web'log by MeteoControl, Webdysun by Webdyn and GreenSense by Ecolibrium Energy.

It should be noted that for Utilities to monitor PV systems at inverter level, such third-party remote monitoring equipment would be required as multiple inverter makes and models would be typically used in a given distribution area.

- *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 entirely 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.

Utilities are strongly recommended to use energy meters with remote communication capability at an interval of at least 15 minutes, as that will enable the Consumer as well as the Utility for advance grid functionalities such as remote metering, time-of-day (ToD) tariff, energy forecasting, and so on, the cost of which may as well be shared with the cost of the rooftop PV system.

Remote communication in energy meters can be realized either using GSM/ GPRS meters; or by using regular meters with RS 232/ 485 or other communication port, and connecting them to a third-party GSM/ GPRS communication module. Short range communication such as ZigBee, RF, Wi-Fi, etc. may be used where sufficient such meters are available in order to create a mesh, radial or any such network from where the meter signals can be concentrated and communicated to the Utility's head-end.

- (iv) Non-optimal orientation: The optimal tilt of the fixed PV module is around the degree of latitude of that location (facing South in India). However, it is an acceptable practice to install the PV modules at lower tilt angles (in the range of 10° to 15°) on flat roofs/ terraces for the following reasons:

- PV modules installed at lower tilt angles encounter lesser wind (and hence, uplift) forces. Hence, the PV modules and their mounting structures can often be installed safely on the flat roof/ terrace by simply adding more weight (like bricks) and using wind blockers rather than using bolts to puncture/ penetrate the terrace to anchor the PV system.
- PV modules installed at lower tilt angles cast shorter shadows, thus allowing lower inter-row spacing between the PV modules. Hence, a higher capacity (in kW) can be installed in a given roof/ terrace area.
- Mounting structures for PV modules at lower tilt angles are lighter, and thus, reduce the cost of the overall PV system.
- Mounting structures for PV modules at lower tilt angles are simpler, thus reduce the time to installation (and hence, also reduce the cost).

On the other hand, non-optimal tilts would reduce the PV system output to a maximum of around 5 percent. Hence, it is usually observed that the benefits of lower tilt angles outweigh the loss in energy generation.

In case a Utility intends to outright procure PV systems (rather than purchase power), then seeking a guaranteed generation from the Bidder for evaluating the bids in addition to the quoted capital and operation and maintenance cost would ensure that the Bidder would pass on the benefit of cost-performance optimization to the Utility.

- (v) Maintenance: Although minimal, rooftop PV systems require maintenance just like any other equipment, which is critical to the performance and also payback of the system. Major preventive maintenance steps include:
- Cleaning of PV modules, inverters, transformers (if applicable), and other equipment,
 - Battery testing and maintenance (if applicable),
 - Visual inspection of modules, mounting structures, wires/ cables, labels, etc.,
 - Testing and tightening of bolts using torque wrench,
 - Random testing of PV modules performance and inverters,
 - Review of performance data and checking for any anomaly,
 - Clean, test and re-calibration (if required) of monitoring equipment, and
 - Verification of availability of all installation, contact and other documents onsite.

In addition, it is also important that the Contractor or its technicians are readily available for corrective maintenance in case of any breakdown. The time for such repairs should be an integral part of the contract with the Contractor.

- (vi) **Security:** There are two main security concerns for a rooftop PV system; the first is from thefts, and the other is from an electrical safety perspective owing to the high DC voltages. Hence, the onus of security of the PV system is not only on the Investor, but also on the occupant of the premises.

4.5. Advanced Inverter Functions

While the practices, standards and specifications discussed in this chapter are relevant to current ongoing practices, it should be kept in mind that the PV system being installed is intended to last for at least the next 25 years. There is also an active transformation of the electricity grid which has begun and broadly termed as the ‘smart grid.’ As per the definition of IEEE, *the smart grid is a next-generation electrical power system that is typified by the increased use of communications and information technology in the generation, delivery and consumption of electrical energy.*

Hence, it is imperative that any investments into the electricity grid, such as solar PV systems, should be ‘future-ready.’ PV

systems are capable of more functionalities than just injecting solar electricity into the grid. These functionalities can be realized at a minimal or no additional cost within the PV system, and may involve adding software functionality or communication. Moreover, countries and states with high PV penetration realize the importance of such functionalities even for stable operation of the grid, and organizations such as IEC and IEEE are already developing standards for such functionalities.

This section discusses such advanced inverter functions, which are highly recommended for incorporating in PV systems, including rooftops, today. If inverters with such functions are not available today, they should at least have the ability to incorporate such provisions through simple software/ firmware updates, rather than involving any hardware updates in the future.

a. Voltage Ride Through (VRT) and Frequency Ride Through (FRT)

Existing inverters are required by standards to disconnect when the grid voltage or frequency shifts beyond the pre-specified ranges. However, such shifts may unintentionally cause the inverter to shut down, and may also cause a cascading effect in areas of high solar penetration.

To avoid such situations, inverters may be programmed with under/ over frequency ride-through and under/ over

voltage ride-through functionality, which may direct them to stay online and respond accordingly to relatively short-term and minor events. In case of severe grid disturbances, the inverter may still disconnect from the grid.

b. Reactive power compensation

Voltages and reactive power need to be kept as close to its nominal value and unity, respectively, in a distribution grid. However, near the distribution grid feeders, and also in case of increasing distributed energy integration within a grid, the voltages may be high. These would make the integration of more renewable energy sources difficult. A grid may also experience large phase shifts caused by motors, transformers and also long cables.

In such cases, inverters with reactive power capability can help to (a) reduce the active power injection to enable the reduction of high grid voltage to its nominal range and also (b) inject reactive power (leading or lagging) to compensate for the existing phase shift in the grid.

Reactive power compensation may be done in the following possible ways:

- (i) Fixing the reactive power value as specified by the Utility.

- (ii) Setting the value based on an agreed-upon time schedule or remote signal provided by the Utility.
- (iii) Adjusting the reactive power fraction based on a characteristic curve, which is a function of the grid voltage and the grid's power factor.

It should be noted that reactive power compensation functionality of the inverter can not only be used during solar energy generation, but also during non-generation hours (i.e. evenings and nights). Thus, such inverters are an alternative to capacitor banks often used by utilities to improve power factors.

Thus, reactive power compensation can not only enable more renewable energy sources into the grid, but also improve the power quality of the grid.

c. Soft Start

In case of a grid outage, once the grid comes online again, the grid-connected inverters would start connecting the PV systems causing spikes and triggering more disturbances in the grid. To prevent this, Utilities can use the soft start functionality, wherein timing of the reconnection of the inverters can be staggered on a given distribution system. The same can also be achieved by controlling the ramp-up rate of the inverter's power output.

While it may be too premature to mandate such advance inverter functions, Utilities should opt for them wherever possible.

4.6. Technical Documentation, Drawings and Inspection

a. Documentation and drawing requirements

Various technical document and drawings are required at different stages of the implementation and operation of the PV system:

- (i) First, during the designing stage of the project;
- (ii) Then these documents and drawings are given to the installation team for executing the construction of the project;
- (iii) Prior to charging or commissioning the rooftop PV project, these documents and drawings would have to be submitted to the Chief Electrical Inspector for approval;
- (iv) At the time of installation approval or commissioning of the project, to be used by the Chief Electrical Inspector, Utility or any Third-Party Agency to inspect and verify the installation;
- (v) To be retained by the beneficiaries of the rooftop PV system (such as Investor, Developers, Rooftop/ Terrace

Owners, etc.) and statutory bodies (such as Chief Electrical Inspector, Utility, State Nodal Agency, etc.) for plant maintenance, safety compliance and even warranty claims;

- (vi) Required in case of sale of the property from one Owner to another, and if the new Owner intends to continue using the rooftop PV system;
- (vii) To plan and implement any further modification in the existing rooftop PV system, and so on.

b. Technical documents of the rooftop PV system

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

- ***IEC 62446, 1st 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 the PV modules, inverters, transformers (if applicable), DC and AC junction boxes, DC and AC cables, DC cable connectors, earthing cable, lightning arrester, surge protection devices, disconnectors/isolators, earth pit, monitoring system (if applicable) and energy meter.
- (iii) IEC certifications of the PV modules and inverters.
- (iv) Warranty documents of the PV modules, inverters, transformers (if applicable), lightning arrester (if applicable), etc. by the Original Equipment Manufacturer (OEM).
- (v) Design document of the module mounting structure with certification of a Chartered Structural Engineer.
- (vi) Warranty document of the entire rooftop PV system as a whole by the Installer or Contractor.
- (vii) Generation estimation report based on historical meteorological data and expected plant losses and performance parameters. Such reports can be developed manually, or using software such as PVsyst or PV*SOL.
- (viii) Operation and maintenance manual of the PV system.

(ix) Test results and commissioning certificate.

(x) Purchase bills and contracting documents.

c. Drawings of a rooftop PV system

The critical drawings of the rooftop PV system include:

- (i) Single Line Diagram (SLD), which indicates the electrical configuration of the PV system with key specifications of various components.
- (ii) Equipment layout diagram, which indicates the physical layouts including dimensions of the rooftop/ terrace as well as location of each equipment such as PV modules, inverters, DC and AC junction boxes, transformers (if applicable), etc. with clear identification and labelling of each equipment. This diagram covers the physical aspects of the installation.
- (iii) Wire and earthing layout diagram, which appears similar to the equipment layout diagram, but indicates the electrical interconnections including PV modules, junction boxes, inverters, transformers (if applicable), disconnectors and various equipment, up to the interconnection or meter. In addition, this drawing also indicates the earthing interconnection scheme for

various DC and AC equipment and lightning arrestor, while also clearly showing the location of the earth pits.

d. Inspection and testing of a rooftop PV system

Purpose of inspection of a PV system could be:

- Installation verification and commissioning of a rooftop PV system by statutory bodies such as the Chief Electrical Inspector, Utility, State Nodal Agency, Third-Party inspection agency, etc.;
- Payment milestone to the EPC Contractor by the Project Developer;
- Appraisal of the system from by an Investor or Lender,
- Operation and maintenance of the system by a Technician or Engineer;
- Verification of the quality of installation during a warranty claim; etc.

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

- ***IEC 62446, 1st 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 then, 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 highly recommended to undertake inspection of the rooftop PV systems during commissioning and also on a regular basis in order to verify the safety, quality and performance of the system.

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 implementation guided by the administrative processes, which mark the success of the overall rooftop solar programme. Hence, the administrative process is one of the most critical aspects of a rooftop solar programme.

If approached without clarity, establishing administrative procedures can become a daunting task leading to unnecessary complexities, ultimately resulting in the failure of the rooftop solar initiative. Hence, the purpose of this chapter is to provide the scope of the administrative processes and streamlining them in order to implement the programme with minimal efforts by the Implementing Agency.

a. How is a rooftop solar initiative different than other electricity-related matters?

It is important to understand that a rooftop solar initiative is also social in nature rather than purely an electricity-related matter. One must understand that the final investor (or a major stakeholder) is a common household or business, which cannot be treated as a typical independent power producer (IPP) with megawatt-scale power plants.

The target Consumer is relatively unaware of the solar technology, and the associated investments are also large (at least in the orders of a few lac rupees). It should also be realized that the Consumers also have other investment options.

Hence, ease of processes and building confidence among Consumers are important components of the administrative process, which have to be instilled by the DISCOMs.

b. Who is responsible for the administrative processes and implementation?

The DISCOM becomes the focal point or the 'Implementing Agency' of the administrative processes because such processes deal with matters such as interconnection with the grid, safety, metering and billing.

Once the policies and targets are set, the SNA and the MNRE become secondary stakeholders as they typically deal with optional aspects such as subsidies, duty exemptions and record-keeping.

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 rooftop solar programme is formally marked by the launch of the State's rooftop solar policy. This could also be a general solar policy with components addressing specific areas concerning rooftop solar systems.

Various aspects of a rooftop solar policy are discussed in Chapter 3 of this Manual.

The State's Energy (or Power) Department is the proponent of the rooftop solar policy. Once the policy is launched, the Energy (or Power) Department should notify the other Stakeholders including the State Electricity Regulatory Commission (SERC) and the DISCOMs to undertake necessary action to implement the policy.

As this policy is also social in nature, it is highly recommended for the Energy (or Power) Department to publicize the policy via various print and electronic media avenues.

It is also recommended to hold stakeholder consultation meetings during the preparation of the policy and after the launch of the policy and receive feedbacks from project developers, installers, consumers, etc. in addition to the SERC and DISCOMs.

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: State Electricity Regulatory Commission (SERC)

The Regulator develops the necessary regulation addressing various provisions of the rooftop solar policy. Various aspects of a rooftop solar regulation are discussed in Chapter 3 of this Manual.

Based upon the power instilled upon the Regulator by the Electricity Act, 2003, the Regulator may even develop the regulations required for rooftop solar 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. The Distribution Company (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 roles of the DISCOM can be distributed based on the three phases of the overall programme implementation:

- (i) Preparatory phase of the programme
 - Delegation of powers and empowerment of committees
 - Budgetary approvals
 - Regulatory approval of process 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
 - Application submission by the Consumer for PV capacity and interconnection
 - Screening of application and preliminary approval by DISCOM

- Installation of PV system and call for inspection and interconnection by Consumer
- Inspection by Electrical Inspector and/ or Third-Party Inspector
- Inspection, meter replacement and commissioning of the PV system by DISCOM

- (iii) Operation and billing of individual rooftop PV system
 - Billing of Consumer
 - Ensuring safe operation of the rooftop PV system
 - Data collection

These processes are discussed in detail in following sections of this chapter.

d. The State Nodal Agency (SNA)

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

- Technical capacities for rooftop solar PV systems, and
- Channels for promoting rooftop solar 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 Chief Electrical Inspector (CEI) is to ensure safe operation of the rooftop solar 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.

In addition, while most state solar policies exempt electricity duty on energy generated from solar projects, it is recommended to the CEI to keep record of solar generators in case duties are to be levied in the future.

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 should be 10 kW, it is highly recommended that smaller systems should be inspected by the DISCOM itself prior to commissioning or any Third-party Inspection (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. These Consumers evaluate the information available to them from DISCOMs and System Installers, and may only seldom refer to the policy and regulation.

The Consumers would evaluate the investment, payback and risks associated with a rooftop PV system.

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.

Although the Consumer would be responsible for the PV system, it would heavily depend upon the System Installer for a substantial amount of paperwork.

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.

The System Installer should quote a reasonable cost of the PV system to the Consumer while not compromising on the quality. The System Installer should build in the maintenance of the PV system as a part of its service.

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.

The System Installer should also pass on all the necessary equipment ownership, guarantee, warranty, designs, approvals and other documents to the Consumer.

Above all, the System Installer should ensure a pleasant and positive overall experience to the Consumer, as it would also promote the overall sector in a peer-to-peer manner.

5.3. The Interconnection Process

The interconnection process forms the heart of the engagement between the DISCOM and the Consumer (or the Rooftop Solar PV Developer). A simple and efficient interconnection process is key to a successful rooftop solar programme.

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.

One of the major objectives of this Manual is to simplify the administrative and interconnection process. It is globally observed that DISCOMs often build in a number of checks and balances, which complicates the process by making it redundant and repetitive, adding additional conditions, paperwork and transactions; which usually happens due to lack of domain

knowledge or an indirect intent to discourage rooftop solar deployment.

A simple yet effective interconnection process is recommended, which is broadly divided into four steps as follows:

- Application Process, which is initiated by the Consumer;
- Screening for technical feasibility and Preliminary Approval given by the DISCOM to the Consumer to start installation;
- Installation of the PV system by the Consumer and, upon installation, call for inspection/ commissioning; and
- Inspection and commissioning of the PV system by DISCOM.

After successful interconnection of the rooftop PV system, the Consumer owns and operates the system, while the DISCOM makes necessary adjustments in the billing of the Consumer.

These steps are presented in more detail as follows, and can be directly adopted by DISCOMs:

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

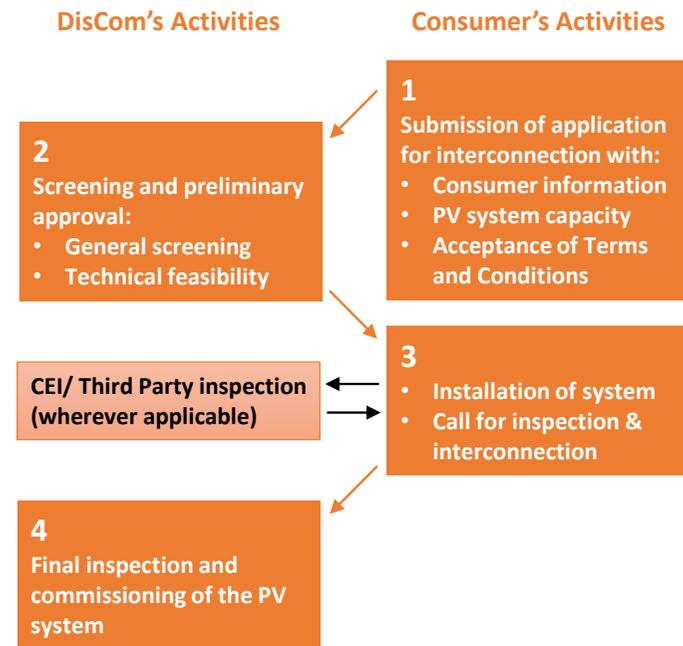


Figure 5-1: Overview of interconnection process.

- Type of Consumer, along with copy of latest electricity bill
- Capacity of the intended rooftop solar PV system
- An undertaking that the Consumer shall abide by all terms and conditions, standards and regulations,

statutory or as notified by the DISCOM from time to time

- If the electricity bill is not issued in the applicant's name, then an authorization letter by the person/ entity in whose name the bill is issued

This application forms the basis of the Consumer's interconnection agreement, and hence, should be treated with equivalent statutory weightage. A sample application form for reference is provided in Annexure 3.

The application should be submitted conveniently at the local sub-division and bill collection offices of the DISCOM where Consumers typically pay their electricity bills. The application should be submitted to a senior, yet easily accessible personnel, of the DISCOM such as the Executive Engineer.

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

Net-Metering Interconnection Process followed by BSES-Rajdhani, New Delhi

1. Receipt of Application Form

- Receipt of Application Form – from Consumer
- Acknowledgement with unique Service Order Number – by BSES
- Site Visit Report - LT & HT level – by BSES
- 1st Approval/ Rejection – by BSES
- Auto Debit of Rs 500/- as Application Fee – by BSES

2. Registration Form

- Receipt of Registration form – from Consumer
- Technical evaluation of Registration form – by BSES
- Registration form approval/ rejection – by BSES
- Demand note charges based on solar capacity – by BSES
- Payment of demand note charges – by Consumer

3. Net Metering Connection Agreement

- Sign off - Net Metering Connection Agreement – between DISCOM and Consumer
- Renewable system installation and Intimation – by Consumer

4. Net Meter Installation and System Energization

- Technical Clearance & Inspection – by Electrical Inspector/ Third Party
- Final approval/ rejection – by BSES
- Scheme for metering system – by BSES
- Payment against scheme – by Consumer
- Net meter installation – by BSES

5. Billing

- IT Updation - System to punch net meter – by BSES
- Development of Billing system in SAP – by BSES

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:

Part 1: General Screening

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

Part 2: 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

Net-Metering Interconnection Process followed by TEDA/ TANGEDCO*

1. Application

- Consumer to make an application to local Executive Engineer (O&M) of TANGEDCO
- HT Consumers to apply to Superintending Engineer of the Distribution Circle
- Application will be registered in a computerized database for a fee of Rs. 100/-.

2. Technical Feasibility

- TANGEDCO to verify technical feasibility as follows:
 - a. Total PV capacity in the local distribution network should not exceed 30% of distribution the transformer capacity.
 - b. Proposed PV system capacity cannot be more than sanctioned or contracted load of the Consumer.
- Once determined feasible, TANGEDCO to provide Technical Feasibility Intimation Letter to Consumer within 10 working days of receipt of application.

3. PV System Installation and Readiness Intimation

- Consumer to procure and install a PV system within 6 months from the date of Technical Feasibility Intimation Letter, which can be further extended by 3 months.
- Upon completion of the PV system, Consumer to intimate its readiness to Executive Engineer (O&M) of TANGEDCO.

(Continued on next page...)

*Notes:

TEDA : Tamil Nadu Energy Development Agency
TANGEDCO : Tamil Nadu Generation and Distribution Corporation Limited

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.

If the capacity of the proposed PV system is not feasible, or there is any other discrepancy in the application, or if the Consumer's application cannot be approved for any reason, the DISCOM should intimate the Consumer of rejection clearly stating the reasons, and also suggest re-submission, if possible, along with suggested amendments to the application. The same should be done within 7 (seven) days of acceptance of the application

No upgradation or modification of the distribution network is foreseen if the rooftop PV system capacities are limited to the Consumer's connected or sanctioned loads, and if the net PV capacity concerning a particular distribution transformer does not surpass the capacity of the distribution transformer itself.

However, as a part of the procedure, the DISCOM, at the sub-division itself, should assess that if any upgradation or modification is required to the distribution network due to the PV system(s), and if so, the same should be undertaken immediately.

Net-Metering Interconnection Process followed by TEDA/ TANGEDCO

(...continued from previous page)

4. Safety Inspection

- Within 10 days of receiving Consumer's readiness intimation, rooftop PV system to be inspected:
 - a. For PV systems up to 10 kW: by TANGEDCO
 - b. For PV systems greater than 10 kW: by Electrical Area of concerned area
- Consumer to receive safety certificate within 5 days of from the date of inspection.

5. 'Service Connection Meter' Replacement and Commissioning

- TANGEDCO to replace existing service connection meter with a bi-directional service connection meter.
- Consumer to pay for new meter; alternatively, Consumer to procure meter from approved meter makes and types as published on TANGEDCO's website.

It is recommended that recovery of any cost of upgradation is not loaded on a particular Consumer, but rather fairly distributed among the Customer base through a pre-defined mechanism.

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 content of the Preliminary Approval depends on the amount of paperwork that the DISCOM intends to sign with the Consumer (e.g. service agreement, interconnection agreement, power purchase agreement, etc.). However, as one of the major objectives of this Manual is to simplify the administrative process, it is recommended to avoid long and complex agreements with the Consumer. The formats should be rather kept short. Instead of including all terms and conditions in the format for signing, they should be annexed and/ or accessible separately. Of course, these terms and conditions should be pre-approved by the SERC.

The Preliminary Approval should be equivalent to a sanction letter to the Consumer, approving its application. This approval can serve as a substitute to signing a power purchase agreement, which would become unviable for the DISCOM to sign due to small individual capacities and large quantities of rooftop PV systems.

The Preliminary Approval should consist of:

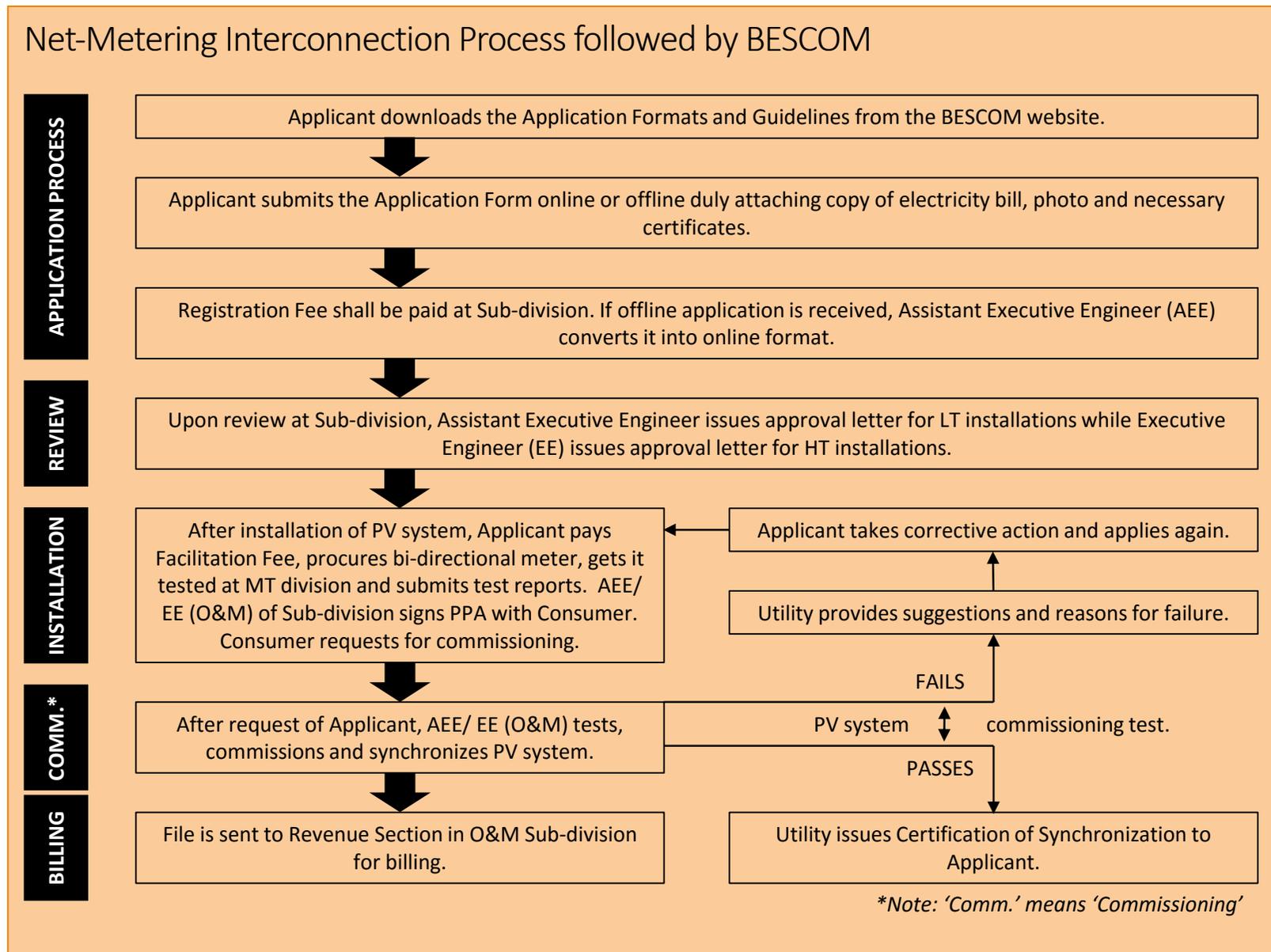
- Acknowledgment of receipt of the Consumer's application, details, interconnection request fees and proposed rooftop PV system capacity,
- Sanctioned capacity of rooftop PV system by the DISCOM,
- Procedure and timeline for installation of the PV system by the Consumer, and call for commissioning,
- 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), and
- Any other informational or promotional material by the DISCOM to further the Consumer's awareness regarding rooftop solar PV systems.

A sample Preliminary Approval letter is presented in Annexure 4 for ready reference.

The Preliminary Approval should indicate a comfortable yet definite timeframe for the Consumer to commission its PV system. This is required not only for the DISCOM to estimate the status of its renewable purchase obligation, but also to ensure that other deserving Consumers are not devoid of an opportunity of installing PV systems in case

there is any overall capacity limitation at a distribution transformer or DISCOM-level.

Net-Metering Interconnection Process followed by BESCO



Recommended timeframes for installing rooftop PV systems are indicated in Table 5-1. These timeframes include the time for a Consumer to select an installer, avail bank loans, construct the rooftop PV system, and call for necessary inspections.

In case of failure of the Consumer to commission the rooftop PV system within the given timeframe, the Consumer should be allowed to seek extension in tranches of, say, 3 months by paying a nominal fee and provided there is no technical limitation from the DISCOM’s side at the time of seeking extension.

c. Installation of PV system and call for inspection and interconnection

Once the Consumer receive 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

Table 5-1: Typical rooftop PV system development timeframes.

Rooftop PV System Capacity	Project Development Time
Capacity < 10 kW	: 6 months
10 kW < Capacity < 100 kW	: 8 months
100 kW < Capacity < 1 MW	: 10 months
Capacity > 1 MW	: 12 months

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 Chief Electrical Inspector, typically for capacities greater than 10 kW, then) Intimation to the Chief Electrical Inspector as per stipulated format for safety inspection and obtaining a ‘Charging Certificate’ for the PV system. A DISCOM or Chief Electrical Inspector may also employ a third party inspection (TPI) agency, which may inspect and certify the rooftop PV system at this point.

[Note: The format for application to the Chief Electrical Inspector would typically exist in most states and the same should be followed. Additionally, details may also be sought as per the format given in Annexure 5.]

- (Once the Charging Certificate is obtained from the Chief Electrical Inspector, 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: Single line diagram (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

[Note: A sample application for the DISCOM for commissioning of the PV system along with list of recommended attachments is given in Annexure 5.]

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:

- Verification of all administrative and technical contents/ compliance of the Consumer's application;
- Intimation to Consumer of date and time of site visit.
- Site visit and inspection to verify the installed PV system as per documents submitted by the Consumer. Refer to Annexure 6.
- Replacement of the existing unidirectional meter to a bi-directional net-meter, thereby commissioning the PV system; and

- Incorporation all necessary changes in the DISCOM's internal registers and IT system, so the changes are reflected in the Consumer's profile as well as billing software.

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. Now the DISCOM's major concerned activities become:

- 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.

In this manner, the complete administrative process for interconnection of a Consumer's rooftop PV system can be undertaken.

5.4. DISCOM's Preparatory Processes

Although the DISCOM's preparatory process for a rooftop solar 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: A centralized Administrative and Technical Process Committee should be formed under the chairmanship of the Technical Director or equivalent senior official of the DISCOM to:
 - 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 rooftop solar 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 rooftop solar programme on the DISCOM.

The DISCOM's balance sheet is affected the most due to a rooftop solar programme, when its Industrial and Commercial Consumers, who pay a higher tariff, start sourcing solar power. Hence, the reduction in sale of power, and consequently the margins, should be taken into account. Hence, it is important that the DISCOM sets targets which are in sync with the policy or renewable purchase obligation (RPO).

There are also positive financial implications on the DISCOM's balance sheet due to a rooftop solar programme, which should be considered:

- Avoided cost of buying solar power towards fulfilling the DISCOM's RPO, if a policy or regulation allows accounting of the solar energy generated on Consumer rooftops towards the DISCOM's RPO,
- Reduction in transmission and distribution losses for the amount of energy generated using solar power,
- Avoided cost of upgrading the capacity of (transmission and) distribution network, if nearing congestion, and

- Avoided cost of improving power quality such as low voltages and power factors.

c. Regulatory approval of process and formats

Although the state may have a rooftop solar 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.

As the application and approval documents between the Consumer and DISCOM would form a part of the overall interconnection agreement, and this agreement would substitute the power purchase agreement, an overall regulatory approval becomes important.

d. Integration with existing processes and changes to billing software

There would be some new process and some modification within 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.

A major modification in the DISCOM's process is in its billing software, so that it can:

- Identify a Consumer with net-metered PV system,
- Indicate the amount of solar energy generated by the Consumer's PV system,
- Calculate appropriate charges and rebates, wherever applicable, and
- Keep track of the surplus energy generation, if any, within the Consumer's billing cycle, and credit it as per appropriate rules and regulations

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.

In principle, it is desired to completely open a market such as solar for any equipment or service provider to freely participate in it. However, as solar is still in its nascent stages of deployment, Consumer's knowledge is limited and administrative processes are complex. 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 and 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 with in intent that the System Installers:

- 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 Ministry of New and Renewable Energy (MNRE), Government of India, 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) Third-Party Inspectors: PV systems are a relatively new topic for the DISCOM's engineers and the Electrical Inspectors. They consist of high DC voltages and inverters, which are very sophisticated equipment. Further, a successful rooftop PV programme would witness a large volume of PV systems, which makes it very difficult for a DISCOM to inspect and test prior to commissioning.

In such a case, it is highly recommended for a DISCOM to empanel qualified Third-Party Inspectors (TPI) that can:

- Verify all necessary designs, drawings, specifications of the rooftop PV system,
- Verify that the system is constructed as per the approved specifications,

- Inspect and test the system, and recommend it for commissioning.

Here, the System Installer can avail services of the Third-Party Inspector, wherein once the Inspector certifies the PV installation, the DISCOM will proceed for commissioning.

- (iii) 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 Manual).

As there are many makes and models of inverters available in the market, which origin from various geographical locations and may be certified based on different features and standards, it may be very tedious to ensure all compliances by a DISCOM's sub-division officer.

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, wherein Installers or Manufacturers can empanel inverters prior to actual design submissions.

- (iv) 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.

It is a misconception that the net-meters are expensive. In fact, there is not much difference between a conventional electronic meter and a bi-directional net meter. The software of a conventional energy meter treats reverse power flow as a tamper event and adds it to the Consumer's consumption; while in a net-meter, the reverse power flow should be deducted from the Consumer's consumption. Hence, 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, time of day (ToD) tariff, etc.

Net meters are already available in the market and several DISCOMs have started procuring them. Sample specification of the net meter is provided in Annexure 1.

The DISCOM may still find net-meters expensive as they would be procured in smaller volumes. Hence, the DISCOMs can consider procuring net-meters in large volumes, and from thereon, upgrade and install all new meters with such net-meters, whether the Consumer has a PV system or not.

f. Capacity building

Capacity building of both DISCOM Engineers as well as System Installers are important to ensure correct technical and procedural compliance under the rooftop solar 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 rooftop solar 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.

5.5. Challenges and Solutions

The DISCOM may face various challenges during the implementation of a rooftop solar programme due to its unique nature. However, these challenges can be easily overcome by ensuring that the DISCOM is sensitive to these challenges and taking appropriate action at the correct time.

a. Information access

Challenge:

- Encourage Consumers to develop rooftop projects
- Educate Consumers on a relatively new subject

Solution:

- Establish multiple channels for decimating information
- Enable information access through web portal, email, social media, etc.
- Develop information annual covering eky requirements, guidelines, formats, etc.

b. Application process

Challenge:

- Develop an application format which is simple yet captures the requisite information from all Consumer categories such as technical and safety requirements, procedures, reporting requirements, timelines, charges, fees, etc.

Solution:

- Develop single multi-user application form to avoid any confusion
- Develop a well-designed format to capture all required information in easily process-able manner
- Minimum layers of process and checks to reduce the processing time

c. Application screening

Challenge:

- Design a fast and efficient screening process for smaller PV systems

Solution:

- Pre-develop database of distribution transformers, and associate approved PV system capacities to them
- Organizing training programmes for DISCOM personnel

d. Installation and inspection

Challenge:

- Inspection of PV system with respect to safety, standards and other compliance
- Checking and installation of meters
- Upgradation of distribution network

Solution:

- Establishment of a dedicated cell for periodic inspection and check for approved rooftop systems
- Approval/ empanelment of System Installers
- Empanelment of inverter makes and models
- Continuous training of DISCOM's personnel

- Creation of solar helpdesk online through both web portal and phone line
- Use of IT tools to monitor, record and maintain useful data

In conclusion, this chapter covers key administrative processes associated with a rooftop solar PV programme. These administrative process are key 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 process should also be governed by a competent and empowered authority of the DISCOM.

e. Post-installation

Challenge:

- Periodic installation of rooftop facility and safety compliance
- Meter reading and checking of meter accuracy
- Resolving post-installation technical issues of Consumers
- Data monitoring, recording and reporting requirements
- Improvement in DISCOM's practices from time to time

Solution:

- Designating competent authority at sub-division level to resolve concerns and queries of Consumers

6. Project Financing

6.1. Introduction to Rooftop Solar Project Financing

Rooftop solar projects, like other renewable energy projects (wind, large solar and small hydro), are more cost-effective over the long run, especially when compared to the increasing costs of conventional energy generation. However, the implementation of these projects is challenging as these projects have a high upfront cost and may be more expensive in the short term as compared to the existing cost of conventional sources of power generation. Hence, it becomes imperative to develop and implement appropriate financing mechanisms and financial instruments to ensure that the viable projects are able to attract appropriate financing which makes these projects affordable over the life cycle, brings down the immediate cost burden and encourages project based financing.

Private financing instruments, such as debt, equity, mezzanine, and partial risk guarantees are being widely used in India and have slowly started to find their way to the rooftop solar sector.

6.2. Financing Methods

a. Debt

Debt financing for Solar and Renewable Energy projects in India is predominantly in local currency term loans, which

Table 6-1: Financial Institutions providing rupee term loans to renewable energy projects.

Government-backed NBFCs	Public-sector banks	Private-sector banks	Private NBFCs
Indian Renewable Energy Development Agency (IREDA)	State Bank of India	ICICI Bank	L&T Infrastructure Finance
Power Finance Corporation	Canara Bank	Axis Bank	Tata Capital
Power Trading Corporation	Central Bank of India	HDFC Bank	
Rural Electrification Corporation	Punjab National Bank	IDFC Bank	
India Infrastructure Finance Company Ltd.	Andhra Bank	Standard Chartered Bank	

Note: Non-banking financial companies (NBFCs) are financial institutions that provide banking services without meeting the legal definition of a bank, i.e. one that does not hold a banking license and, thus, is not allowed to take deposits from the public.

are provided by the local financial institutions (FIs). Conventional term loans from banks and other FIs are a major source for financing renewable energy projects. However, solar rooftop projects are new types of projects for banks and financial institutions with their new and evolving business models and inherent risks. Therefore considerable capacity building and awareness generation needs to be undertaken before they achieve the same seamless financing the way other capital goods and power generation sectors have achieved.

Developers typically approach banks for debt financing during the development stage once the PPAs are signed. Banks evaluate these projects and sanction funding, after which the project construction begins. Majority of these loans are balance sheet-funded, i.e., the borrowers guarantee the loan repayments by providing full or partial guarantee from their existing asset base.

Renewable energy projects in India are being debt financed both by government backed FIs as well as private FIs.

(i) Government-backed NBFCs: The Indian Renewable Development Agency (IREDA) and the Power Finance Corporation (PFC) are two of the leading government backed Non-Banking Financial Institutions and amongst the debt financing sector of RE projects in India. The interest rates for loans provided to RE projects by IREDA and PFC range from 9 percent to 13 percent, with

tenures between 10 and 15 years. Most loans provided by these institutions have a partial or full recourse to the parent entity in case of default.

IREDA is a public limited government company, established in 1987, under the administrative control of MNRE to promote, develop and extend financial assistance for the development of renewable energy and energy efficiency/ conservation projects. IREDA has played the critical role of a catalyst for renewable energy deployment in India and has funded a large number of such projects over the last several years.

IREDA is also the preferred vehicle for international development banks for promoting RE deployment in India. It has received substantial funding from development banks such as KfW, Asian Development Bank (ADB), International Development Agency (IDA)/ World Bank, Agence Française de Développement (AFD), Japan International Cooperation Agency (JICA) and the Nordic Investment Bank in the form of low cost credit lines guaranteed by the GoI. IREDA also sources funds from the domestic financial market through domestic bond placements (both taxable and tax free) and loans from domestic commercial banks.

(ii) Public Sector Banks (PSBs): PSBs dominate commercial lending in India, while their presence in the power sector (which also consists of lending to renewable

energy projects) is limited. The exposure of PSBs to the power sector varies from bank to bank. Exposure to state-owned utilities forms a major part within the power sector exposure of these banks. Increasing losses and deteriorating financial health of public utilities has increasingly become a cause of concern for PSBs. PSBs are now using stricter norms for lending to renewable energy projects in order to limit their exposure to utilities.

In majority of the cases, debt financing for the renewable energy sector is recourse based, i.e. the loans provided to RE projects by these banks are either backed by balance sheet or by promoter guarantees. Most renewable energy projects being funded by PSBs are based on their existing relationships with the promoters. Moreover, PSBs are more stringent in project evaluation and thus, end up lending to fewer RE projects. Interest rates on loans for RE projects range from 12 to 14 percent with tenure ranging from 8 to 12 years. PSBs provide loans with debt-equity ratio of around 60:40 to 70:30.

(iii) Private Sector Banks: Indian private sector banks, such as ICICI Bank and HDFC Bank, are relatively inactive in the power sector. The largest private sector banks, viz. ICICI Bank and HDFC Bank, have a much lower exposure to the power sector, as compared to the PSBs' average exposure. Private banks lend to RE projects based on

their relationship with promoters and guarantees provided by the promoters.

(iv) Private NBFCs: Private NBFCs such as L&T Infrastructure Finance and Tata Capital are more receptive to RE financing projects and have been active in the solar and wind energy space.

Key challenges for Debt Financing

A number of challenges related to debt financing have been afflicting the development of the renewable energy sector and these will impact the advancement of debt to the solar rooftop sector as well.

1. Unfamiliarity with solar rooftop projects and associated risks: A number of banks and financial institutions lack the basic understanding of the renewable energy sector, which gets magnified in the case of the solar rooftop sector. The solar rooftop sector is a new and emerging sector with limited installations in the country, new and emerging business models and very little understanding amongst the financial institutions of the risks associated with this sector. There is also very little performance data from earlier projects in public domain. These factors constrain financial institutions from understanding and properly evaluating these projects.

2. Lack of long tenure loans: Long tenure debt of over 10-15 years is mostly unavailable for these types of projects, thus stressing the cash flows from these projects in the initial years and impacting their financial attractiveness.
3. Lack of project-based financing: Most FIs demand full or partial recourse for financing solar rooftop projects. Debt funding of solar rooftop projects by FIs that are not guaranteed partially or fully by parent entity is being undertaken in rare cases with only a few private FIs providing debt to projects without guarantee from the parent entity.
4. Solar rooftop projects come under power sector lending for most banks: Banks internally define sector limits, and RE projects, which consist of solar rooftop projects, come under the power sector limits. These limits define the level to which the banks are willing to provide financing to a sector. Most banks today are approaching their power sector limits due to lending to state utilities and conventional power plants and thus are not very forthcoming on RE lending to new and emerging areas like solar rooftop. However, this situation is now changing as banks have started considering rooftop solar projects under home improvement and related schemes.

b. Lease financing:

In the past, FIs and independent power producers (IPPs), especially those focused on wind energy, worked together to benefit from accelerated depreciation via lease financing. Lease financing is a commercial arrangement between an FI and the Project Developer forming a special purpose vehicle (SPV), where the former purchases equipment and other components (usually equivalent to 70 to 80 percent of the project cost) and leases them to latter. Project Developers traditionally hold power projects in SPVs and are thus, unable to claim accelerated depreciation on such projects.

Table 6-2: Mutual benefits of leasing finance to FI and Project Developer.

Benefits to FI	Benefits to Project Developer
Generates business by providing debt in the form of lease to the Project Developer.	The Project Developer is able to get access to debt, but in the form of lease.
Since the assets are purchased on the balance sheet of the FI, latter can claim accelerated depreciation benefits applicable for RE projects under the IT Act, 1961.	The terms a Project Developer gets under leasing finance arrangement are usually better than those of a term loan, as some benefits from the accelerated depreciation are passed on to the developer by the FI.

Thus, the capital lease is mutually beneficial to both the FI and the Project Developer while working as a proxy for the debt component in the capital structure for the project.

In India, the leasing industry is dominated by NBFCs. Though the banks are allowed to perform leasing activities, they do not have significant presence in this sector.

However, as stated in the chapter, while lease financing does provide upfront relief in terms of lower costs, the Developers/ Rooftop Owners leasing the equipment needs to pay a service tax (14.5 percent) on the leased rental, which may make this form of financing non-viable in a number of cases.

c. Equity financing:

Equity finance is an essential component of project finance. Strategic investments, venture capital, private equity, tax equity investments and hedge funds are various direct equity providers to RE projects. Equity typically comprises 30 to 40 percent of the total project cost, while the rest is financed through debt. In India, the hurdle rates for direct equity investments range between 16 and 20 percent, and are dependent on factors such as size of the project, background of sponsor, risk assessment of the technology, stage of maturity, and geographic and policy risks.

In the recent past, some investments have been made in companies developing small-scale RE applications and projects. However the key focus of Developers and Equity investors has been on commercial scale RE projects. Wind energy projects are favourites among investors, whereas private equity funds have dominated the equity investment scene in India's RE industry. Most investments are in Indian Rupees and the funds stay invested for a period of five to seven years in the companies.

6.3. Roles of a Financial Institution

As a FI provides a large majority of the capital required for solar rooftop projects (debt is usually around 70 percent), the FI has to be very sure of the long term viability and sustainability of the project to be financed. For any given project, the FI will estimate both the risks and returns of the project. Therefore, FIs need to undertake a thorough review of the proposed projects generation, cash flows as well as any risks and challenges that can impact these.

The FIs usually undertake a detailed technical, financial, commercial and regulatory due diligence before finalising on the financing of these projects. The financier will analyse each individual risk and look at how to manage its potential impact on the project. As for the returns, the projected costs and revenues will be verified and then compared with the cost of the financing instruments to be used. The framework used by these FIs to evaluate the long term viability and sustainability of the

projects can also be used by Project Developers to design projects better, address risks upfront and also understand the key requirements from FIs.

Therefore a FI can provide both technical and commercial guidance and suitable financing advice to Project Developers while they are structuring their projects.

Commercial FIs usually have existing capabilities in due diligence, borrower appraisals, administration of loans and guarantee products. They also have empanelled equipment suppliers, understand the market conditions, the policy and the regulatory frameworks. The knowledge and understanding of each of the above can help Project Developers better structure projects and mitigate risks.

In project finance, or limited recourse finance, the debt is borrowed and the amount of debt made available will be linked to the revenue the project will generate over a period of time, as this is the means to pay back the debt. This amount is then adjusted to reflect inherent risks, e.g. the production and sale of power. In the case of a problem with loan repayment, rather like a typical mortgage, the banks will establish first 'charge' or claim over the assets of a business.

Funds use Internal Rate of Return (IRR) of each potential project as a key tool in reaching investment decisions. It is used to measure and compare the profitability of investments. Funds will generally have an expectation of what IRR they need to

achieve, known as a hurdle rate. The IRR can be said to be the earnings from an investment, in the form of an annual rate of interest

There is also an option for on-bill financing through which participating Utility Companies allow solar customers to repay their loans through payments added to their monthly electric bill. Other options like financing residential energy upgrades whereby the upgrade is paid off over an assigned term of years through an assessment on the homeowner's property tax bill can be looked for solar financing. Such assessment attaches to the property rather than to the homeowner, which can make it easier for homeowners to purchase a solar PV system even if they may want to sell their home before the system is fully paid off.

Sometimes banks also need financing and the best way to get finance is through public funds. There are three main routes for providing public funds:

- Direct provision: Represents direct grants, equity contributions, or loans to the Project Company/ banks. The original public financing agency is responsible for due diligence. Funds may be given directly or on-lent by governments, the route for most funds provided by multilateral organizations, such as the International Development Association (IDA) and International Bank for Reconstruction and Development (IBRD), and arms of the World Bank Group.

- Through a Commercial Financial Institution (CFI): In this instance, public financing is used to provide a credit line or guarantee for a CFI, which is then responsible for providing funds to RE project companies—whether as grants, loans, or guarantees. The CFI might supplement the public funds with complementary funding from its own resources or blend public and its own funds into a single loan. The CFI is responsible for due diligence, following procedures and processes approved by the public financing agency.
- Through a fund or similar vehicle established for the purpose: Public financing is used to provide the initial capital for the fund, which then provides this to RE project companies. The fund may either be dedicated to RE projects or may have broader remits—for example, to support rural electrification. The fund is responsible for due diligence, following procedures and processes approved by the public financing agency. This chapter briefly considers the respective merits of using CFIs or funds as intermediaries and provides guidance on the selection between these.

6.4. Cost and Trends

The solar PV industry has in recent years experienced rapid growth in the volume of output produced, sharp price declines for solar PV modules and a significant shift in the composition

Case Studies from Tanzania: FINCA & CRDB

FINCA (Foundation for International Community Assistance) is a micro-finance organization while CRDB is a commercial bank in Tanzania. Both FINCA and CRDB have tried to lend to energy enterprises through pilot tests that lasted two years each. But both faced the problem of requiring collaterals from the users or businesses as borrowers mostly came from low end income earners in the rural areas without adequate assets to pledge.

FINCA also did not consider the equipment that was bought, such as solar PV systems, as part of the collateral, which made it very difficult for customers to meet the banks requirements. Also as so often, buy-in by the bank staff was lacking as the energy products were more complicated to manage than their regular products.

Challenges encountered:

- Supply networks, service and maintenance issues, knowledge and attitude of Loan Officers were found to be crucial for the success of small PV projects.
- The lengthy approval process made most of the initial setups challenged by more pressing issues like pricing, supply chains and networks that did not work out as planned.
- Success or failure of such a project required a thoroughly efficient localized network of supply, installers, service and maintenance as other factors to which a lot of emphasis was laid play only a peripheral role.

of module suppliers. Photovoltaics are a fast growing market. The Compound Annual Growth Rate (CAGR) of PV installations globally was 44 percent in 2000 to 2014.

Table 6-3 provides a breakdown of the cost of a typical 10 kW grid-connected rooftop solar PV system. It should be noted that the PV modules comprise of about half the cost of the PV system; and hence, they have a substantial impact on the overall cost. On the other hand, all other equipment (which are collectively known as the 'balance of system' or BoS) and

Table 6-3: Typical capital cost of a 10 kW grid-connected PV system.

Sr.	Item	Cost (Rs. per kW)	Cost (in %)
1.	PV modules	35,000/-	47%
2.	Inverter	12,000/-	16%
3.	Module mounting structure	10,000/-	13%
4.	Building and civil works	3,000/-	4%
5.	Isolation transformer*	4,000/-	5%
6.	Wires and electrical	3,000/-	4%
7.	Engineering and project management	3,000/-	4%
8.	Contingency, Fees, etc.	5,000/-	7%
Total Cost		75,000/-	100%

**Note: May be used only in some cases.*

associated works are equally critical as they can also collectively have a major impact on the cost of the PV system.

The total cost of the PV system indicated in the table would vary with respect to scale of the system, combination of inverters used to reach the desired capacity, type of mounting used for the PV modules, and so on. While cost may vary slightly from case to case, it is often seen that lower costs are achieved only through compromise in quality and performance of equipment and installation. Hence, the investors as well as bankers need to be educated on the PV system to ensure that they are funding a product with the right balance of cost and quality.

As PV modules are treated as a commodity, their costs are relatively easy to identify. Figure 6-1 from Mercom Market Intelligence Report for the week of 16 November 2015, shows an 8.5 percent drop in module spot prices over the first ten months of 2015. However, last few months show a steady trend, possibly due to year-end drawing close.

Another report from pvXchange shows a varied trends over the past one year. Figure 6-2 shows region-wise average monthly prices in USD/ Watt for a period of twelve months, from November 2014 to October 2015.

The data shows that since November 2014, regional module prices dropped anywhere between 11-15 percent (maximum drop), though they recovered a bit by the end of year due to heavy demand from China and US. Assuming a similar maximum

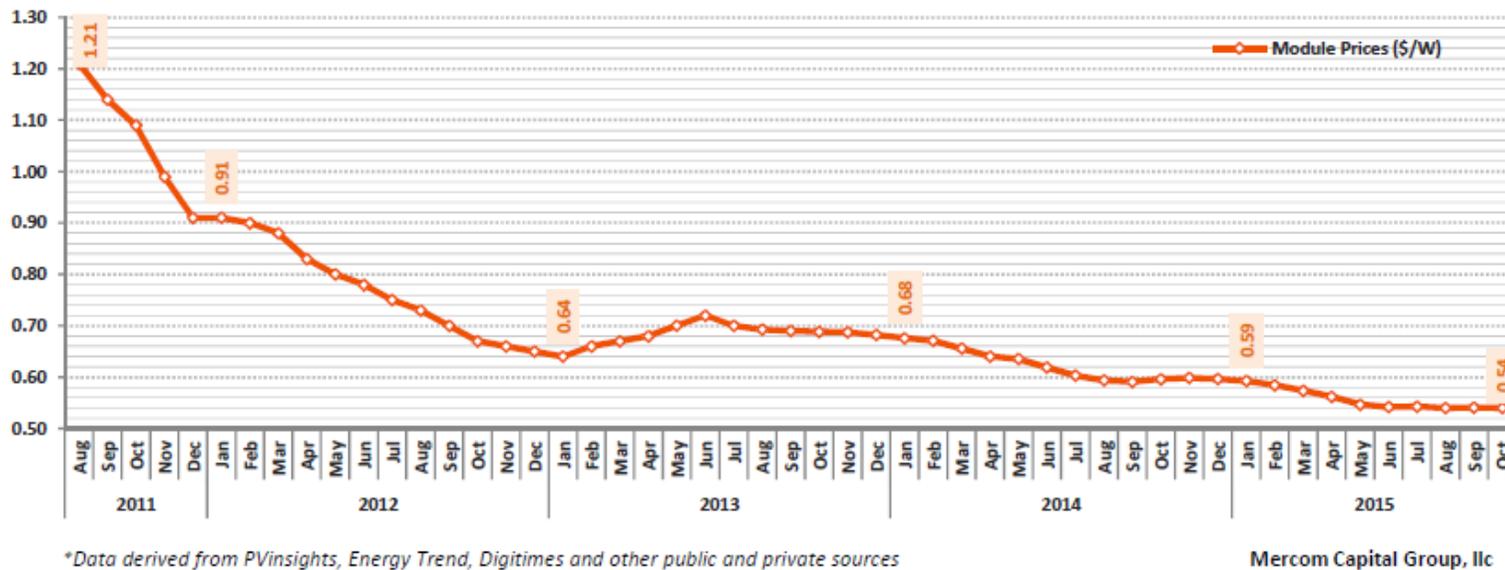


Figure 6-1: Monthly average Chinese module spot prices (2011-2015).

drop over the next twelve months as in the regional table from pvXchange, i.e. 11 percent from year-end prices for South-East Asia of USD 0.54 per Watt, the expected module spot price by end of next year would be USD 0.48 per Watt. It should be noted that discovered spot prices are typically higher than bulk prices that are negotiated by companies for large MW-scale projects.

Additionally, from interactions with industry, it has emerged that prices for modules being deployed in the Indian market currently are in the range of USD 0.43-0.50 per Watt. Thus, it may be observed that current projects are being implemented at module prices well below existing spot market prices.

Considering the data trends shown, and factoring in expected price reductions over the next year, the CERC has proposed the benchmark cost of modules to be considered at USD 0.465 per Watt for FY 16-17. Average exchange rate of Rs. 64.58 per USD is considered for this exercise.

The prices of other components of the PV system such as inverters, mounting structures, etc. also vary based on the market factors; however, they are steadier and have a lesser impact on the overall system cost due to a lower cost fraction within the PV system.

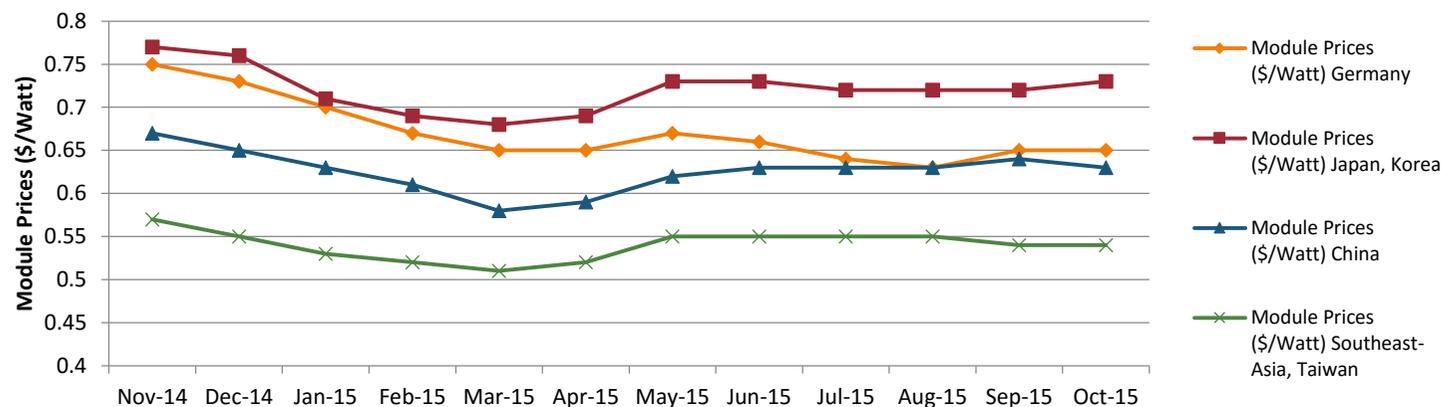


Figure 6-2: Monthly module prices for different regions (November 2014 – October 2015).

6.5. Considerations for Financing of Rooftop PV Projects

Solar rooftop is a new sector for most FIs and they often lack appropriate frameworks to understand the key technical and commercial considerations and risks associated with these solar rooftop projects. This section identifies the key technical and commercial considerations which have been taken into account while developing solar rooftop projects and also highlights some of the key risks associated with these projects which financiers need to evaluate while evaluating the projects.

a. Technical Considerations in Financing

A number of technical parameters need to be evaluated while financing solar rooftop projects. These range from grid uptime to the quality of the roofs, the quality and

standards of components for the design and installation of the solar rooftop plant, the type of metering as well as interconnection procedures including safety requirements for the commissioning of the plants.

(i) Performance of the PV system:

The estimated performance of the PV system plays a major role in return expectations for the Consumer as well as qualification for project financing by the FI. Typical capacity utilization factors (CUF) range around 16-18 percent for rooftop PV systems. (It is assumed that these are flat plate collectors without any tracking.) Loan Officers should ensure that cash flows in the financial model of PV system are based on realistic

CUFs, which are primarily based on the location and orientation of the system.

(ii) Reliability of the grid (“grid uptime”):

Grid uptime defines the availability of the grid electricity in a year after discounting downtime of the grid due to grid failure, maintenance or any other reason. Solar rooftop projects are equipped with intelligent inverters which sense the synchronizing voltage (also called reference voltage) from the grid to generate electricity.

In the event of grid downtime, the inverter loses this reference voltage and shuts down, resulting in loss of generation. Thus, grid uptime in the area where the solar project has to be installed is a critical variable for viability of the project. Data on grid uptime can be either obtained from the Distribution Company to which the project will be connected to or it can be calculated from historical data based on the use of alternate sources of generation like diesel generators.

The average downtime during daytime is more relevant for solar projects as solar generation is maximum during this time. Financial institutions should ensure that a realistic uptime is considered while calculating the revenue generated from the PV system.

(iii) Profile and quality (structural) integrity of the roof:

Suitability of rooftops for solar installations is critical from a feasibility standpoint. Rooftops not only support the installation but also need to be oriented in a direction that yields sufficient quantities of power to meet the basic commercial return requirements. While designing a rooftop solar system, an evaluation of the profile of the rooftop is critical. Suitability of rooftops for solar installations depends on the following:

- *Load bearing capacity of the roof:* This is to ensure that the roof has the required structural strength to bear the load of the solar rooftop installation during the construction and operation of the project. Usually, all flat RCC roofs are capable of hosting rooftop PV systems, but this might not be true for all steel-structure roofs, which are typically inclined and are used on sheds. Structural Engineers can assess the load bearing capacity of the roof and issue certificates on the same.
- *Inclination of the roof:* The inclination of the roof is a critical factor which governs the amount of solar insolation that the roof is exposed to and has a direct impact on the solar energy generation from the installation.

- *Material of the roof:* The material, which the roof is made up of defines the need for any additional enhancement to make the roof suitable for solar installation. This also has an impact on the project cost as the additional enhancement leads to cost escalation.
- *Shadows:* Features such as parapets, water tanks, etc. can cast shadows on the rooftop solar installation at some point in time. Hence, a shadow analysis and determination of shadow-free area is a very important step during the layout design stage of the installation. While it may not be possible to completely eliminate shadows, the System Owner should at least be aware and account for the expected generation loss due to shadows.

(iv) Ownership of the roof:

The ownership of the roof can lie with the consumer itself or can be through another party who has a lease or rent agreement with the consumer as the tenant. For any FI evaluating a solar rooftop project, it becomes critical for the bank to assess whether the contractual relation between the owner and the tenants/consumers is adequate to cover the risk of early requisition of the premises which in turn shall put the PPA in jeopardy. For example, there is a need to check if the remaining tenure of the lease agreement between

the consumer and rooftop owner is sufficient to cover the loan repayment tenure or the lease agreement is extendable to a period to meet this condition. A No Objection Certificate (NOC) or a contractual agreement between the Third Party and the rooftop owner (in case the premises are leased to a tenant and the PPA is being signed by the tenant) is also recommended.

(v) Access to the roof and right of way (RoW):

In Third Party-based business models, easy 24x7 access to the rooftops is a key requirement for personnel to ensure smooth operation of the equipment and quickly rectify any issues. To ensure seamless access, there is a need for both legal and physical access to the rooftops. There are two major hindrances in the procurement of roof which are:

- *Legal Access to the roof:* In case of Third Party ownership of systems, it becomes critical that the Third Party Owner has legal access to the roof for the duration of the project or the length of the PPA. This requires that the legal owner of the roof is identified and modalities put in place that allows access rights for the solar rooftop developer to the installation based on legal agreements entered by the Building Owner and the Third Party.

- *Physical Access to the Roof:* The physical access to the roof is evaluated as provision of easy, efficient and quick access to the roof not only for personnel but also the heavy equipment like solar panels, inverters, mounting structures etc. There needs to be adequate provisions in terms of stairs/ lifts/ passageways. It is to be noted that suitable alternate arrangements can also be made to facilitate access but these will add to the cost of the project.

b. Commercial Considerations in Financing

Solar rooftop projects, although simple to implement, need to be judiciously designed in order to ensure adequate returns on the investment as well as address most of the risks associated with these projects. Therefore a number of commercial arrangements need to be evaluated and addressed while financing solar rooftop projects. These range from the returns from the project, the nature of the tariff charged, cost of electricity replaced, contract sanctity, lease arrangements, etc.

(i) Cost of the Project:

Cost of the rooftop solar project is one of the first indicators of the health of the overall health of the rooftop solar ecosystem. A low indicated capital cost may raise quality concerns, resulting into performance

and loan payback concerns. On the other hand, a high indicated capital cost may raise concerns of price inflation either by the Project Developer or the System Installer, which may be unhealthy in the long term.

(ii) Internal Rate of Return (IRR):

Rooftop Owners primarily install PV systems to reduce either their utility bills or to feed electricity to the grid and earn a basic rate of return. To understand whether this proposition makes economic sense, project IRRs need to at least meet market benchmarks. This IRR depends on the difference between the actual rate per kWh avoided by generating on-site power on solar rooftops. The IRR calculations depend on a wide variety of factors which the FIs need to consider – these range from the cost of retail grid based power, cost of per unit solar power, annual escalation of cost of grid based retail power, cost of borrowing and the tax and fiscal benefits available to the Developer/ Generator. All of these factors have an implicit impact on the IRR and need to be evaluated.

(iii) Tariff of the Power Purchase Agreement (PPA):

This is the contractual agreement between the Third Party Developer and the Purchaser of solar electricity, and governs the conditions of supply during the power purchase period. The cornerstone of the PPA is the

tariff, the price per unit of electricity purchased. The tariff is fixed for the complete tenure of the PPA, however the structure of the tariff can be combination or any of the following:

1. *Constant Tariff:* In this case, a tariff is agreed upon in the first year of the agreement and it is kept constant throughout the tenure of PPA. A levelized tariff is selected in this structure. The advantage of this type of tariff is its simplicity, and a steady cash flow for the Project Developer. However, the disadvantage is that, with increasing conventional tariffs, the Power Purchaser may find the solar tariffs relatively high during the initial years of the agreement.
2. *Independent Escalation:* A variable tariff can be developed with a constant or variable annual escalation (e.g. to the tune of 3-5 percent per year). The PPA may pre-define the period (either the complete term of the PPA or a limited term during the PPA) of escalation. The advantage here is that the Purchaser of solar electricity will not have bear the brunt of high upfront solar tariffs. However, in the longer term, the conventional power tariffs may not follow the same escalations rates as defined in the PPA, which may result into either (i) the Project Developer selling cheaper solar power than its actual value, or (ii) the Consumer paying a higher

tariff than the conventional tariff; both these situations can put the PPA in risk.

3. *Conventional Tariff-based Escalation:* The PPA may link the solar purchase tariff to the conventional power tariff and further provide a discount to it to make it attractive for the Power Purchaser. The advantage here is that the Consumer is always assured of a lower tariff and hence, motivated to honour the PPA. The disadvantage is that if the conventional tariff does not escalate substantially, then the Project Developer may not receive high returns. However, such a tariff arrangement may balance out the risks in the long term.

(vi) Business Models:

Business models play a critical role in defining the commercial arrangements between the stakeholders as well as the risk profile of the project. A number of permutations and combinations can be developed under business models and FIs/ banks will have to evaluate the key risks and commercial arrangements that these different models bring to the table during the financing phase. Table 6-4 outlines the various permutations and combinations for the design of a business model for solar rooftop.

Table 6-4: Rooftop PV model designs with metering schemes.

Owner of roof	Applicant (Owner of the solar plant)	Consumer of solar energy	Metering scheme
Consumer	Consumer	Consumer	Self-Consumption
Consumer	Consumer	Consumer	Net Metering
Consumer	Consumer	Utility	Gross Metering
Third-Party	Consumer	Consumer	Self-Consumption
Third-Party	Consumer	Consumer	Net Metering
Consumer	Third-Party	Utility	Gross Metering
Third-Party	Third-Party	Consumer	Self-Consumption
Third-Party	Third-Party	Consumer	Net Metering
Third-Party	Third-Party	Utility	Gross Metering
Consumer	RESCO	Consumer	Self-Consumption
Consumer	RESCO	Consumer	Net Metering
Consumer	RESCO	Utility	Gross Metering
Third-Party	RESCO	Consumer	Self-Consumption
Third-Party	RESCO	Consumer	Net Metering
Third-Party	RESCO	Utility	Gross Metering

(iv) Payment Security Mechanism:

Payment security mechanisms are adopted to avoid default against payment of dues by the Consumer to the Project Developer. Security could be in the form of a Letter of Credit or a Bank Guarantee. It gives a third party (e.g. bank) an authority to retain the amount equivalent to the amount defaulted by another party. Late payment penalties can also be added in the PPA to motivate the Consumer for timely payments.

(v) Tenure of the PPA:

From the lender’s perspective, the tenure of PPA must be longer than the loan repayment tenure. Further the lender evaluates the project based on Debt Service Coverage Ratio (DSCR) and the credentials of the Consumer as well as the Project Developer.

6.6. Risk Assessment and Mitigation

It is important for the FI to identify risks and mitigate them to the maximum possible extent. These risks stem from the interactions, contractual relations and inter-dependencies of the stakeholders. This section attempts to identify the key risks which can impact the viability of solar rooftop projects and their mitigation measures, wherever possible.

a. Underperformance of the PV system

There is a risk that the PV system may underperform, which may result into a lower revenue for the Project Developer, which in turn may affect its ability to pay the loan. Such underperformance does not typically occur due to variation in solar irradiation (or insolation), but rather on the quality of the PV system or availability of the grid.

The loan repayment is projected on the estimated revenue based on an estimated performance. A benchmark shall be agreed on minimum guaranteed performance with a penalty for under performance. For example a benchmark CUF can be defined in the contract and penalties for underperformance.

Mitigation: It is highly recommended that FIs audit the rooftop solar plants through Third-Party Engineers/ Inspectors or Lender's Engineers to ensure appropriate quality. FI's can pre-approve PV system configurations, equipment and even System Installers.

b. "Deemed generation" for addressing loss of generation

The Deemed Generation is a concept which aims to address situations around offtake and loss of generation issues that are not on account of the Project Developer and not on account of Force Majeure events. These usually cover situations where either the grid is not available due to the

Distribution Utility's supply issues and/ or the Consumer is not able to off take the power from the solar rooftop plant. This clause protects the Project Developer and the Lender from revenue loss and delays in the repayment of the loan. It is crucial that the Deemed generation clause is included in the PPA, appropriately designed to cover appropriate contingencies including but not limited to:

- Lack of off-take of the electricity generated due to either power quality/ unavailability issues of the distribution grid, or internal faults of the Consumer's network;
- Unplanned displacement of the PV system;
- Inability to rectify faults in the PV system on time;
- Any loss of generation due to shadow by new buildings or objects in the future; etc.

Mitigation: The deemed generation clause should indicate a grid availability or uptime of a certain minimum time fraction of the year (e.g. 95-98 percent), which should in turn reflect the realistic availability of the distribution grid. The Consumer cannot be penalized for any issues with the distribution grid. On the other hand, in case of grid unavailability beyond a certain extent arising from reasons attributed to the Consumer, the Project Developer may charge the Consumer for the solar energy which could have been generated and purchased by the Consumer. The methodology for calculating deemed generation should be clearly mentioned in the PPA, which could be as simple as

equating it to the amount of solar energy generated in the same time window of grid unavailability on the closest day when no grid default had occurred.

c. Early Termination of the Power Purchase Agreement

This is an applicable risk for the scenario where the Project Developer is a Third Party or a Renewable Services Company (RESCO), who has applied for a loan against the PPA with the Consumer. Early termination of the PPA due to any reason will have implications on the loan repayment. It is critical to evaluate if there are appropriate remedies and measures have been built into the PPA to safeguard the Lenders and the Project Developer/ RESCO itself.

Mitigation: The PPA can address the issue of early termination by the Consumer via a guarantee mechanism either through a buy-back or a buy-out clause or through a penalty payment which may cover all the costs as well as lost revenues for redeployment of the PV system.

d. Early termination of the lease agreement for the roof

This is a risk under a scenario where the Rooftop Owner is not directly a party to the PPA. The risk is of early termination of the rooftop lease/ rent agreement. Commitment of the Rooftop Owner is an important issue which needs to be taken care of through a separate (lease

or rent) agreement between the Rooftop Owner and the Project Developer.

Mitigation: The Project Developer should attempt to sign a 25-year lease agreement with the Rooftop Owner, or at least maximize the term of the lease with simple and pre-defined provisions to extend the lease from time to time. While long-term leases more probable in commercial setups, they are challenging to achieve for residential buildings. Hence, residential PV systems should be made modular and mobile, which can be moved on a higher floor if an additional floor is constructed by the Rooftop Owner, or the PV system can be relocated altogether in case the lease agreement is not renewed.

e. Buyout of PV system by Consumer

Rooftop solar PPAs between the Project Developer and the Consumer often consist of a buyout clause, wherein the Consumer is given an option to buy the PV system from the Project Developer after a certain amount of time (typically, after 2-5 years).

Mitigation: The loan repayment terms for the Project Developer should be clearly defined in the loan agreement. It should also be ensured that the repayment amount is consistent with the buyout amount that the Consumer would pay to the Project Developer. Alternatively, the FI

can even keep an option of transferring the loan to the Consumer if this Consumers meets the FI's lending criteria.

f. Termination from default

Events of default should be covered and unambiguously defined in the PPA between a Project Developer and the Consumer, while their implication on loan repayment should also be identified and addressed.

(i) Consumer default: The understanding of defaults on the Consumer-side should cover (but not be limited to) the following concerns:

- In case of non-payment, how much delay after the credit period is considered default?
- For non-availability of synchronizing power, what percent of operating hours lost is considered default?
- For non-availability of access to roof or temporary unavailability, what percent of days in a year is considered default?
- In case of damage of major equipment caused by Consumer, to what extent of damage lead to termination?

(ii) Project Developer default: The understanding of defaults on the Project Developer-side should cover (but not be limited to) the following concerns:

- How many months of non-availability of solar plant is considered default?
- What is the minimum guaranteed (benchmark) CUF to the Consumer, the failure to achieve which is considered default?
- Is there an extent to damage caused by the Project Developer to the rooftop that is considered default?

Mitigation: The FIs should consider the impact of these defaults and possible pre-mature termination on project feasibility and loan payback. A certain technical knowledge of PV systems by the FIs (either directly or via Third-Party Inspectors/ Evaluators) is necessary in order to identify whether the defaults are deliberate or accidental, and if they can be rectified. In the worst case scenario, if the termination is enforced, the FI should be prepared to confiscate the PV system and put it for reuse. This also implies that if it favourable to the FI if the PV system configuration and installation is simple and standardized.

g. Delay in administrative approvals

Due to several dependencies on government agencies for interconnection and commissioning, subsidies, etc., there are possibilities that although the Project Developer would have incurred expenses to install the rooftop PV system, its corresponding cash flow may not start within the expected timeframe.

Mitigation: FIs are recommended to educate themselves with the approval procedures and realistic timeframes. This can be done through consultative meetings with the concerned DISCOMs and the State Nodal Agencies. Familiarity with the administrative processes will help the FI in verifying the Project Developer's timeframes, procedures followed, subsidies claimed, etc.

In conclusion, this chapter discusses various financing methods for rooftop solar programmes along with key roles of the Financial Institutions. It is critical to understand the cost trends of rooftop PV systems to ensure the correct amount of financing; while technical and commercial matters are interrelated for a healthy operation of the system during its life. Rooftop PV systems pose several unique risks that are not present even in ground-mounted PV plants, but they can be substantially mitigated through appropriate terms in the loan contracts and PPAs.



Annexure

Annexure 1: Brief note on net meter standards and specifications

[Acknowledgement: Auroville Consulting]

Solar energy generation meter

In solar PV systems with net-metering, the Distribution Licensee may require the system owner to install an energy meter that records the gross energy produced by the solar PV system since this will allow the Distribution Licensee to claim the solar energy produced towards fulfilment of renewable energy purchase obligations (RPOs). An energy meter that records the gross solar energy production will also be needed if there is a mechanism that includes generation-based incentives (GBIs).

The solar energy generation meter shall be installed close to the solar grid inverter and shall be inserted in between the AC output of the solar grid inverter and the distribution board to which the solar grid inverter AC output is connected.

The solar energy generation meter may be a unidirectional or bidirectional energy meter with the same accuracy as the energy meter of the electrical service connection. The solar energy generation meter shall be single phase for single phase solar grid inverters and three phase for three phase solar grid inverters.

Distribution Licensees are advised not to insist that the solar energy generation meter is located near the service connection

meter. This may not be possible in all cases since the solar energy generation meter must be installed close to the solar grid inverter, which in turn must be installed as close as possible to the solar PV panels to reduce the length of DC cables for both safety and energy loss reasons. If the location of the solar energy generation meter makes it inconvenient for the Distribution Licensee to take readings for each billing cycle, Distribution Licensee may request their customers to take and send the readings of this meter with an annual or bi-annual on-site verification by the Distribution Licensee.

Bidirectional Service connection energy meter (for net metering)

For the implementation of solar energy net-metering, the existing electrical service connection meter needs to be replaced with a bidirectional energy meter that records and displays imported and exported energy in separate registers. If the existing energy meter is already of the bidirectional type, there is no need of meter replacement.

The bidirectional energy meter may of the same accuracy and capacity as the existing unidirectional energy meter for the given service connection category.

Since most electronic digital energy meters are capable of four-quadrant metering with active and reactive energy import and export registration, the bidirectional meter differs from the unidirectional meter only in the manner in which the meter is configured by the manufacturer or the Distribution Licensee.

It is recommended that Distribution Licensees consider installing service connection meters that are configured for bidirectional energy recording as their standard meter for all new service connections and for all meter replacements of existing service connections so that these service connections are solar net metering ready.

Energy meters for gross feed-in

For the implementation of gross feed-in tariff mechanisms an energy meter shall be installed that records the solar energy fed into the grid of the Distribution Licensee. If the solar PV system is installed at the premises of an energy consumer, the gross feed-in energy meter may be of the same type and accuracy as the energy meter used for the registration of energy consumption for the given category of consumers.

It is recommended to configure gross feed-in energy meters for bidirectional energy recording so that self-consumption by the solar PV plant, if any, is recorded and automatically deducted from grid export.

If the premises where the solar PV system is installed also consume energy, the existing service connection meter that records energy consumption for the purpose of tariff billing may be retained.

In cases where gross feed-in energy meters are installed, there is no need of a separate Solar Generation Energy Meter near the solar grid inverter since the gross feed-in energy meter itself records the gross generation of the solar energy system.

Energy meters for rooftop solar PV systems – General guidelines

It is recommended that the Distribution Licensees procure the energy meters required for solar net metering and solar gross feed-in metering so that price reduction can be achieved on account of the economies of scale. Since bidirectional energy meters differ from unidirectional energy meters only in parameter configuration and not in hardware, the Distribution Licensees are advised to procure these meters at prices that are similar to the prices of the electronic digital unidirectional energy meters that are already being procured on a regular basis.

It is recommended that Distribution Licensees charge their customers only a nominal meter replacement fee which covers the cost of installation labour since the unidirectional meters

that are replaced with bidirectional meters will, in most cases, be re-deployed elsewhere.

As stated above it is recommended that Distribution Licensees make bidirectional energy metering the standard for their new service connections.

It is recommended to standardize the parameterization of energy meters in general and meters used for solar energy systems in particular and use the three digit OBIS code for the identification of each meter parameter. The parameter sequences as given below may be considered in this regard.

Table: Proposed energy meter display sequences.

(a) Single-phase meters, auto scroll.

S.No.	OBIS			Description
1	0	9	2	Date (DD.MM.YY)
2	0	9	1	Current time (hh:mm:ss)
3	1	8	0	Active energy import (+A) total [kWh]
4	2	8	0	Active energy export (-A) total [kWh]
5	16	8	0	Active energy net (+A - -A) [kWh]

(P.T.O.)

(b) Single-phase meters, manual scroll.

S.No.	OBIS			Description
1	0	9	2	Date
2	0	9	1	Real Time
3	1	8	0	Active energy import (+A) total [kWh]
4	2	8	0	Active energy export (-A) total [kWh]
5	16	8	0	Active energy net (+A - -A) [kWh]
6	1	6	0	Maximum demand register - Active energy import (+A) [kW]
7	1	6	0	Maximum demand register - Active energy import - date
8	1	6	0	Maximum demand register - Active energy import (+A) - time
9	2	6	0	Maximum demand register - Active energy export] (-A) [kW]
10	2	6	0	Maximum demand register - Active energy export] (-A) - date
11	2	6	0	Maximum demand register - Active energy export] (-A) [kW] - time
12	1	7	0	Instantaneous active import power (+A), (Q1 + Q4) [kW]
13	2	7	0	Instantaneous active export power (-A), (Q2 + Q3) [kW]
14	14	7	0	Frequency [Hz]
15	16	7	0	Instantaneous active power net (+A - -A) [kW]
16	32	7	0	Instantaneous voltage (U) in phase L1 [V]
17	31	7	0	Instantaneous current (I) in phase L1 [A]
18	C	6	0	Power down time counter
19	C	6	1	Battery remaining capacity
20	0	2	0	Firmware version
21	C	1	9	Meter serial number

(c) Three-phase meters, auto scroll.

S.No.	OBIS			Description
1	0	9	2	Date
2	0	9	1	Real Time
3	1	8	0	Active energy import (+A) total [kWh]
4	2	8	0	Active energy export (-A) total [kWh]
5	16	8	0	Active energy net (+A - -A) [kWh]
6	1	7	0	Instantaneous active power import (+A) (QI+QIV) [kW]
7	2	7	0	Instantaneous active power export (-A) (QII+QIII) [kW]

(d) Three-phase meters, manual scroll.

S.No.	OBIS			Description
1	0	9	2	Date
2	0	9	1	Real Time
3	1	8	0	Active energy import (+A) total [kWh]
4	2	8	0	Active energy export (-A) total [kWh]
5	16	8	0	Active energy net (+A - -A) [kWh]
6	3	8	0	Reactive energy import (+R), (Q1 + Q2) [kVARh]
7	4	8	0	Reactive energy export (-R), (Q3 + Q4) [kVARh]
8	5	8	0	Reactive energy import (+Ri), (Q1) [kVARh]
9	6	8	0	Reactive energy import (+Rc), (Q2) [kVARh]
10	7	8	0	Reactive energy export (-Ri), (Q3) [kVARh]
11	8	8	0	Reactive energy export (-Rc), (Q4) [kVARh]
12	9	8	0	Apparent energy import (+S) total [kVAh]
13	10	8	0	Apparent energy export (-S) total [kVAh]
14	13	5	0	Last average power factor import (+A/+S)
15	84	5	0	Last average power factor export (-A/-S)
16	1	6	0	Maximum demand register - Active energy import (+A) [kW]
17	1	6	0	Maximum demand register - Active energy import - date
18	1	6	0	Maximum demand register - Active energy import (+A) - time
19	2	6	0	Maximum demand register - Active energy export] (-A) [kW]
20	2	6	0	Maximum demand register - Active energy export] (-A) - date
21	2	6	0	Maximum demand register - Active energy export] (-A) [kW] - time
22	9	6	0	Maximum demand register - Apparent energy import (+S), (Q1 + Q4) [kVA]
23	9	6	0	Maximum demand register - Apparent energy import (+S), (Q1 + Q4) - date
24	9	6	0	Maximum demand register - Apparent energy import (+S), (Q1 + Q4) - time
25	10	6	0	Maximum demand register - Apparent energy export (-S), (Q2 + Q3) [kVA]
26	10	6	0	Maximum demand register - Apparent energy export (-S), (Q2 + Q3) - date
27	10	6	0	Maximum demand register - Apparent energy export (-S), (Q2 + Q3) - time

(Continued on next page...)

(...continued from previous page)

28	1	7	0	Instantaneous active import power (+A), (Q1 + Q4) [kW]
29	2	7	0	Instantaneous active export power (-A), (Q2 + Q3) [kW]
30	3	7	0	Instantaneous reactive import power (+R), (Q1 + Q2) [kVar]
31	4	7	0	Instantaneous reactive export power (-R), (Q3 + Q4) [kVar]
32	5	7	0	Instantaneous reactive import power (+Ri) (Q1) [kVar]
33	6	7	0	Instantaneous reactive import power (+Rc) (Q2) [kVar]
34	7	7	0	Instantaneous reactive export power (-Ri) (Q3) [kVar]
35	8	7	0	Instantaneous reactive export power (-Rc) (Q4) [kVar]
36	9	7	0	Instantaneous apparent import power (+S), (Q1 + Q4) [kVA]
37	10	7	0	Instantaneous apparent export power (-S), (Q2 + Q3) [kVA]
38	13	7	0	Instantaneous power factor import (+A/+S)
39	84	7	0	Instantaneous power factor export (-A/-S)
40	14	7	0	Frequency [Hz]
41	16	7	0	Instantaneous active power net (+A - -A) [kW]
42	32	7	0	Instantaneous voltage (U) in phase L1 [V]
43	52	7	0	Instantaneous voltage (U) in phase L2 [V]
44	72	7	0	Instantaneous voltage (U) in phase L3 [V]
45	31	7	0	Instantaneous current (I) in phase L1 [A]
46	51	7	0	Instantaneous current (I) in phase L2 [A]
47	71	7	0	Instantaneous current (I) in phase L3 [A]
48	C	6	0	Power down time counter
49	C	6	1	Battery remaining capacity
50	0	4	2	Current transformer ratio (numerator)
51	0	4	3	Voltage transformer ratio (numerator)
52	0	2	0	Firmware version
53	C	1	9	Meter serial number

Annexure 2: Sample detailed specification of typical rooftop photovoltaic system

Sr.	Equipment/ Item	Specification
1.	General	<ul style="list-style-type: none"> • Grid-connected PV systems shall always conform to Central Electricity Authority’s (CEA) (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013. • Grid-connected PV systems shall be guided by the latest edition of IEC 60364, “Electrical installations of buildings – Part 7-712, Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems”. • The PV system and all components shall always comply with the latest relevant standards, as amended from time to time.
2.	PV Modules	<ul style="list-style-type: none"> • The PV modules used shall qualify to the latest edition of IEC PV module qualification test or equivalent BIS standards. • PV modules shall comply with one of the following three certifications; <ul style="list-style-type: none"> ○ Mono- and Poly-crystalline silicon solar cell modules shall conform to IEC 61215, 2nd Ed. (2005-04), “Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval”. ○ Thin-film PV modules shall conform to IEC 61646, 2nd Ed. (2008-05), “Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval”. ○ Concentrator photovoltaic (CPV) modules and assemblies shall conform to IEC 62108, 1st Ed. (2007-12), “Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval”. • In addition to one of the above three certifications, the PV modules shall also conform to IEC 61730-1, Ed. 1.2 (2013-03), “Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction” and IEC 61730-2, Ed. 1.1 (2012-11), “Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing”. • For solar PV installations in saline marine and/ or corrosive environments, the PV modules shall conform to IEC 61701, 2nd Ed. (2011-12), “Salt mist corrosion testing of photovoltaic (PV) modules”.

	<ul style="list-style-type: none"> • All PV modules shall have performance warranty of 90 percent and 80 percent for the first 10 (ten) years and then subsequent 15 (fifteen) years, respectively. • All PV modules shall have a workmanship warranty for at least 5 (five) years.
3. Inverter	<ul style="list-style-type: none"> • The inverter may be (i) grid-connected without batteries or (ii) hybrid with batteries. • Inverters shall comply with CEA's (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013. • Grid-connected inverter shall comply with IEC 61727, "Photovoltaic (PV) systems – Characteristics of the utility interface". • All inverters shall conform to IEC 62116, 2nd Ed. (2014-02), "Utility-interconnected photovoltaic inverters – Test procedure for islanding prevention measures". • All inverters shall conform to IEC 62109-1, 1st Ed. (2010-04), "Safety of power converters for use in photovoltaic power systems – Part 1: General requirements" and IEC 62109-2, 1st Ed. (2011-06), "Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters". • The PV inverter may be undersized compared to the rated PV module capacity without, however, compromising on the power (and energy) output of the PV system. • Inverter shall have a warranty for at least 5 (five) years.
4. Specific Safety and Performance	<ul style="list-style-type: none"> • DC surge protection device (SPD) shall be used at the DC input of the inverter. If the DC SPD are not in-built into the inverter, then external DC SPDs shall be used by mounting them in the DC String Junction Box. DC SPD of appropriate specification shall be of Class 2 as per IEC 60364-5-53. • Manual DC disconnectors (isolators or circuit breaker) shall be employed at the DC input of the inverter. If the DC disconnector is not in-built into the inverter, then external DC SPD shall be used by mounting it near the inverter. The DC disconnector switch shall be clearly labelled. • DC overcurrent protection device (fuse or DC MCB) shall be employed between the strings of the PV modules and the inverter. If the DC overcurrent protection devices are not in-built into the inverter, then external DC overcurrent protection devices shall be used by mounting them in the DC String Junction Box. DC overcurrent protection devices shall be employed at both positive and negative terminals of the incoming DC inputs.

- At all DC junction boxes and at the input of the inverter, a non-corrosive caution label shall be provided with the following text:

**WARNING: High Voltage DC Power
SOLAR PHOTOVOLTAIC (PV) SYSTEM**

The size of the caution label shall be 105mm (width) x 20mm (height) with white letters on a red background.

- AC SPD of appropriate specification and Class 2 as per IEC 60364-5-53 shall be used at the output of the inverter.
- Earth leakage circuit breaker (ELCB) or residual current circuit breaker (RCCB) shall be used at the output of the inverter.
- Manual AC disconnectors shall be employed at the interconnection of the PV system in the AC distribution box. The AC disconnect switch shall be clearly labelled.
- If the grid voltage tends to sag or swell beyond the operating range of the inverter, then an isolation transformer of appropriate capacity, standards and specifications shall be used at the output of the inverter prior to interconnection in order to ensure that the inverter does not trip due to grid voltage issues.
- In addition to the standard caution and danger boards or labels as per Indian Electricity Rules, the AC distribution box near the solar grid inverter, the building distribution board to which the AC output of the solar PV system is connected and the Solar Generation Meter shall be provided with a non-corrosive caution label with the following text:

**WARNING: Dual Power Source
(i) Grid and (ii) Solar**

The size of the caution label shall be 105mm (width) x 20mm (height) with white letters on a red background.

- The PV system shall carry an overall warranty of at least 5 (five) years.
- All junction boxes shall be IP65 or higher for outdoor applications, IP 54 or higher for outdoor applications under appropriate sheds, and IP 21 or higher for indoor applications.

5. Junction Boxes and Enclosures (General)

6. Module Mounting Structure (MMS)	<ul style="list-style-type: none"> • All module mounting structures shall conform to IS:875 (Part 3)-1987, “Code for practice of design loads (other than earthquake) for buildings and structures”. • Important: For PV installations on tall buildings, the design should consider the ‘height factor’ as per IS:875 (Part 3)-1987, which quantifies higher wind loads on tall structures within the same wind zone. • All fasteners shall be of stainless steel. • Module mounting structures shall be carefully installed, without causing any physical damage to the terrace/ roof and without affecting the waterproofing of the terrace/ roof. In case fasteners are anchored in the terrace/ roof, it shall be ensured that waterproofing of the terrace/ roof remains secure.
7. Cables	<ul style="list-style-type: none"> • All cables shall be supplied conforming to IEC 60227/ IS 694 & IEC 60502/IS 1554, Voltage rating: 1,100V AC, 1,500V DC. • For the DC cables, XLPE or XLPO insulated and sheathed, UV stabilised single core flexible copper cables shall be used. Multi-core cables shall not be used. • The total voltage drop on the cable segments from the solar PV modules to the solar grid inverter shall not exceed 2.0 percent. • Cables and wires used for the interconnection of solar PV modules shall be provided with solar PV connectors (MC4 or similar) and couplers. • All cables and conduit pipes shall be clamped to the rooftop, walls and ceilings with thermo-plastic clamps at intervals not exceeding 50 cm. • The DC cables from the SPV module array shall run through a UV stabilised PVC conduit pipe of adequate diameter with a minimum wall thickness of 1.5mm. Alternatively, a cable tray on the ground with sufficient clearance for passage of water and a cover may be used. • The minimum DC cable size shall be 4.0 mm² copper. • The following colour coding shall be used for DC cable: <ul style="list-style-type: none"> ○ Positive: Outer PV sheath shall be Red OR Black with a red line marking ○ Negative: Outer PV sheath shall be Black

	<ul style="list-style-type: none"> ○ Earth: green ● For the AC cables, PVC or XLPE insulated and PVC sheathed single or multi-core flexible copper cables shall be used. Outdoor AC cables shall have a UV-stabilised outer sheath. ● The total voltage drop on the cable segments from the solar grid inverter to the building distribution board shall not exceed 2.0 percent. ● The minimum AC cable size shall be 4.0 mm² copper. In three phase systems, the size of the neutral wire size shall be equal to the size of the phase wires. ● The following colour coding shall be used for AC cable: <ul style="list-style-type: none"> ○ AC single phase: Phase → red; Neutral → black ○ AC three phase: Phases → red, yellow, blue; Neutral: black ○ Earth: green ● Cables and conduits that have to pass through walls or ceilings shall be taken through a PVC pipe sleeve. ● Cable conductors shall be terminated with tinned copper end-ferrules to prevent fraying and breaking of individual wire strands. The termination of the DC and AC cables at the inverter shall be done as per instructions of the manufacturer.
8. Earthing	<ul style="list-style-type: none"> ● All earthing shall be as per IS:3043-1987 (Reaffirmed 2006), “Code of Practice for Earthing”. ● AC, DC and body earthing of the PV system may be connected to the same earth, while the earthing of the lightning arrestor shall be isolated from the rest of the PV system. ● At least 2 (two) numbers of earth pits shall be used at a time for earthing.
9. Metering	<ul style="list-style-type: none"> ● An energy meter shall be installed in between the inverter and the AC distribution box to measure gross solar AC energy production (the “Generation Meter”). The Generation Meter shall be of the same accuracy class as the Applicant’s (i.e. Consumer’s) service connection meter.
10. Documentation	<ul style="list-style-type: none"> ● Grid-connected PV systems shall be guided by the latest edition of IEC 62446, “Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection”.

- The documentation of the rooftop PV shall consist of the following:
 - System description with working principles
 - Single Line Diagram
 - Equipment Layout and Wire Routing Diagram
 - Earthing Layout Diagram with Detailed Specification
 - Datasheets, drawings and/ or specifications (PV module, inverter, junction box and components, MMS, cables, battery, transformer, lightning arrestor, etc.)
 - IEC and other test certificates of PV modules and inverters
 - Warranty cards of equipment and complete PV system
 - Operation and maintenance manual
 - Maintenance register
 - Contact information of Installer and/ or Service Technician
 - Photographs of installed PV system
 - All statutory and other approvals received

Annexure 3: Sample format of application form for net-metered interconnection

Notes:

1. The given format is only indicative in nature.
2. DISCOMs/ SNAs should customize this format as per their specific requirements.
3. It is recommended to only seek minimum and relevant information from the Applicant, as redundancy may result into duplication and mistakes.

**Application Form for Preliminary Approval of Interconnection for
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

Date: _____

To: Assistant Engineer
Sub Division: _____
[DisCom Name], [Place]

Please affix recent
passport-size
photograph with
signature across

Applicant Details

Name of Applicant : _____

Address where rooftop PV system is intended to be installed : _____

City/ Town/ Village : _____

Pin Code : _____

Telephone/ Mobile : _____

Email ID : _____

Existing Account Details

Account Number : _____

Type of Connection : Single Phase 3-Phase LT 3-Phase HT

Sanctioned Load OR Contract Demand : _____ kW OR kVA

Type of Applicant (Please check one) : Residential Educational Institution
 Commercial Government Organization
 Industrial Hospital
 Other (Please Specify): _____

Type of Roof (Please check one) : Flat RCC Sheet Metal Slanted Tile Roof
 Other (Please Specify): _____

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**Application Form for Preliminary Approval of Interconnection for
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

Proposed PV System Details

Proposed PV Capacity : _____ kW

Have you identified a PV System Installer? : No Yes

If answered 'yes' to previous question, please specify : Name of Company: _____
Name of Contact Person: _____
Mobile of Contact Person: _____
Email of Contact Person: _____

Note: This is for information purpose only. [Name of Distribution Licensee] shall not prohibited you at any time to change the PV System Installer.

Are you planning on applying for subsidy? : No Yes

Note: Answering this question will not affect [name of the Distribution Licensee]'s decisions for this application. Answering 'yes' does not automatically qualify you for subsidy; the Applicant will separately have to undertake the process for availing subsidy as per applicable rules and guidelines.

Bank Account Details

Name of Bank : _____
Bank Branch : _____
Account Number : _____
Type of Account : _____
IFSC Code : _____

**Application Form for Preliminary Approval of Interconnection for
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

Please attach the following documents with your application:

- Copy of latest electricity bill.
- If applying on behalf of an organization (e.g. Pvt. Ltd., Partnership, Trust, NGO, etc.), please attach an appropriate letter authorizing you to apply on behalf of the Organization.
- A void cheque from the bank mentioned in this application.
- An application fee of Rs. 100/- in the form of a cheque or demand draft in favour of [name of the Distribution Company].

Certification

I hereby certify that:

- I am the duly authorized person to file this application on behalf of my premises and/ or organization.
- I/ my Organization is duly authorized to utilize the intended rooftop/ terrace for solar energy generation through the rooftop solar PV system for which interconnection is sought in this application.
- All information provided herein is true to the best of my knowledge, and that any deviation, identified now or later, may lead to the disqualification of this application and even dismantling of the rooftop PV system thereof.
- I will abide by all terms and conditions as stipulated by [name of the Distribution Licensee] towards interconnection and operation of the rooftop PV system, as amended from time to time.

Place	:	_____	(Seal &)	
Date	:	_____	Signature	: <input type="text"/>
			Name	: _____

Annexure 4: Sample format of preliminary interconnection approval by Distribution Company

Notes:

1. The given format is only indicative in nature.
2. DISCOMs/ SNAs should customize this format as per their specific requirements.

[On Official Letterhead of Distribution Licensee]

Ref. No. xxxxx/xx

Date: xx/xx/xxxx

To:

[Applicant's name]

[Applicant's address]

Sub: Preliminary approval for interconnection of rooftop PV system.

- Ref:
1. Your application for Interconnection of Grid-connected Rooftop Solar PV System on Net Metering-basis dated _____.
 2. Your Consumer Account No. _____.

Dear Sir/ Madam,

With reference to your above application, you are herewith accorded approval for installation of rooftop solar photovoltaic system of capacity _____ kW(AC) with the following terms and conditions:

1. You may identify an appropriate installer for the rooftop PV system and proceed with the installation of the system. [Optional] The Installer should be an empanelled channel partner of the Ministry of New and Renewable Energy (MNRE), Government of India or the [State] Renewable Energy Development Agency.
2. The technical specifications of the rooftop PV system shall be as per the technical specifications stipulated by [name of the Distribution Licensee], as amended from time to time. [Optional] Only [name of Distribution Licensee]-empanelled grid-connected and hybrid inverters should be used.
3. The Applicant shall ensure that the installation is undertaken through a Licensed Electrical Contractor and approvals are taken from the Chief Electrical Inspector, wherever necessary.
4. Any changes to the Applicant's own electrical, civil, structural or any other infrastructure (i.e. on the consumer-side of the Applicant's meter) shall be undertaken by the Applicant at its own cost.

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5. The Applicant shall ensure that the rooftop PV systems is installed and [name of the Distribution Licensee] is intimated for interconnection within 90 (ninety) days from the date of this letter. The intimation should be done as per the stipulated format, which should be accompanied with the following attachments:
 - a. Signed copy of net metering interconnection agreement with [name of the Distribution Licensee].
 - b. [For PV systems of capacity greater than 10 kW] Approval and inspection report from Chief Electrical Inspector.

The Applicant may use this letter as an official communication from [name of the Distribution Licensee] for the purpose of loans from banks/ financial institutions.

During the commissioning, [name of the Distribution Licensee] shall install the bi-directional net meter, the cost of which shall be borne by the applicant.

Detailed guidelines for installation and commissioning of net-metered rooftop PV systems are available at [link to appropriate website].

[Stamp of Distribution Licensee and
Signature of Appropriate Engineer]

[Designation of Engineer]

Date: [Date]

Annexure 5: Sample application to Distribution Company for commissioning of rooftop solar photovoltaic system

Notes:

1. The given format is only indicative in nature.
2. DISCOMs/ SNAs should customize this format as per their specific requirements.

Application Form for Interconnection and Commissioning of Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis

Date:

To:

Assistant Engineer

Sub Division: _____

[DIISCOM Name], [Place]

Sub: Application for interconnection and commissioning of rooftop PV system.

- Ref:
1. My application for preliminary approval of interconnection for rooftop PV system dated xx/xx/xxxx.
 2. My Consumer Account Number _____.
 3. [Name of Distribution Licensee]'s preliminary approval for interconnection of rooftop PV system via Letter Ref. No. xxxxx/xx dated xx/xx/xxxx.
 4. [If applicable:] Approval of the Chief Electrical Inspector for charging of the rooftop PV system via Letter Ref. No. xxxxx/xx dated xx/xx/xxxx.

Dear Sir,

With reference to the above, I hereby submit my application to request for interconnection and commissioning of the grid-connected rooftop PV system with the following details:

A. PV Modules					
Sr.	Manufacturer	Model	Power Rating (Wp)	Quantity	Net DC Capacity (Wp)
1.					
2.	*				
TOTAL					

B. Inverter					
Sr.	Manufacturer	Model	Power Rating (W)	Quantity	Net AC Capacity (W)
1.					
2.	*				
TOTAL					

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

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**Application Form for Interconnection and Commissioning of
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

C. DC Cables			
Sr.	Manufacturer	Model	Type
1.			
2.	*		

D. String Junction Box					
Sr.	Item	Manufacturer	Model	Specification	Quantity
1.	Junction Box				
2.	DC Fuse (+ve Terminal)				
3.	DC Fuse (-ve Terminal)				
4.	DC Surge Protection Device				
5.	DC Isolator/ MCB				
6.	*				

E. DC Disconnect	
Is a separate DC Disconnect Switch provided for the PV system with visible label? (Please check one)	<input type="checkbox"/> Yes <input type="checkbox"/> No

F. AC Cables			
Sr.	Manufacturer	Model	Type
1.			
2.	*		

G. AC Distribution Box					
Is a separate AC Disconnect Switch provided for the PV system with visible label? (Please check one)					<input type="checkbox"/> Yes <input type="checkbox"/> No
Sr.	Item	Manufacturer	Model	Specification	Quantity
1.	Junction Box				
2.	AC MCB				
3.	AC RCCB				
4.	AC Surge Protection Device				
5.	Generation Meter				
6.	*				

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

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**Application Form for Interconnection and Commissioning of
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

H. Battery Bank*				
Sr.	Manufacturer	Model	Type & Specification	Quantity
1.	*			

I. Isolation Transformer*				
Sr.	Manufacturer	Model	Type & Specification	Quantity
1.	*			

J. Lightning Arrestor*				
Sr.	Manufacturer	Model	Type & Specification	Quantity
1.	*			

K. Earthing Equipment					
Sr.	Item	Manufacturer	Model	Type & Specification	Quantity
1.	Earth Pit				
2.	Earthing Wire/ Strip				
3.	*				

L. Weather Monitoring System*					
Sr.	Item	Manufacturer	Model	Specification	Quantity
1.	Pyranometer/ Radiation Sensor				
2.	Anemometer				
3.	Wind Direction				
4.	Humidity Sensor				
5.	Rainfall Gauge				
6.	*				

M. Metering					
Sr.	Meter	Manufacturer	Model	Accuracy	Type & Specification
1.	Net Meter				
2.	Generation Meter				
3.	*				

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

Page 3

**Application Form for Interconnection and Commissioning of
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

N. Performance Monitoring System				
Sr.	Manufacturer/ Service Provider	Model	Local or Remote?	Monitoring via
1.	*		<input type="checkbox"/> Local <input type="checkbox"/> Remote <input type="checkbox"/> Both	<input type="checkbox"/> Inverter <input type="checkbox"/> Meter <input type="checkbox"/> Both <input type="checkbox"/> Other (Pl. Specify)

O. Installer, Warranty and Maintenance Information	
1.	Company Name :
2.	Name of Contact Person :
3.	Designation of Contact Person :
4.	Mobile Number of Contact Person :
5.	Landline Number of Contact Person :
6.	Email Address of Contact Person :
7.	Company Website :
8.	Company Local Address :
9.	Is the Company Channel Partner of MNRE? :
10.	Has the Company provided warranty on the equipment and installation with appropriate documents? Please check those applicable and fill details. <input type="checkbox"/> PV module performance: ___ years <input type="checkbox"/> PV module workmanship: ___ years <input type="checkbox"/> Inverter: ___ years <input type="checkbox"/> Battery: ___ years <input type="checkbox"/> Overall installation: ___ years <input type="checkbox"/> If other, Please specify
11.	Is the Company providing maintenance service? <input type="checkbox"/> No <input type="checkbox"/> Yes, for ___ years. If yes, please specify nature of service.

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

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**Application Form for Interconnection and Commissioning of
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

P. Subsidy Information	
1.	Is subsidy being availed? : <input type="checkbox"/> No <input type="checkbox"/> Yes, already received. <input type="checkbox"/> Yes, in process.
2.	If yes, where is the subsidy availed from? :
3.	If yes, what is the subsidy amount? :
4.	Who is receiving the subsidy? : <input type="checkbox"/> Installer <input type="checkbox"/> Applicant <input type="checkbox"/> If other, please specify:

Q. Applicant Details	
1.	Name of Applicant :
2.	Mobile Number :
3.	Landline Number :
4.	Email Address :
5.	Address where rooftop PV system is intended to be installed : City/ Town/ Village: Pin Code: State:
6.	Coordinates of the PV Installation : Latitude: ° ' " N (Example: 12°34'56.78"N) Longitude: ° ' " E

R. Costing and Financing Information	
1.	Cost of the PV system including Taxes :
2.	Is loan availed on the PV system? : <input type="checkbox"/> No <input type="checkbox"/> Yes, In process <input type="checkbox"/> Yes, Received.
	If 'yes', then please answer the following questions:
3.	Name of Bank :
4.	Branch :
5.	Amount of Loan Availed :
6.	Interest Rate on Loan :
7.	Repayment Period :
8.	Monthly EMI :

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

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**Application Form for Interconnection and Commissioning of
Grid-connected Rooftop Solar Photovoltaic System on Net Metering-basis**

S. Attachments (Check whichever attached)

- Single Line Diagram
- Equipment Layout and Wire Routing Diagram
- Earthing Layout Diagram with Detailed Specification
- Datasheet, PV Module
- Datasheet, Inverter
- Datasheet, Battery, if applicable
- Datasheet, Isolation Transformer, if applicable
- Datasheet or Drawing, Module Mounting Structure
- Datasheet or Drawing, String Junction Box with Components
- Datasheet or Drawing, AC Distribution Box with Components
- Datasheet, DC Cable(s)
- Datasheet, AC Cable(s)
- Datasheet, Lightning Arrestor
- Copy of charging certificate from Chief Electrical Inspector, if applicable.
- If applying on behalf of an organization (e.g. Pvt. Ltd., Partnership, Trust, NGO, etc.), an appropriate letter authorizing you to apply on behalf of the Organization.

T. Certification by Applicant

- I am the duly authorized person to file this application on behalf of my premises and/ or organization.
- I/ my Organization is duly authorized to utilize the intended rooftop/ terrace for solar energy generation through the rooftop solar PV system for which interconnection is sought in this application.
- All information provided herein is true to the best of my knowledge, and that any deviation, identified now or later, may lead to the disqualification of this application and even dismantling of the rooftop PV system thereof.
- I will abide by all terms and conditions as stipulated by [name of the Distribution Licensee] towards interconnection and operation of the rooftop PV system, as amended from time to time.

Place : _____
Date : _____

(Seal &)

Signature :

Name :

(*Note: Other/ if applicable. In case of more information, please add as attachments.)

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Annexure 6: Sample commissioning certificate by Distribution Company (or Third Party Agency)

Notes:

1. The given format is only indicative in nature.
2. DISCOMs/ SNAs should customize this format as per their specific requirements.

[On Official Letterhead of Distribution Licensee or Appropriate Agency]

Ref. No. xxxxx/xx

Date: xx/xx/xxxx

COMMISSIONING CERTIFICATE (For Rooftop Photovoltaic System)

A. Contact Information	
1.	Name of Plant Developer/ Owner :
2.	Contact Person :
3.	Phone :
4.	Email :

B. Plant Information	
1.	Metering : <input type="checkbox"/> Net-metered <input type="checkbox"/> Gross-metered
2.	Mounting : <input type="checkbox"/> Rooftop <input type="checkbox"/> Ground-mounted
3.	Topology : <input type="checkbox"/> Grid-tied <input type="checkbox"/> Hybrid with battery <input type="checkbox"/> Stand-alone
4.	Capacity : DC: _____ kW, AC: _____ kW
5.	Battery : _____ Ah @ _____ VDC
6.	Address :
7.	Coordinates : Latitude: ____° ____' ____" N, Longitude: ____° ____' ____" E

C. Plant Information	
1.	Metering : <input type="checkbox"/> Net-metered <input type="checkbox"/> Gross-metered
2.	Mounting : <input type="checkbox"/> Rooftop <input type="checkbox"/> Ground-mounted
3.	Topology : <input type="checkbox"/> Grid-tied <input type="checkbox"/> Hybrid with battery <input type="checkbox"/> Stand-alone
4.	Capacity : DC: _____ kW, AC: _____ kW
5.	Battery : _____ Ah @ _____ VDC
6.	Address :
7.	Coordinates : Latitude: ____° ____' ____" N, Longitude: ____° ____' ____" E
8.	Rooftop Ownership : Check One: <input type="checkbox"/> Owned Rooftop <input type="checkbox"/> Leased Rooftop If leased, Term of Lease: ____ Years

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[On Official Letterhead of Distribution Licensee or Appropriate Agency]

D. Commissioning Details	
1.	Date of Commissioning : _____
2.	Commissioning Test Results : _____
	<input type="checkbox"/> Commissioning test is based on IEC 62446 Ed. 1.0 (2009-05), "Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection."
	<input type="checkbox"/> Plant has passed the Commissioning Test.
	<input type="checkbox"/> Commissioning Test Report is attached.
3.	Other Remarks : None

THIS IS TO CERTIFY THAT THE PLANT IS SUCCESSFULLY COMMISSIONED.

For [name of Distribution Licensee or Appropriate Agency]

[Sign & Seal]

[Name of Commissioning Official]

Attachment: Commissioning Test Report

To:

[Plant Owner]

CC:

1. (If commissioned by Third Party) [Name of Distribution Licensee]
2. [State Nodal Agency]
3. [Chief Electrical Inspector]

Notes

Notes

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