PACE-D TECHNICAL ASSISTANCE PROGRAM

Rooftop Solar PV Training Program – Handbook for Entrepreneurs

May 2016

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PARTNERSHIP TO ADVANCE CLEAN ENERGY DEPLOYMENT (PACE-D)

Technical Assistance Program

Rooftop Solar PV Training Program Handbook for Entrepreneurs

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ACRONYMS

Acronyms	Definition
AC	Alternate Current
AD	Accelerated Depreciation
ADB	Asian Development Bank
BOS	Balance of System
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CEI	Chief Electrical Inspector
CFA	Central Finance Assistance
CI	Consumer Import
COD	Commercial Operation Date
CPI	Consumer Price Index
CSP	Concentrated Solar Power
CUF	Capacity Utilization Factor
DC	Direct Current
DISCOM	Distribution Company
DSCR	Debt Service Coverage Ratio
DT	Distribution Transformer
EI	Electrical Inspector
ETC	Evacuated Tube Collector
EPC	Engineering, Procurement and Construction
ESCO	Energy Service Companies
FI	Financial Institute
FiT	Feed-in-Tariff
GBI	Generation-based Incentive
GIS	Geographic Information System
GSES	Global Sustainable Energy Solutions Pty. Ltd.
GW	Gigawatt
GZI	Galvanized Iron
HT	High Tension
IAD	Independent ATM Deployment
IEC	International Electrotechnical Construction
IEEE	Institute for Electrical and Electronics Engineer
IREDA	Indian Renewable Energy Development Agency Limited
IFC	International Finance Corporation
IRR	Internal Rate of Return
IPP	Independent Power Producer

Kg/m^2	Kilogram per Square Meters
KVA	Kilovolt Ampere
KW	Kilowatt
kWp	Kilowatt Peak
kWh/m^2	Kilowatt per Square Meters
LT	Low Tension
LPS	Lightning Protection Systems
LCOE	Levelized Cost of Energy
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracker
MPERC	Madhya Pradesh Electricity Regulatory Commission
MPPMC	Madhya Pradesh Power Management Company Ltd.
MUDRA	Micro Units Development & Refinance Agency Ltd.
MWp	Megawatt Peak
NSM	National Solar Mission
NABARD	National Bank for Agriculture and Rural Development
NBFC	Non-banking Financial Company
NVVN	NTPC Vidyut Vyapar Nigam Limited
OERC	Orissa Electricity Regulatory Commission
O & M	Operations and Maintenance
OPIC	Overseas Private Investment Corporation
PACE-D	Partnership to Advance Clean Energy – Deployment
PCE	Power Conversion Efficiency
PFC	Power Finance Corporation
PPA	Power Purchase Agreement
PR	Performance Ratio
PSH	Peak Sun Hour
PSB	Public Sector Bank
PSU	Public Sector Undertaking
PV	Photovoltaic
Wp	Watt Peak
RE	Renewable Energy
RCC	Reinforced Cement Concrete
RECs	Renewable Energy Certificate
RESCO	Renewable Energy Services Company
RPO	Renewable Purchase Obligation
RSDO	Research Design & Standard Organisation
SE	Solar Export
SERC	State Electricity Regulatory Commission
SECI	Solar Energy Corporation of India
SHW	Solar Hot Water
SNA	State Nodal Agency
SPD	Surge Protective Device
SPO	Solar Purchase Obligation
SPV	Solar Photovoltaic

SRTPV	Solar Rooftop Photovoltaic
STC	Standard Test Conditions
STU	State Transmission Unit
RPOs	Renewable Purchase Obligation
RTPV	Rooftop Photovoltaic
TA	Technical Assistance
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterrupted Power Supply
UPPCL	Uttar Pradesh Power Corporation Limited
U.S.	United States
USAID	United States Agency for International Development
V	Voltage
VGF	Viability Gap Funding
VNM	Virtual Net Metering
V_{mp}	Maximum Power Point Voltage
W/m^2	Watt per square meter
Yf	Final Yield

About The Manual

The Government of India has adopted an ambitious national target for solar capacity deployment by 2022. It aims to deploy 100 GW of solar PV capacity by 2022, 40 percent of which (40 GW) will come from rooftop solar photovoltaic (SPV) installations. In order to achieve this target, concerted efforts would be required from a number of stakeholders. The scale of this target provides a huge opportunity for entrepreneurs who wish to either start their own business or expand their existing one to cover rooftop solar service. These entrepreneurs are expected to play an important role in achieving this target, fostering innovation and creating jobs, which will contribute to the growth of Indian economy.

The U.S.-India bilateral Partnership to Advance Clean Energy - Deployment Technical Assistance (PACE-D TA) Program has developed a five-day training program for entrepreneurs on rooftop solar to familiarize them on solar PV technology, system design and engineering, component sourcing, project financing, project management, approaches to market entry and potential business models as well as opportunities. This handbook aims to serve as a reference guide to the participants of the five-day training program.

INTRODUCTION

Objective

To provide basic information and raise awareness amongst entrepreneurs on the following:

- Concept, design and components with specific focus on technical architecture of rooftop solar system/project.
- Policy and regulatory framework for rooftop solar at the national and state level.
- Different implementation/business models followed in the rooftop solar market and role of stakeholders.

To provide specific information to the entrepreneurs and project managers on the following:

- Rooftop solar PV project costing and financing.
- Feasibility report, tenders, and techno-economic reports.
- Solar PV rooftop project management: procurement, contract management, financing and work scheduling.

Who can use this manual?

People looking to enter the rooftop solar PV market as entrepreneurs and/or existing entrepreneurs wanting to expand their services offering.

Main features of the manual

- Introduction to solar technologies
- Rooftop solar PV technology overview
- Site assessment and planning for rooftop PV system
- Design and safety overview of rooftop PV system design
- Rooftop solar PV business models
- National policy framework for rooftop solar PV
- Key programs for rooftop solar PV development
- Incentives for rooftop solar PV promotion
- Project costing and economics
- Rooftop solar project financing
- Contract structures and agreements
- Rooftop solar project management

CHAPTER 1: INTRODUCTION TO SOLAR ENERGY TECHNOLOGIES

Renewable energy technologies

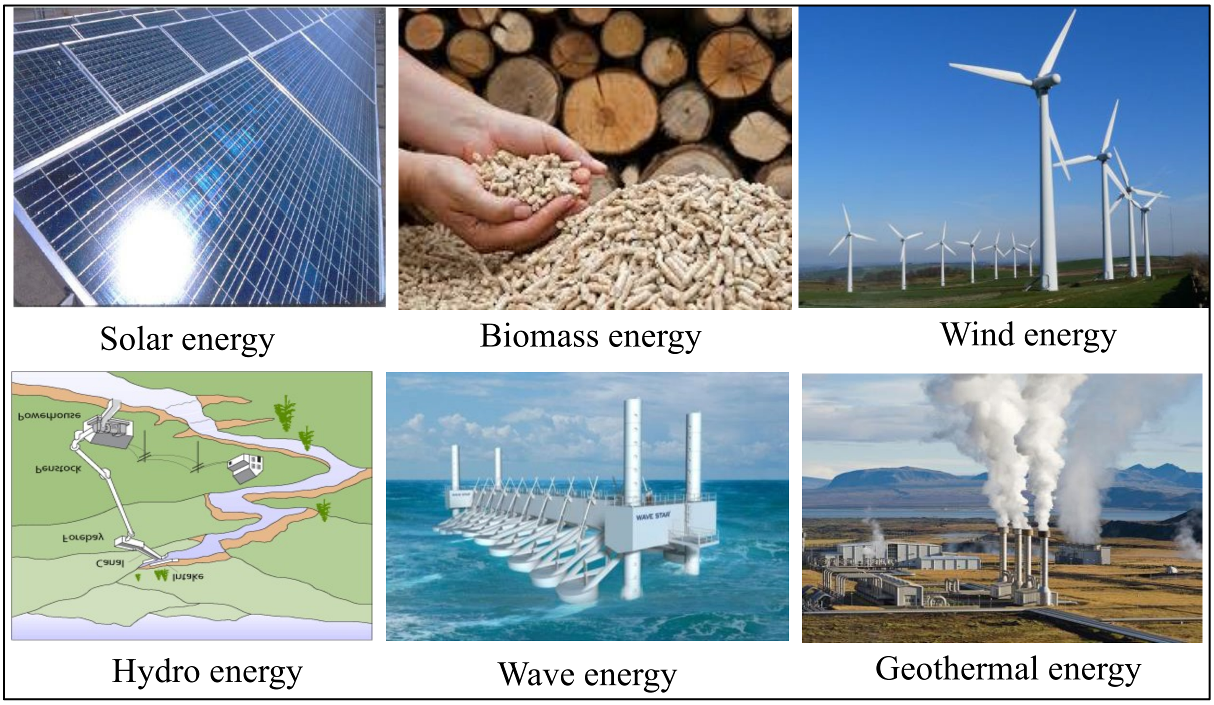


Figure 1: Renewable energy technologies

Renewable energy (RE) is generally defined as the energy that can be replenished after a period of time. The various types of RE sources are listed as:

Solar Energy

Energy harnessed from the sun is termed as solar energy. There are two widely used methods of harvesting solar energy:

Solar PV: The energy from the sun is directly converted to electricity by using PV modules.

Solar Thermal: The energy from the sun is converted to thermal energy by using either concentrating collectors to produce high temperatures or by non-concentrating collectors to produce low temperatures.

The solar PV modules use light particles of sun rays to generate electricity, while the concentrated solar power (CSP) and the solar hot water (SHW) concentrate solar energy in a targeted manner to heat water. Hot water from CSP process is used to drive turbine and generate electricity, and the SHW is typically used in domestic or industrial process heating.

Biomass Energy

Biomass energy or "bio energy" term is used to describe energy coming from plants and plant-derived materials. Wood is the largest biomass energy resource today, but other sources of biomass include food crops, grassy and woody plants, residues from agriculture or forestry, oil-rich algae, and the organic component of municipal and industrial wastes.

Wind Energy

Energy harvested from the velocity of wind is known as wind energy. Large wind turbines make use of the wind velocity to power motors that generate electricity.

Hydro Energy

The energy harnessed from the potential energy of water from a height or flowing downwards due to the effect of gravity is known as hydro energy. In this case, dams store water at a height and when needed, release it through flood gates which discharge the water with enough force to rotate a turbine that generates electricity.

Wave Energy

Wave energy is created using velocity of tidal waves during the high and low tides (or the ocean currents). The rise and fall of the tides is made to pass through moving turbines that are connected to generators that produce electricity.

Geothermal Energy

The energy harnessed from the stored thermal energy below the earth’s surface is known as geothermal energy. This energy is used to rotate a turbine. The turbine is connected to generators which produce electricity.

Solar energy technologies

At present, there are a number of commercially viable solar energy technologies available in the market. These include:

Solar PV Systems

Solar PV technology works on the principle of using the energy of photons (packets of energy) coming out of the sun to generate electricity. The working of the photovoltaic technology will be discussed later.

Depending on the type of loads to be connected, solar photovoltaic systems can be classified in the following ways:

- **Off-Grid Systems:**

Off-grid applications include lighting systems, small loads for domestic house lighting or mobile chargers. In case of rural areas, applications are mainly used for irrigation and lighting. Off-grid systems are usually used in cases where the load is not so high that it should be connected to the grid or in areas where grid stability is quite low.

Figure 2: Off-grid solar PV applications

- **Small Distributed Applications:**

A solar PV system is classified under small distributed applications if the system size falls under 20 kWp.

Figure 3: Small distributed solar PV applications

- **Large Distributed Applications**:

These are typically installed on buildings with large roof areas, such as warehouses, industrial or commercial buildings. The systems that fall under this category are generally from a few kilowatts up to 1 MWp.

Figure 4: Large distributed solar PV applications

- **Utility-scale Grid-connected Applications:**

Utility-scale projects tend to be of 1 MWp or above and are generally ground-mounted since they occupy a very large area. These large PV systems tend to be directly connected to the grid.

Figure 5: Utility-scale solar PV applications

- **Micro-grid Applications:**

Micro-grids essentially consist of a number of energy generation sources that cater to interconnected loads and can be operated in parallel or independent of the utility grid.

In terms of only solar PV systems-based operation, a number of houses connected to a number of solar panels operating independently on battery banks can also be classified as a micro-grid.

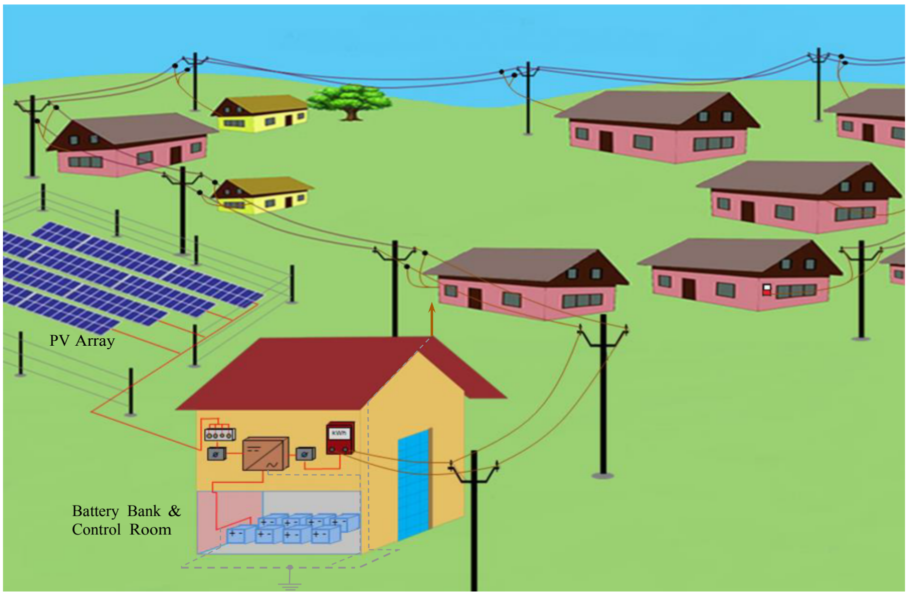


Photo credit: CLEAN

Figure 6: Micro-grid solar PV applications

- **Building Integrated Applications:**

As the name suggests, solar PV modules are integrated into the building architecture in an aesthetic manner for onsite generation of electricity.

Figure 7: Building integrated systems

Solar Hot Water Systems

Hot water systems are used to heat water by using the thermal energy present in the sun. There are many types of solar water heaters but the most commonly used evacuated tube collectors (ETCs) will be discussed. The water piping in an ETC is surrounded by two concentric tubes of glass with a vacuum in between that admits heat from the sun (to heat the pipe).The cool water enters through the top of the structure, passes through the tubes, and gets heated up in the process. The heated water is then stored in a tank, or used directly.

Figure 8: Solar hot water applications

Concentrated Solar Power (CSP)

CSP technologies use different mirror configurations to concentrate the solar energy onto a receiver and convert it into heat. The heat can then be used to create steam to drive a turbine to produce electrical power or used as industrial process heat.

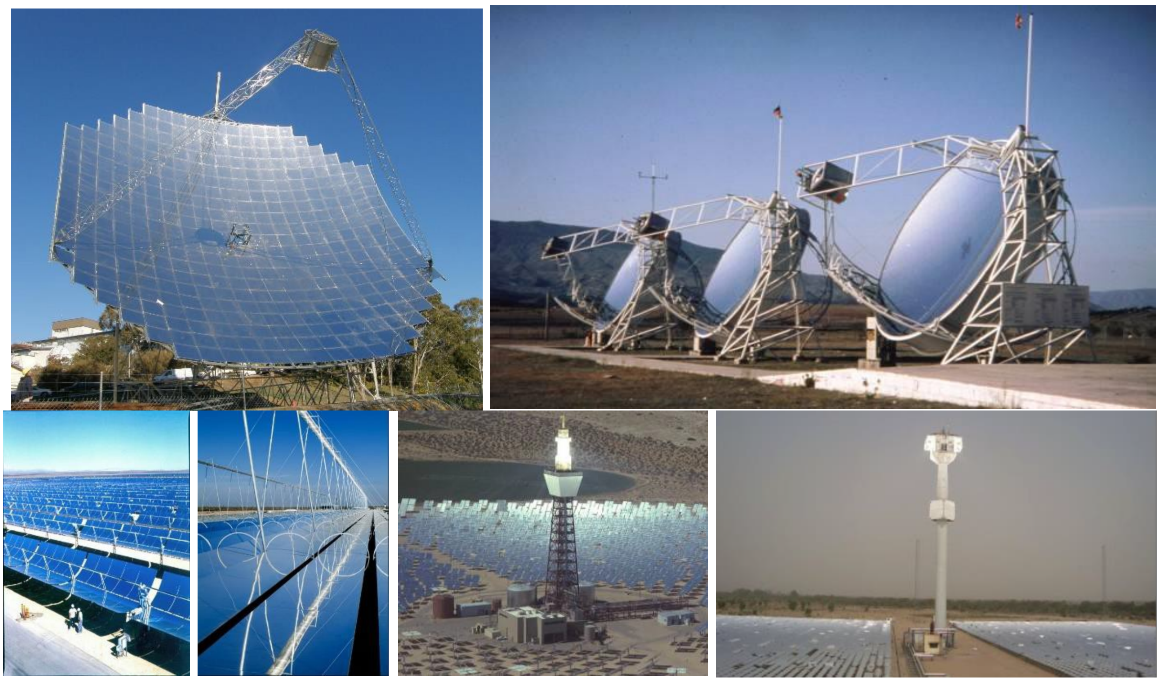


Figure 9: CSP applications

Passive Solar Design

Passive solar design integrates the architecture of the building with the movement of the sun across the sky in order to provide natural heating from the sun in winter and shading in summer months.

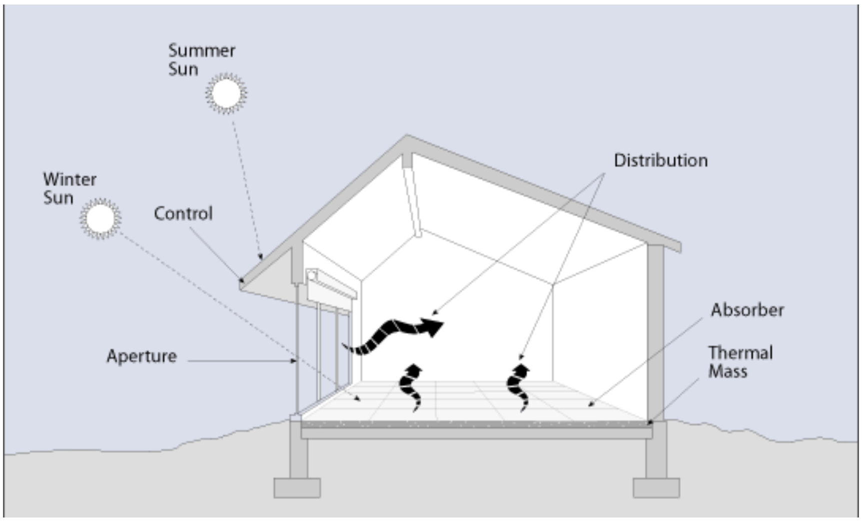


Figure 10: Five elements of passive solar design

How a solar PV system works?

Solar panels work by allowing photons, or particles of light, to knock electrons free from atoms, generating a flow of electricity. Solar panels actually comprise many, smaller units called photovoltaic cells. These cells are made of two different kinds of semiconductors and are joined at p-n junction. These p-n junctions consist of an energy barrier that requires a minimum threshold of photons in order to exceed the barrier potential in order to generate electricity.

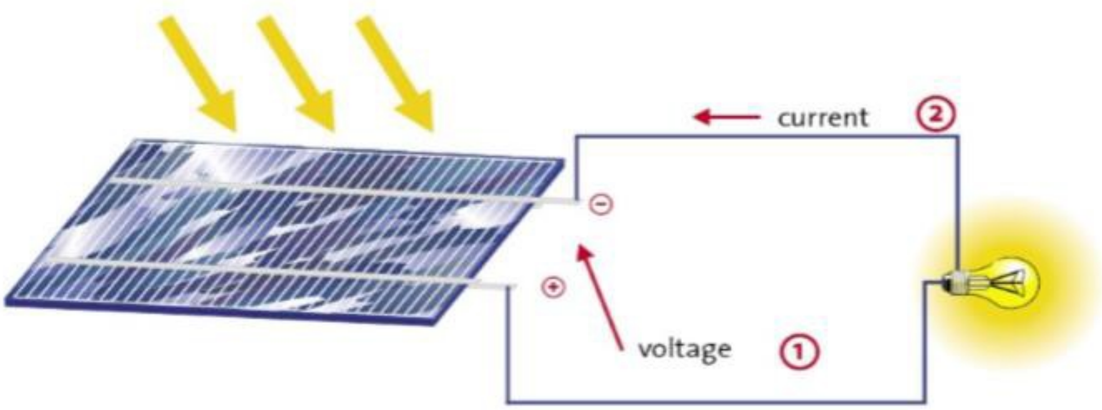


Figure 11: Operation of a PV module

Movement of sun across the sky

Solar radiation available at a particular location keeps changing both on a daily basis as well as annually. Hence the amount of solar radiation keeps fluctuating at any given time interval depending on the position of the sun and the location of the site. The three main cases of solar radiation depending on the position of the sun can be categorized with the help of the Solstices. The Southern solstice occurs on December 22. The Equinox is when the sun is directly over the equator and occurs between March 21 and September 23 and the Northern Solstice occurs on June 22.

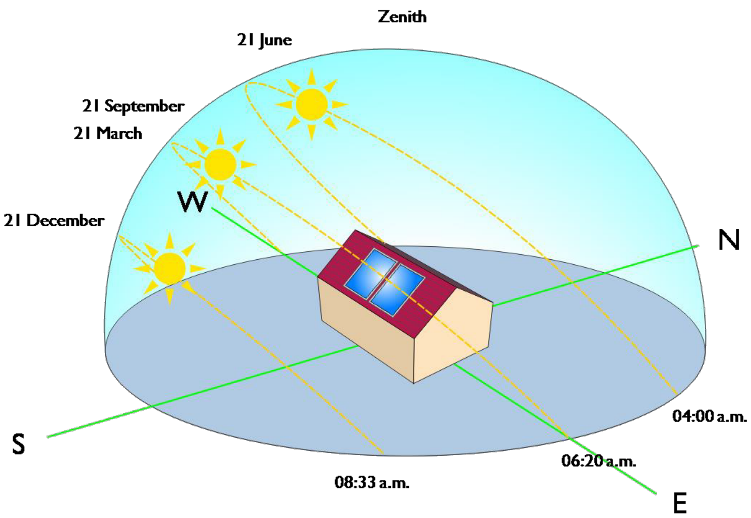
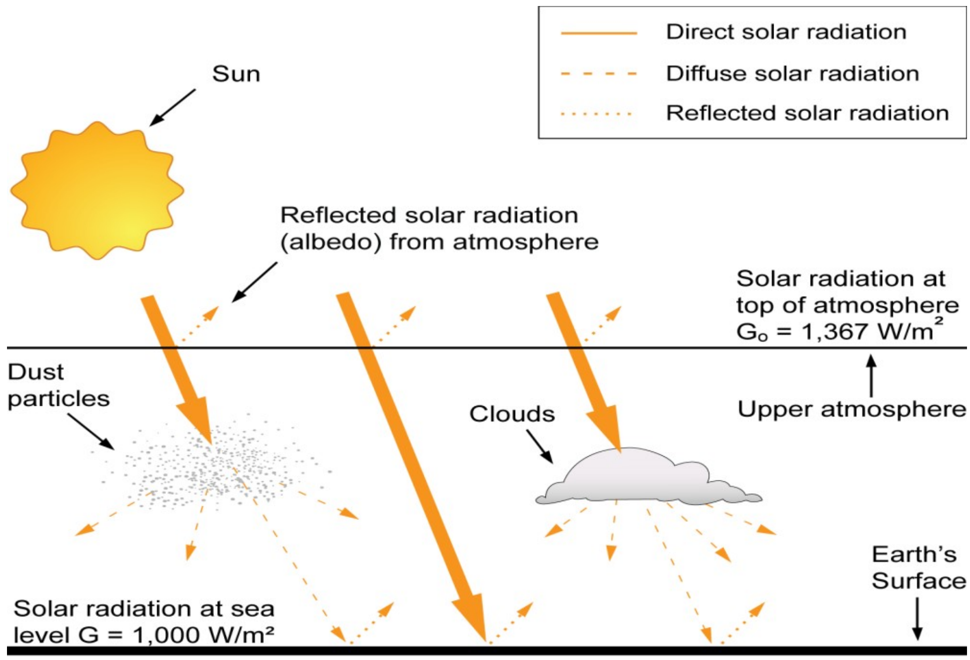


Figure 12: Orientation of the sun throughout the year

Solar radiation

The energy produced by the sun is emitted to the PV system primarily as radiation. The radiation that falls directly on the earth's surface is termed as direct radiation. The fraction of solar radiation that is reflected back into space is known as the albedo of the atmosphere, and the radiation that passes through clouds and gases in the atmosphere is known as diffused radiation.



Ilustration credit: GSES

Figure 13: Types of solar radiation

CHAPTER 2 : ROOFTOP SOLAR PV TECHNOLOGY OVERVIEW

Introduction to grid-connected rooftop solar PV system

As the name suggests, a grid-connected rooftop solar PV system is located on the roof of a home, factory, shed or any other building. The installation is secured with help of frames and structures. The technology works in the same manner as described in the earlier chapter - solar array converts photon particles in sunrays to DC current, which is converted to AC current using an inverter. In case of net metering arrangement, the electricity generated by the PV array is consumed by the loads first and the excess power generated is exported to the grid. In case of gross metering, generated energy is directly fed in to the grid.

Sizing of the PV array depends on the following variables: load demand, demand profile, availability of structurally sound shadow free roof area and availability of grid interconnection facilities.

Photo credit: GSES

Figure 14: Typical array in rooftop PV system

Components of grid-connected rooftop solar PV system

The major components of a grid-connected rooftop solar PV system:

1. PV modules
2. Grid-connected inverter
3. Balance of system components, including mounting frame, junction box, cables, fuses, isolators.

For grid-connected PV system with battery storage, following are added:

- Multimode inverter or hybrid inverter
- Storage battery

These components are further detailed in the following section.

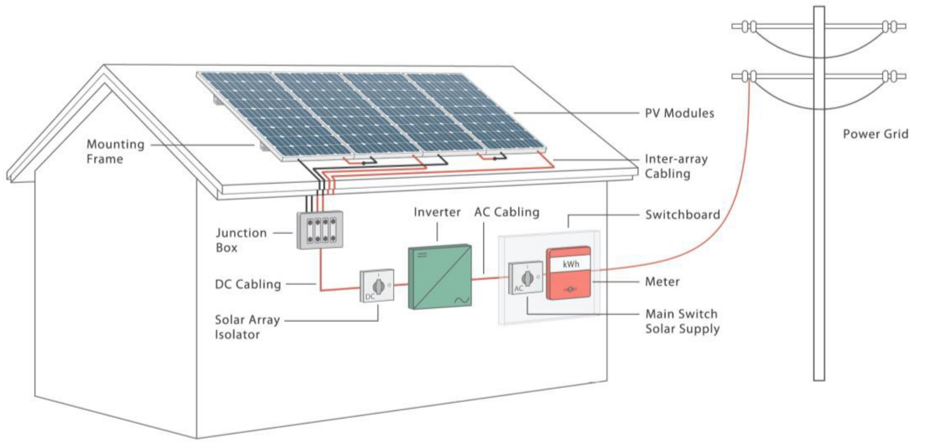


Illustration credit: GSES

Figure 15: Components of a grid-connected rooftop PV system

1. PV modules:

The solar photovoltaic technology is evolving and different technologies have emerged in recent years. There are two major types of solar modules - crystalline and thin film modules. Crystalline modules are further classified as mono-crystalline and poly-crystalline based on the process of growth of silicon crystal. Thin film modules are classified based on compounds used in making the modules.

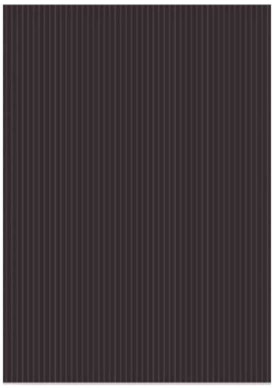
Irrespective of the types of modules being used, attention must be paid on their test and compliance certificates to ensure relevant codes and standards. Some commonly used PV modules are summarized below.

Mono – crystalline module

Module Efficiency: 15-22%
Module Area/kWp: 6.5–4.6m^2

Poly-crystalline module

Module Efficiency: 14-16.7%
Module Area/kWp: 7- 6m^2



Amorphous thin film module

Module Efficiency: 5–10%
Module Area/kWp: 20–10m^2

		
Micro-morph thin film module Module Efficiency: 10-12% Module Area/kWp: 10-8 m^2	**CdTe thin film module** Module Efficiency: 12-13% Module Area/kWp: 8-7.5 m^2	**CIGS thin film module** Module Efficiency: 14-16.7% Module Area/kWp: 7- 6m^2

Figure 16: Different types of PV modules and their efficiency and area/kWp

Note: Here the module efficiency denotes the amount of DC power converted by the module with respect to the solar radiation falling on the surface area of the module per square meter, therefore implying that the module efficiency is directly dependent on the area required for respective capacities. However, the energy generated by the same capacity power plant (using different efficiency modules) at a particular location does not change due to module efficiency.

2. Grid-connected inverter:

Inverter changes DC electricity produced from the arrays into AC sine wave that matches the grid AC supply in voltage and frequency to which it is connected. The resulting power can then be used by the AC loads, and also exported to the grid.

In a grid-connected PV system, the PV array is directly connected to the grid-connected inverter. These inverters cannot produce a grid equivalent AC sine wave independently, as the inverter must detect and reference the grid to be able to operate. If the AC grid is not present, the inverter will simply NOT function.

Grid-connected inverters can be classified based on the following criteria:

- Isolated or non-isolated
- Interfacing set-up in respect to PV array

Isolated inverter: According to IEC 62548 standard, an isolated inverter is an “inverter where there is at least a simple separation between input and output circuits (e.g. by means of a transformer with separate windings)”.

Non-isolated inverter: According to IEC 62548 standard, a non-isolated inverter is an “inverter that does not have at least a simple separation between input and output circuits”. These inverters are known as transformer-less inverters.

Inverters classified based on their interfacing features are listed below.

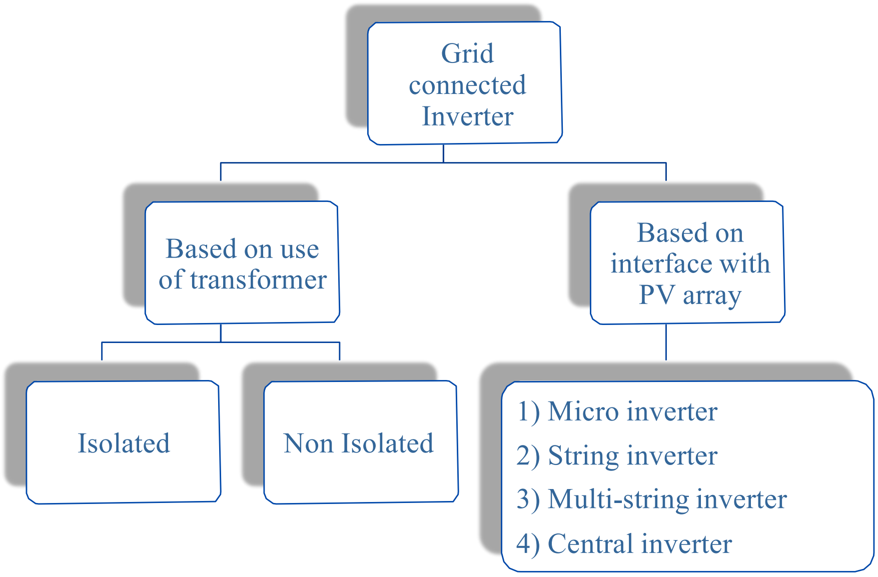


Figure 17: Classification of grid-connected inverter

Micro inverters or modular inverters are small inverters that are designed to be mounted on the back of the solar module. The capacity of micro inverter is equal to the module capacity to which it is connected.

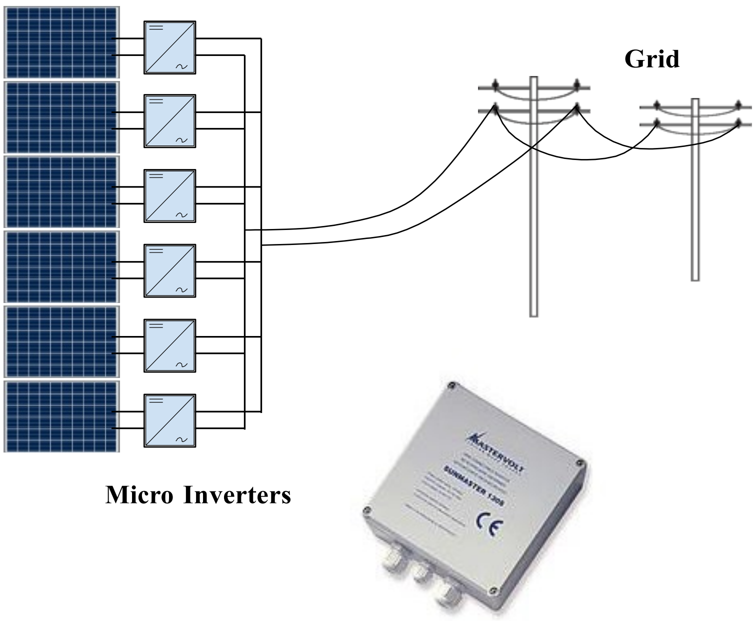


Figure 18: Micro inverters (also known as modular inverters)

String inverters range from 1 kW up to approximately 35 kW, and are connected to one or multiple strings of a PV array to a single maximum power point tracking (MPPT). A "string" is made of PV modules connected in series. An example of a string inverter is shown in figure 19. Multiple inverters can be used to spread the generated power over more than one phase.

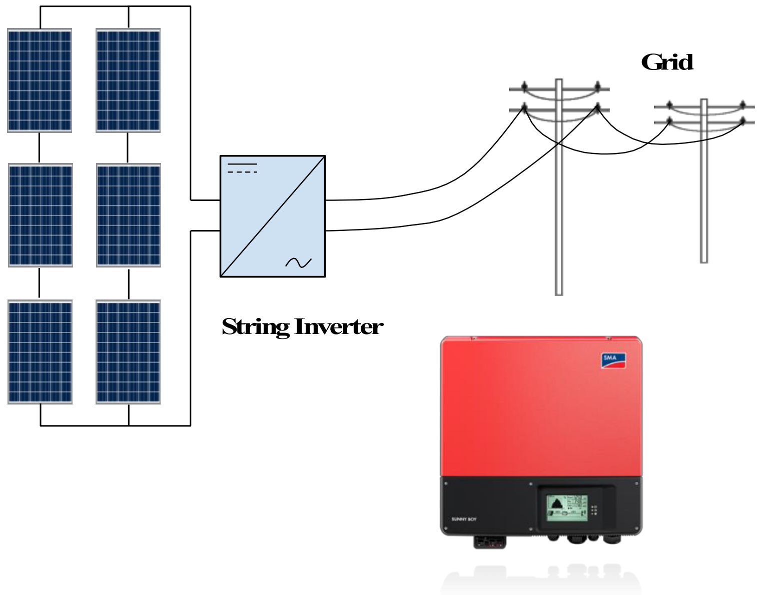


Figure 19: Grid-connected string inverter

Multi-sting inverter is only one inverter with more than one MPPT inputs. Therefore the solar array can be divided into sub-arrays with single or multiple strings and then each sub-array is connected individually to one MPPT as shown in Figure 20.

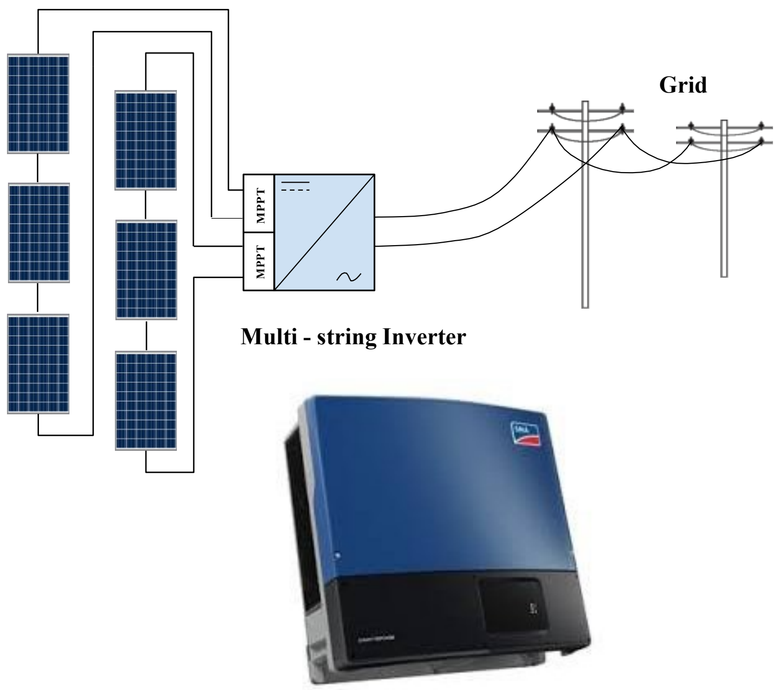


Figure 20: Grid-connected multi-string inverter

Central inverters are used for large grid-connected solar systems. A central inverter may have a single MPPT or multiple MPPTs. Most of the central inverters in the solar market today have only one MPPT. PV array is divided into a number of sub-arrays comprising of a number of strings. An example diagram of a central inverter is shown in Figure 21.

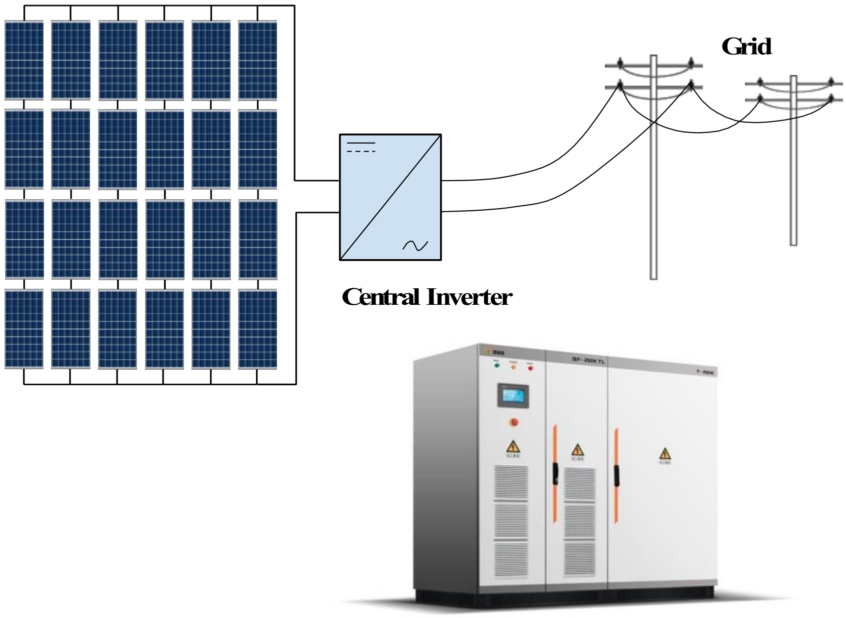


Figure 21: Grid-connected central inverter

Multimode inverter, also called hybrid inverter in Indian solar market, is used with a grid-connected PV system with battery bank storage. This type of inverter works as a grid-connected inverter when grid is available, and works a standalone inverter when there is no grid. There could be multiple options in configuring a multimode inverter based on the requirement of the customer and regulatory framework.

Figure 22: Grid-connected multimode inverter and storage battery

There are different types of batteries available for use in solar systems and they all have their unique operating principles. Currently, lead acid batteries are easily available, most affordable and common for solar storage applications. Developments in advanced battery chemistries such as the lithium ion and ferrous derivatives will provide affordable and more reliable storage solutions in the near future.

3. Array mounting structure

Support structures and module mounting arrangements should comply with –

- Applicable building codes/regulations,
- Standards, and
- Module manufacturer's mounting requirements.

The following aspects should be considered while designing array mounting structure –

- **Thermal aspects –** to allow expansion/contraction of modules/structure.
- **Mechanical loads on PV structures –** to comply with related standards.
- **Wind –** structures will be rated for the maximum expected wind speeds for the location of installation.
- **Material accumulation on PV array –** snow, ice, or other material which can substantially increase dead weight on the structure.
- **Corrosion –** mounting will be made from corrosion resistant materials suitable for the lifetime and duty of the system.

Figure 23: Different rooftop array mounting structures

1. Balance of System (BOS) Components

The balance of system equipment must be selected and installed correctly. If appropriate design procedures are not followed, the system could have performance and reliability problems, premature faults and even failure.

The key BOS components include:

- DC cables and AC cables
- Array junction box/ DC combiner box
- Over current protection device/circuit breakers
- Disconnection devices
- Plugs, sockets and connectors
- Lightning protection system
- Earthing and bonding arrangement
- Energy meters
- System monitoring
- Marking and signage
- Mounting frame

DC cables are used to connect the modules with one another, then to the array junction box, the array junction box to the DC isolator and the DC isolator to the inverter. It is important to select a cable that meets the requirements *of IEC 62548: Design requirement for PV arrays* (in terms of voltage and current specifications), and minimises voltage drop or losses along its full length.

AC cables connect the inverter to the distribution board and finally to the grid. The voltage from the inverter is typically either 230V AC single phase or 415V AC three-phase depending on the capacity of inverter. The AC cables required are the same cables used in general electrical installations.

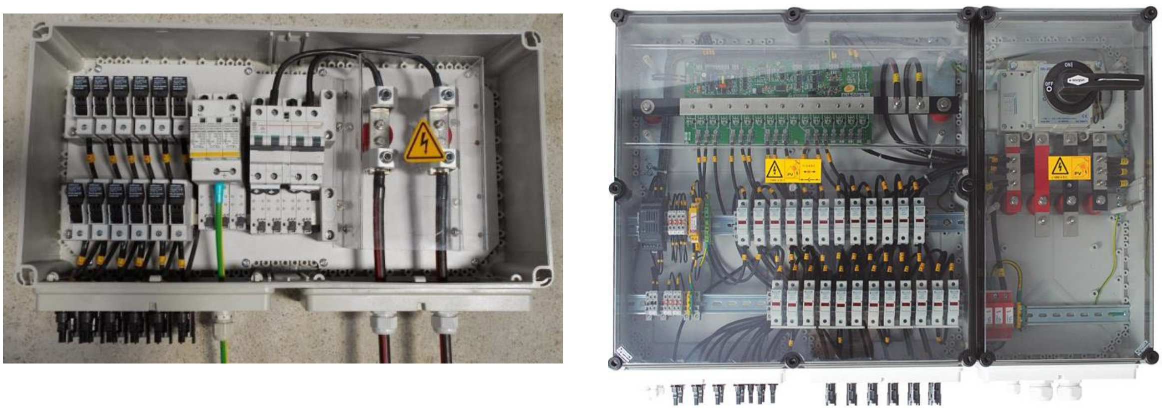


Figure 24: Array junction box

Array junction box/DC combiner box is used when the array is comprised of a number of parallel strings. Cables from the array strings are interconnected in this array junction box.

If there are multiple parallel strings, the array junction box will house the connection of the positive and negative cables and fuses from the different PV strings to identical or similar links. There will be only one DC positive and negative output array cable from the junction box interconnecting with the inverter (via the DC isolator).

The array junction boxes and string (DC) combiner boxes shall be at least IP 54 compliant in accordance with IEC 60529, and shall be UV resistant.

Overcurrent protection device or circuit breakers

PV modules are current limited sources but can be subjected to over currents. The over current can originate from multiple parallel strings or inflows from external sources.

Overcurrent within a PV array can also result from earth faults in array wiring or from fault currents due to short circuits in modules, in junction boxes, combiner boxes or in module wiring.

(Note: Requirement of overcurrent protection devices is discussed in chapter 4 of this manual.)

Disconnection devices such as fuses and isolators are used to protect the system during the time of maintenance.

Plugs, sockets and connectors for use at the array level connections should be rated for DC use. They should be also rated for outdoor use with the appropriate UV resistant and IP rating. The plugs and sockets used for household equipment should not be used in PV arrays.

Lightning protection systems (LPS) are installed in areas where there is high occurrence of thunderstorms. Some buildings are already equipped with LPS and in such cases, proper integration with the RTPV system as per IEC 62305 – 3 is required.

Earthing and bonding arrangement for earthing exposed conductive parts of a PV array is important due to the following reasons:

- Bonding to avoid uneven potentials across an installation,
- Protective earthing so that there is fault current path,
- Lightning protection.

In order to perform these operations, an earthing conductor must be used as per the guidelines described in IEC 62548. This topic is discussed in chapter 4 of this manual.

Energy meters record the electrical energy flowing across the points where the meters are connected. The electricity consumer is then billed for this consumption on the tariff set for that consumer. Electricity distributors will often have different rates for residential houses compared with industrial and/or commercial consumer.

There are two categories of energy meters in the context of solar PV installation under the net metering framework:

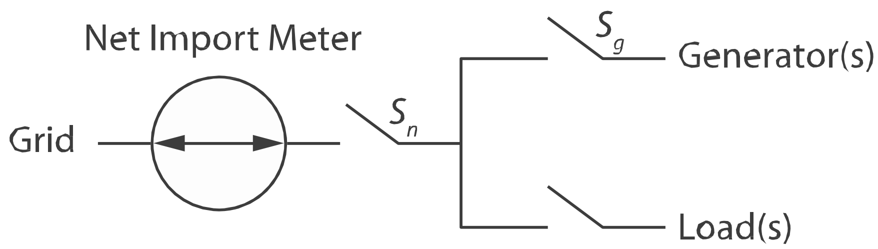


Figure 25- Bi directional analog meter for net metering

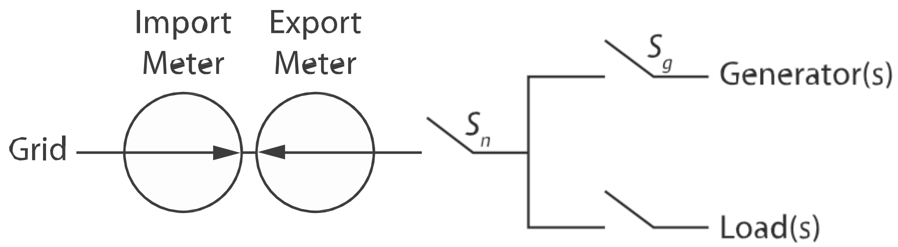


Figure 26- Two directional analog meter for net metering

System monitoring plays an important role as it gives an overview of the entire system based on the number of units or kWh generated per annum. Additionally, the monitoring system highlights the generation of the system as per its design as well as the expectation from the system.

Most inverters are equipped with a data module and communication system that constantly updates the amount of power generated on a timely basis (hourly, daily, monthly) and sends the same to its respective online portal on which the customer can monitor his/her system.

For commercial plants, system monitoring is more relevant as the investment is at a larger scale.

Figure 27: System monitoring application

Marking and signage is required to make the installation and operation as safe as possible for everyone involved. All electrical equipment must be marked according to the requirements for marking in IEC 62548 or to local standards and regulations when applicable. Markings should be in the local language or use appropriate local warning symbols.

For reasons of safety of the various operators (maintenance, personnel, inspectors, public distribution network operators, emergency aid services, etc.), it is essential to indicate the presence of a photovoltaic installation on a building.

A sign should be fixed at the following places:

- origin of the electrical installation,
- metering position, if remote from the origin,
- distribution board to which the supply from the inverter is connected, and
- all points of isolation of all sources of supply.

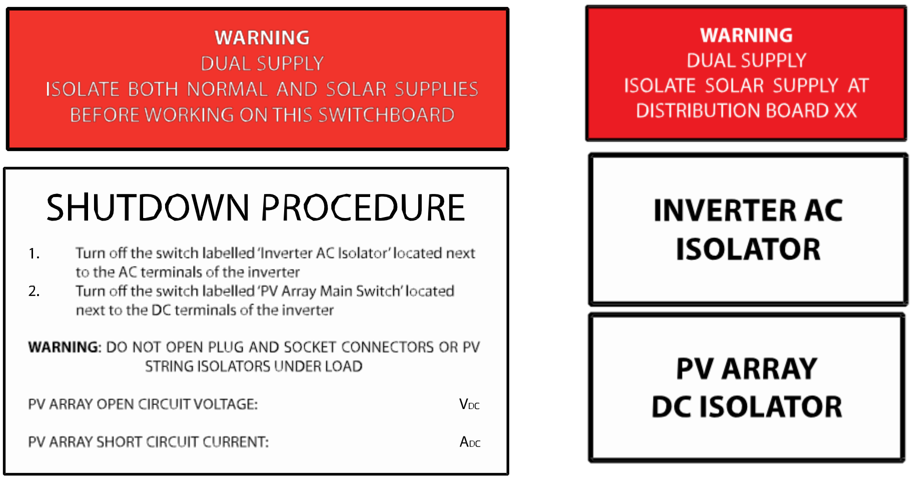
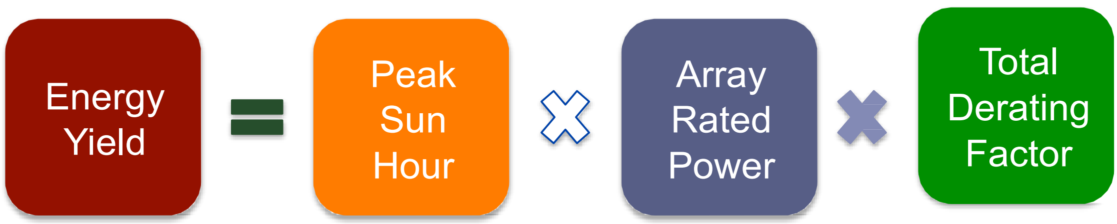


Illustration credit: GSES

Figure 28: Examples of marking and signage

Energy generation estimation from PV system

The amount energy delivered by the PV system is calculated using the following equation:



The inputs of this equation are explained below.

- **Amount of solar irradiation falling on the modules (expressed as Peak Sun Hours or PSH):**

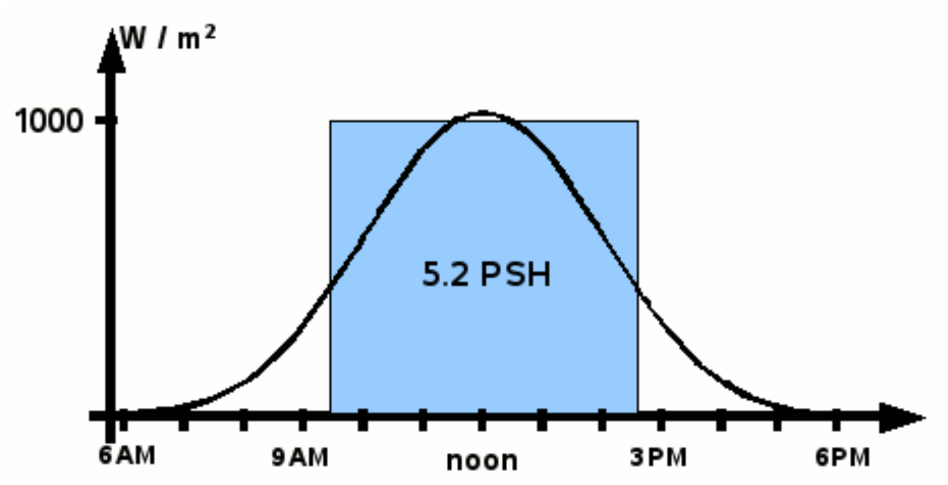


Figure 29: Illustration of PSH

Solar energy available in a given location is expressed as kWh/m^2/day. This is commonly referred as PSH. For example, if solar radiation for a particular location is 5.2kWh/m^2/day then PSH for that location will be 5.2 hours.

- **Array Rated Power (peak watt or W_p):**

This is the rated nameplate capacity of the system, derived from total rated power of the modules.

The peak wattage of a solar module is the number of watts it will produce under Standard Test Conditions (STC) i.e. 1000W/m^2 of solar irradiance, Cell temperature of 25º C and Air Mass 1.5. It is important to note that a PV array never works in those standard test conditions in the field and therefore array power will always be less than the rated power at STC.

- **Total De-rating or Loss Factor:**

Factors such as temperature, shadow and dust over PV array, manufacturer's tolerance, orientation, tilt angle and loss due to irradiance level directly affect power generation. PV array will also degrade over its period of life cycle. Apart from loss of module power there will also be losses due to inverter efficiency, voltage drop and losses in the transformer if used.

Total efficiency of the system after considering all the losses expressed as total de-rating or loss factor

Losses in a solar PV system arise from weather factors, site constraints and voltage drop. A summary of typical losses is provided in Table 1.

Cause of loss	*Estimated Loss (%)	De-rating Factor
Temperature	10%	0.90
Dirt	3%	0.97
Manufacturer's Tolerance	3%	0.97
Shading	2%	0.95
Orientation	0%	1.00
Tilt Angle	1%	0.99
Voltage Drop	2%	0.98
Inverter	3%	0.97
Loss due to irradiance level	3%	0.97
Transformer & AC transmission	1%	0.99
Total de-rating factor (multiplying all de-rating factors)		0.73

** Typical losses in PV systems. Actual loss will be as per site conditions*

Table 1: Typical losses in PV system

In the above example, there are 27 percent losses in the system. It simply means that an array rated 1kWp will actually produce power equivalent to 0.73kW.

- **Performance degradation over life cycle**

The performance of a PV module will decrease over time. The degradation rate is typically higher in the first year upon initial exposure to light and then stabilizes. Factors affecting the degree of degradation include the quality of materials used in production, the manufacturing process, the quality of assembly and packaging of the cells into the module, as well as maintenance levels employed at the site. Generally degradation of a good quality module is considered to be about 20 percent during the module life of 25 years @ 0.7 percent to 1 percent per year.

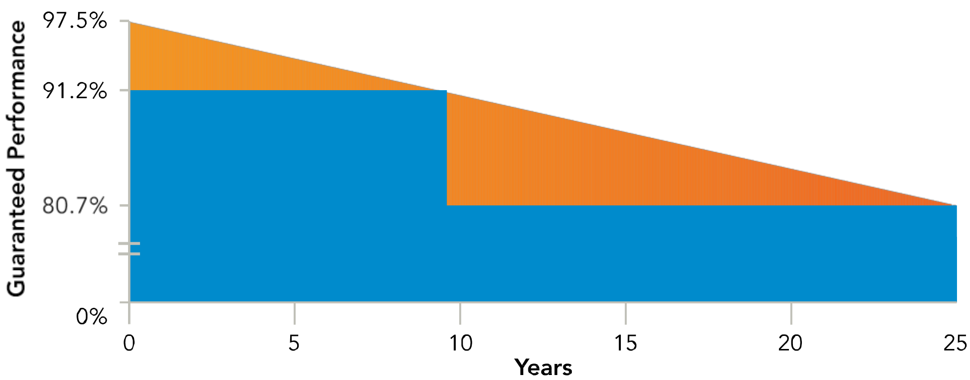


Figure 30: Example of PV module degradation

Module manufacturer may provide degradation warranties in two different ways; either linear degradation or stepped degradation as shown in Figure 30.

Working example of energy generation estimation

On a clear and a sunny day, a 10 kWp PV array received 5 Peak Sun Hours. Total loss (de-rating factor) in the system is estimated as 0.73 (73 percent).

Expected output can be determined as follows:

Expected Output = Peak Sun Hours x Peak Power Output x Total de-rating factor

= 10 kWp x 5 hour/day x 0.73
= 36.50 kWh per day (1st year)

Considering the example of module degradation as shown in the Figure 30 the expected annual output from the plant after 10 years and 20 years will be as following:

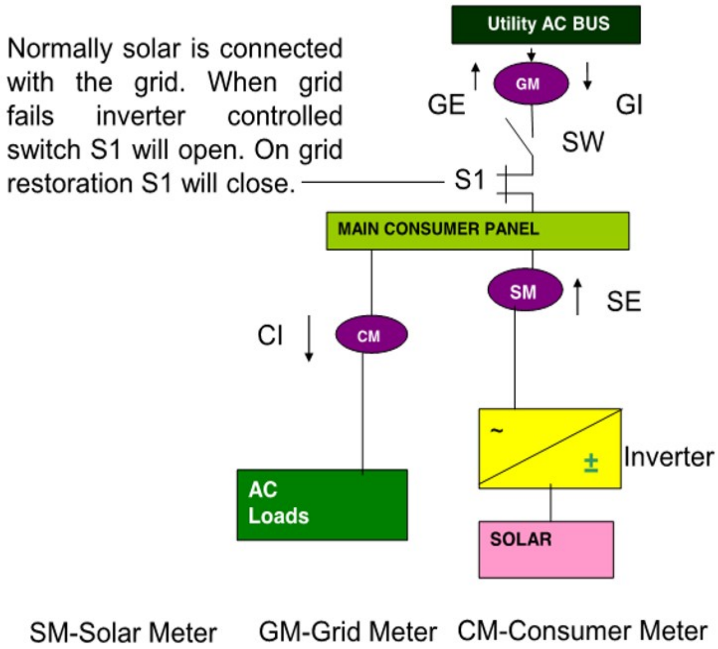
= 32.85 kWh per day (on 10th year)
= 29.56 kWh per day (on 25th year)

Different configurations of rooftop PV system

Rooftop PV systems can be configured in different ways based on a) how they are connected to grid, and b) if they are connected to any other energy supply or storage system. Four different types of configurations are illustrated below:

Grid-connected rooftop solar PV system with no battery or DG backup

In this setup, the solar PV array is connected to the grid with the help of an inverter. Excess power, which is not drawn by the load, is sent to the grid. The inverter acts as a first line of defense in this system. In the event of grid failure, the inverter senses the over voltage or under voltage and disconnects the system from the grid. The drawback of such a system however, is that since it is directly connected to the grid, during a grid fault, the PV system will not supply any energy.



Source: Central Electrical Authority

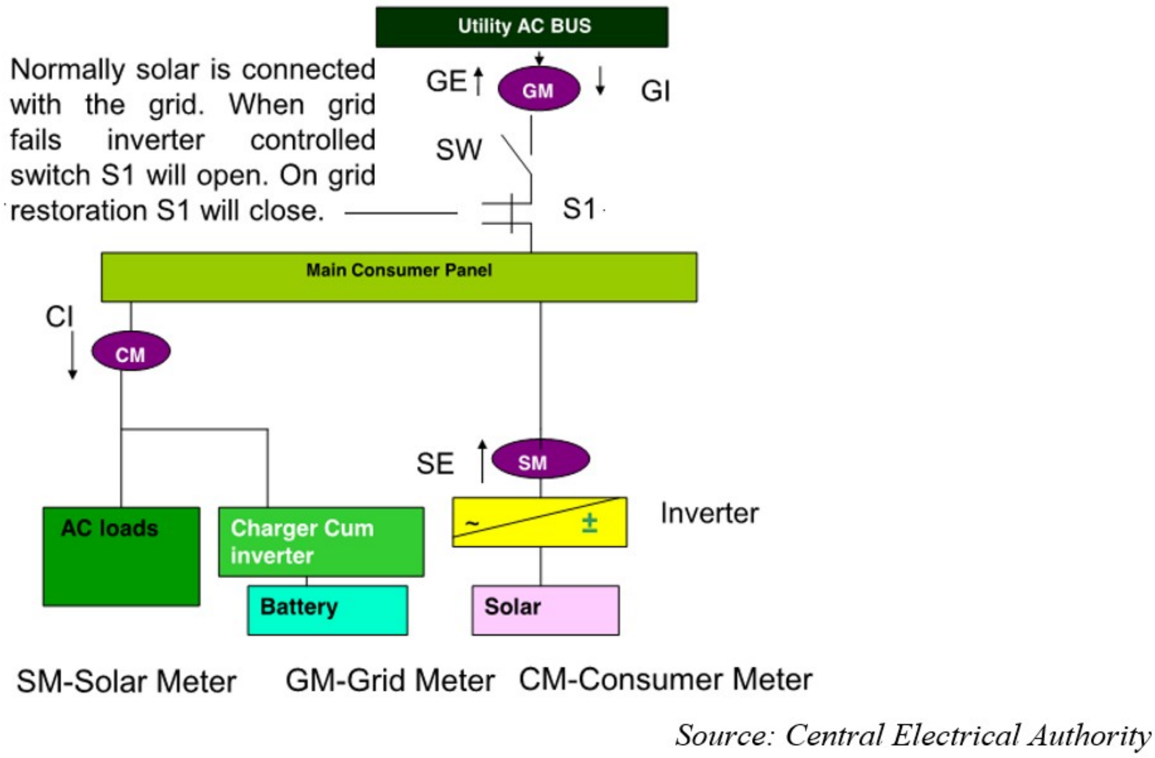
(GE – Grid Export, GI – Grid Import, CI – Consumer Import, SE – Solar Export)

Figure 31: Grid connected system

Grid-connected rooftop solar PV system with charger cum inverter as load

This configuration is similar to the simple grid-connected system in the manner it connects with the grid. The feature which differentiates it is the presence of battery and charger cum inverter in the load circuit. A proportion of power is sourced from the load circuit, which can either come from solar PV or grid electricity, to charge a battery bank. This charger is a converter to change AC current to DC. This battery bank can either be sized to power only the critical loads in the circuit, or the entire load within the meter boundary. A battery inverter is also present in the circuit to change the DC electricity back to AC for consumption.

In the event of a grid outage, the energy stored in the battery is used to provide electricity to the selected loads.



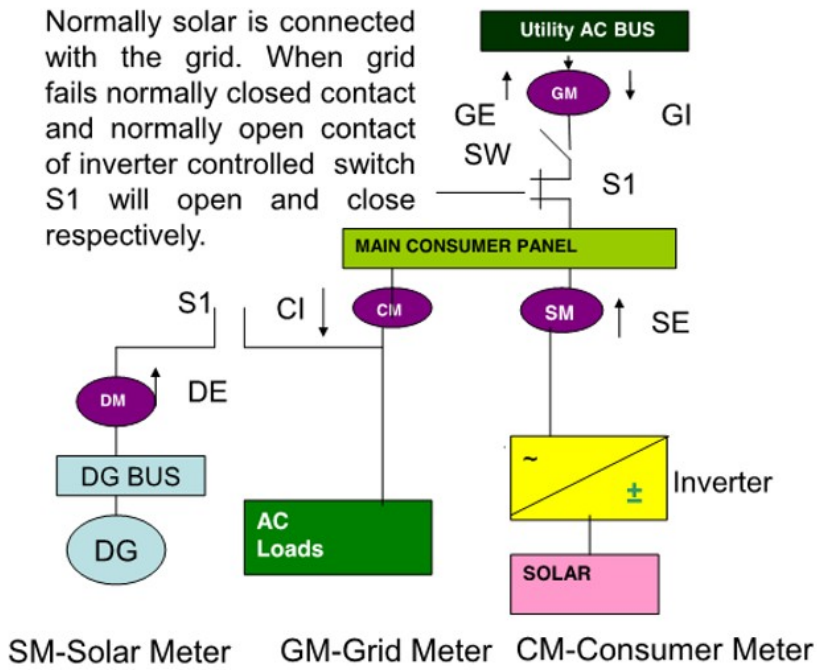
(GE – Grid Export, GI – Grid Import, CI – Consumer Import, SE – Solar Export)

Figure 32: Grid connected system with charger cum inverter as load

Grid-connected rooftop solar PV with DG set as backup

The operational fundamentals of this system are similar to the earlier configuration of grid-connected system with charger cum inverter. The only difference is that the battery in this system is replaced with a diesel generator.

The generator is started when no power supply is available in the system. As generator provides AC electricity, no additional inverter is required in the system. An Uninterrupted Power Supply (UPS) is typically added to critical loads to manage the gap times between power outage and generator startup.



Source: Central Electrical Authority

(GE – Grid Export, GI – Grid Import, CI – Consumer Import, SE – Solar Export)

Figure 33: Grid connected system with DG set

Grid-connected rooftop solar PV with multimode/hybrid inverter and battery storage In this configuration, PV array, battery storage and specified AC loads are all connected to the multi-mode Inverter. When the grid is available the specified and non-specified loads are powered by the grid as well as the PV system. Excess power from the PV system can be used to charge the battery, or can be exported to the grid. When the grid is not available the PV system charges the batteries, which supplies power to the loads.

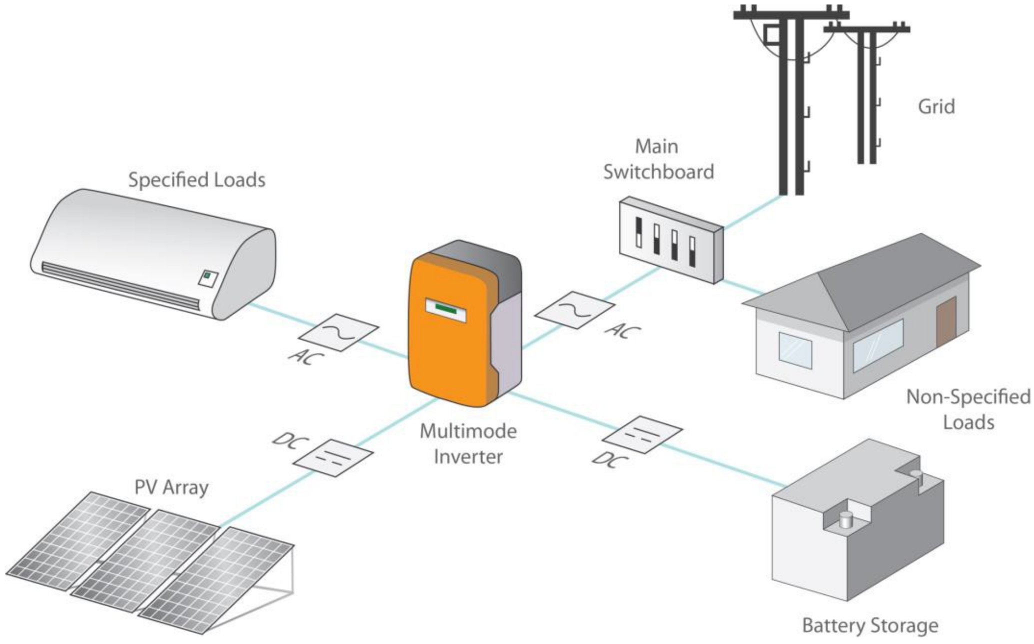


Illustration credit : GSES handbook on Grid connected PV systems with battery storage

Figure 34: Grid-connected system with multimode/hybrid inverter and battery storage

CHAPTER 3: SITE ASSESSMENT AND PLANNING FOR ROOFTOP PV SYSTEMS

A site assessment is a crucial step before the design and installation of a rooftop PV system. The following tasks need to be carried out during a site assessment:

- Assess customer requirement
- Assess the location for installation of PV array
- Conduct a shadow analysis
- Determine space between two rows in case of flat roof
- Determine PV array orientation and tilt
- Assess how the PV modules will be mounted
- Identify suitable location for inverters and other electrical equipment
- Determine cabling routes and cable run distances
- Study site parameters that are likely to affect the design considerations
- Assess occupational health and safety requirement

Assess Customer Requirement

A critical source of information which may directly affect the design of the photovoltaic system is the clientele demand and requirement. The information gathered at this phase helps to form a blueprint for the system installation.

As a starting point, the first essential requirement would be the budget of the client. Identifying the budget at the initial stages helps to determine how much the client can afford to invest in the project.

The next immediate focus point shifts to the intention of setting up a rooftop solar PV system. Some clients may look for a reduction in their electricity bills whereas others might be more inclined to reducing their carbon footprint and contributing to the environment. Sometimes the clients may give more priority to aesthetics. Whatever the scenario may be, it is crucial to understand the reason behind installing a PV system.

Once the intent and budget has been clearly understood, the next point of consideration is the load profile of the client. Here, questions that confirm the critical loads, hours of operation, number of AC loads, number of DC loads, voltages, currents etc. should be of paramount importance. In addition, the profile of the load demand over a typical week or for each month must be specified. It is also important to know the months (summer or winter) when the demand will be maximum. Information on load should be collected in a tabular format as shown below:

Name of Appliance	Load (W)	No of such appliances	Hours of usage (Hours)	Time of usage	Power cut timing (if any)	Energy Consumed	Critical Load (Y/N)

When designing a system it is also important to take into account if the client will want to expand his/her system in the future. This factor will determine the size of the current system so that it can accommodate a larger system in the future, if required. This is directly related to the available area for installation and cases may arise where the client is willing to expand but is constrained by the available area on the roof.

After obtaining the client's requirements and load profile, it is crucial to validate the information provided by the client. Since the system will be designed based on the information provided, the data obtained should be reliable. Sometimes, clients may seek replacements for diesel generators and they make the simple mistake of thinking that the load is equal to the power rating of the generator without looking at detail at the actual loads. If a large diesel generator was installed for addressing only surge power requirements, then the sizing of the solar plant will have to be appropriately downsized as the energy requirements might not be high enough to justify the same size of solar PV rooftop plant. Figure 35 depicts the key factors that contribute to obtaining client requirements.

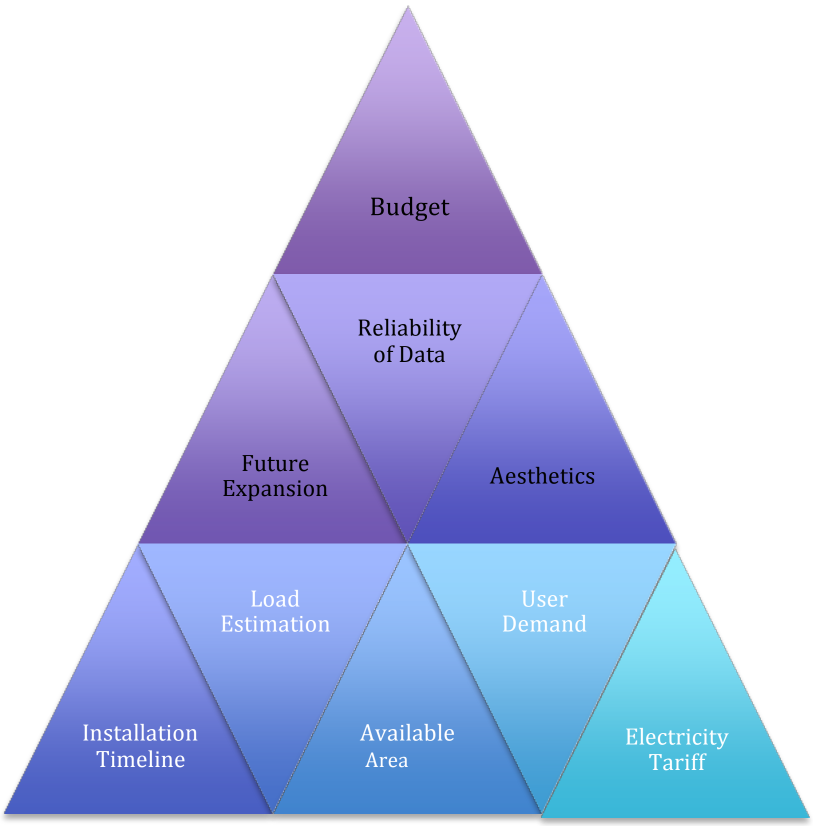


Figure 35: Key parameters to be considered whilst obtaining the client requirement

Note: Customer requirement is also elaborated in Chapter 15.

Tools for site assessment

The following tools are required for site assessment.

- Site survey format
- A solar pathfinder/sun eye
- A compass

- A measuring tape/digital distance meter
- A camera
- An angle measuring equipment
- A notebook
- A working partner

Figure 36: Tools for site assessment

Identify location for installation PV array:
The location of PV array should be selected such that it is –

- Free from shadow in all days of the year
- Has access for maintenance
- Provide ample space for air cooling
- Prevails aesthetic of the building or premises
- Not far from the inverter
- Protected from theft and vandalism

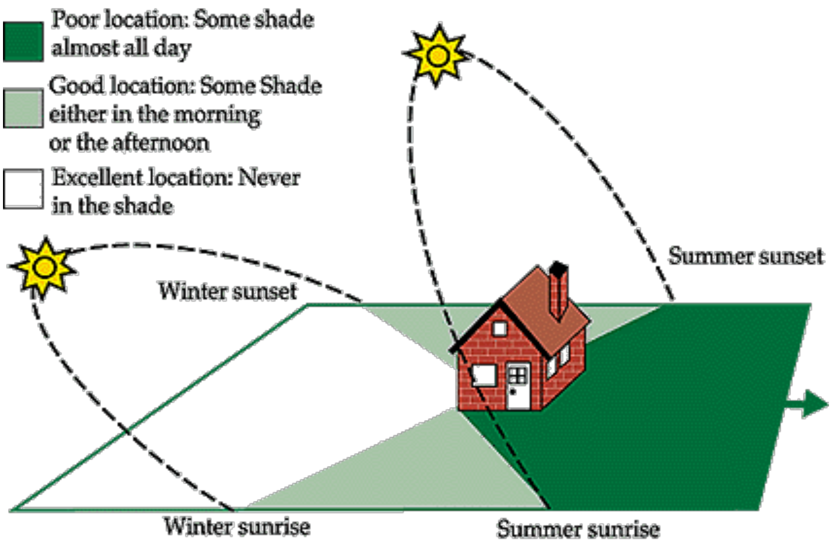


Figure 37: Placement of solar arrays considering summer and winter sun position

Sometime shadow in the early morning and late afternoon cannot be avoided due to very low altitude of sun. In such a situation, arrays must be placed in such a way that there is no shading between the hours of best insolation, usually from 8 a.m. to 4 p.m., on the day with the longest shadows, December 21 in the Northern Hemisphere.

Shadow Analysis

Using a solar path finder:
The most accurate and convenient way to place the array away from any tall object that can possibly cause shadow is to use a solar pathfinder. When you use a solar pathfinder there is no need to measure distance or height of any objects that can create shadow at any point of time during the year. You can determine if there is any shadow by simply placing the solar pathfinder in the potential array location. If there is any shadow image seen in the pathfinder, move away from that point to the direction where the shadow can be avoided. Solar pathfinder should be located at the four corners of the array to ensure that the complete array is shadow free.

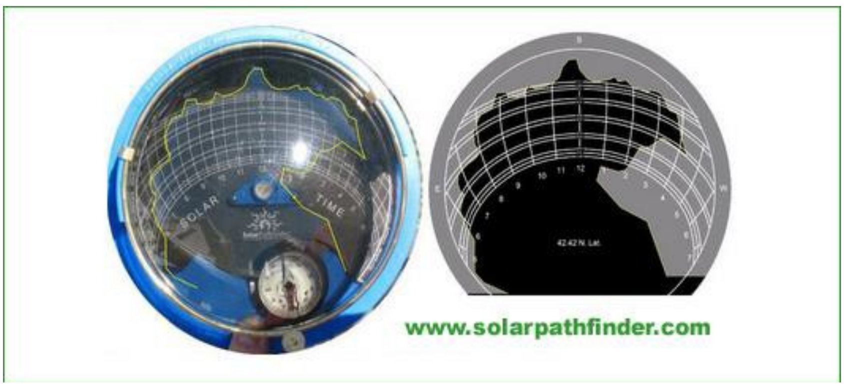


Figure 38: Application of solar pathfinder for shadow analysis

If you do not have access to a solar pathfinder, use the following calculations to ensure that the array will be located away from potential shading. However, these methods require some measurement, calculation and good assumptions to decide whether the array will be shadow free for all days of the year.

Using spacing factor graph:
One easy approach is to use the "spacing factor graph" given in Figure 39. This graph will help in deciding where to place an array for no winter shading. Read up from the latitude of the site to the curve for the hour when no shadows are to reach the array (again usually 8 a.m. to 9 a.m.). Then read across to find the spacing factor. Multiply this factor times the height of the object to calculate the distance the array must be placed away from the object.

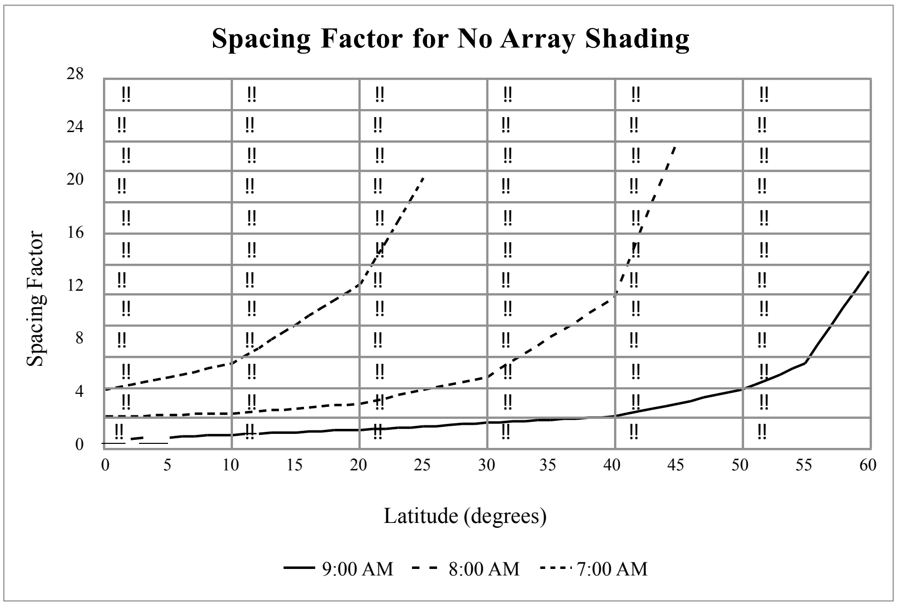


Figure 39: Graph to determine array spacing factor

The proper distance depends on the latitude, the time, and the height of the nearest tall object. With the help of the graph you can calculate the minimum distance from object to the array using the following formula.

$$\boldsymbol{Distance\ from\ object\ to\ array = Object\ Height\ x\ Spacing\ Factor}$$

Applying rule of thumb:
The general rule of thumb is to locate the array at a distance away from the object that is at-least twice the height of the object. This will ensure that the object will not cast a shadow for four hours either side of solar noon.

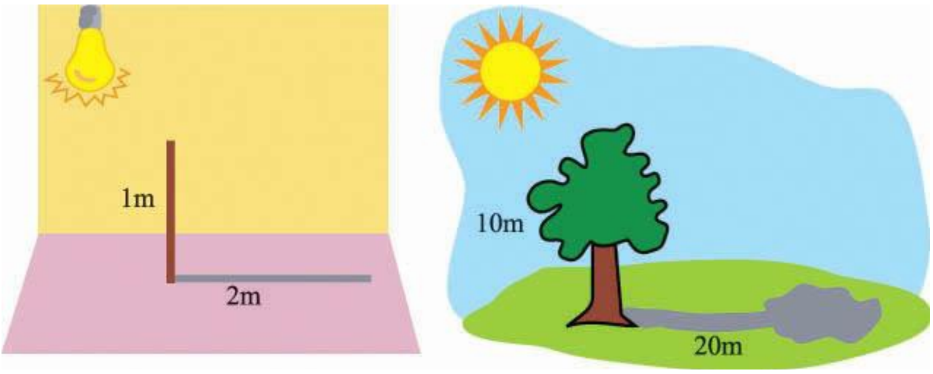


Figure 40: Placing of array away from objects

Space between two rows:
When PV modules are installed in multiple rows, consideration must be given so that one row of modules does not cast a shadow on the row behind. Calculations need to be done to find the minimum distance between PV array rows to avoid winter mid-day shading. This can be calculated using basic trigonometry as shown in Figure 41.

$$\textbf{Row spacing } (Y) = (X)\ x\ \frac{Cos\ (azimuth\ angle)}{Tan\ (altitude\ angle)}$$

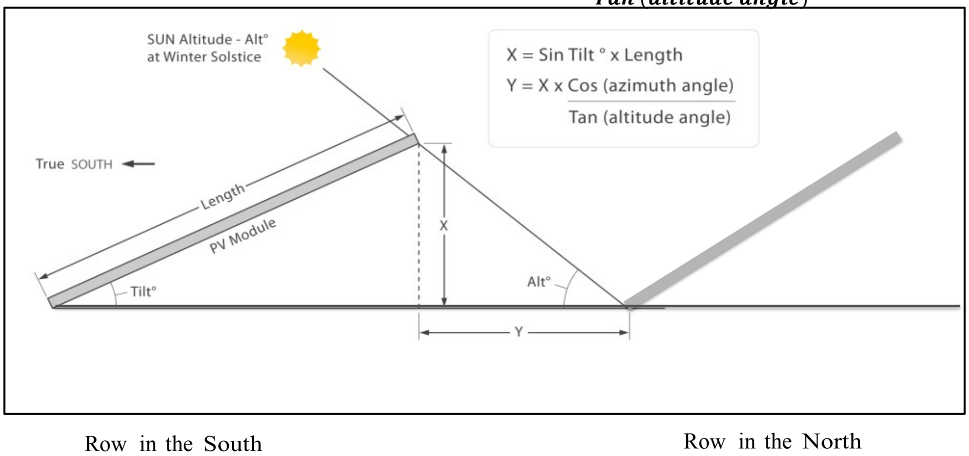


Illustration credit: GSES

Figure 41: Calculating the minimum distance between rows

Example:
The PV array is located in New Delhi: Latitude 28.5°N. The row spacing should avoid shading at solar noon on December 21.

Azimuth = 173°
Altitude = 38° at solar noon on December 21

$$Y = X\ x\ \frac{Cos\ (173^o)}{Tan\ (38^o)} = X\ x\ \frac{0.99}{0.78}$$
$$= X\ x\ 1.27$$

If height of the row is 1m, distance between two rows shall be 1m x 1.27 = 1.27m.

Location of electrical equipment

1. Location of inverter should be such a way that access is controlled
2. Minimize distance from the solar PV array to reduce losses
3. Protection from environment as needed by the inverter class
4. Sufficient ventilation for cooling
5. The location of overcurrent protection devices and/or load breaking disconnecting means should be at the end of the cable that is electrically most remote from the PV modules.

Design Considerations

1. Load bearing capacity of roof depends of the age of roof.
2. Typically a RCC roof has a life of 100 years. Asbestos roof have much lower life at 30 years. Corrugated metal has life span between 20 and 100 years.
3. Usually the load of the structure including PV and the supporting structure varies from 30 kg/m^2 to 60kg/m^2.
4. As per MNRE technical specification the total load of the structure should be less than 60 kg/m^2.
5. For a large system a suitable walk-way will be required for maintenance purpose.
6. Operating temperature affects performance. Therefore PV arrays should be installed in such way that there sufficient air flow/ventilation for cooling.
7. High wind pressure can damage the structure and modules. Therefore mounting structure should be opted such a way that there is minimum wind pressure.
8. High humidity and salty atmosphere can corrode the structure and the extreme levels in the site should be known.
9. Lightning strikes can damage the electrical equipment and sometimes the modules. Therefore lightning vulnerability in the site should be evaluated.

Occupational health and safety considerations

- Safe access to the roof
- Exposure to the sun
- Falling from the roof or injuries from falling objects from roof
- Injuries from lifting and installing heavy inverters
- Cut, bump and burns from sharp and hot metallic items/tools
- Insects biting – some insect may be poisonous

Typical site survey format for rooftop PV project

A generic site survey format has been provided in Table 2.

Sl. No	Information to be collected	Value/ data
1	General Information	
1.1	Date of Survey	
1.2	Name of Building	
1.3	Address	
1.4	City	
1.5	Latitude/Longitude of site	________˚N, _________˚E
1.6	Surveyed by:	
1.7	Checked by:	
2	Roof type - RCC	
2.1	Items installed on the roof	
2.2	Usable area for installation of solar modules	
2.3	Age of the Roof	
2.4	Accessibility to the roof	
2.5	Load bearing capacity	
2.6	Building Orientation	
3	Roof Type - Pitched/Slant Roof	
3.1	Roof orientation	
3.2	Roof tilt angle	
3.3	Roof material	
3.4	Roof age	
3.5	Roof structure - material, load bearing capacity	
3.6	Accessibility and convenience to work on the roof	
4	Assess potential source for near and far shadow	
4.1	Shadow from tress & vegetation	
4.2	Shadow from other buildings	
4.3	Shadow from objects, trees	
4.4	Shadow from natural landscape in hilly areas	
5	Maximum wind velocity, occasion of cyclone	
6	Environment: salinity, humidity, dust, pollution	
7	How is the building separated from the roof?	
8	Activities under the roof	
9	Are there any flammable materials inside?	
10	Space available for the installation of inverter	
11	Load details – list of appliances and working hours	
12	Details of standby power supply system if any	
13	Location of balance of system equipment	
14	Health, safety & environmental risks	

Table 2: Site assessment checklist

CHAPTER 4: DESIGN AND SAFETY OVERVIEW OF ROOFTOP SOLAR PV SYSTEMS

Determining PV system capacity/size

The capacity or size of a rooftop PV system is generally determined by the roof area availability, installation purpose and policy and regulatory framework under which the system is to be installed.

Deciding factors for rooftop PV system capacity

(1) Availability of shadow free area
(2) Installation purpose and budget
(3) Government program and incentive guidelines
(4) State electricity regulation
    a. Distribution transformer capacity
    b. Connected load

Rooftop PV system design configuration

Rooftop PV system design configurations are based on the type of inverter used and the arrangement of the PV modules, i.e. how many modules are connected in series (strings) or how many modules are connected in parallel.

The array consists of solar modules wired in series to provide a maximum power point voltage (V_{mp}) that lies within the operating window of the grid-connected inverter. The output voltage of the solar module, and therefore the array, will be dependent on the temperature. Hence, while designing systems, it is important that the solar array operates within the operating range of the inverter voltage for all the expected day time temperatures for a particular location where solar array is installed.

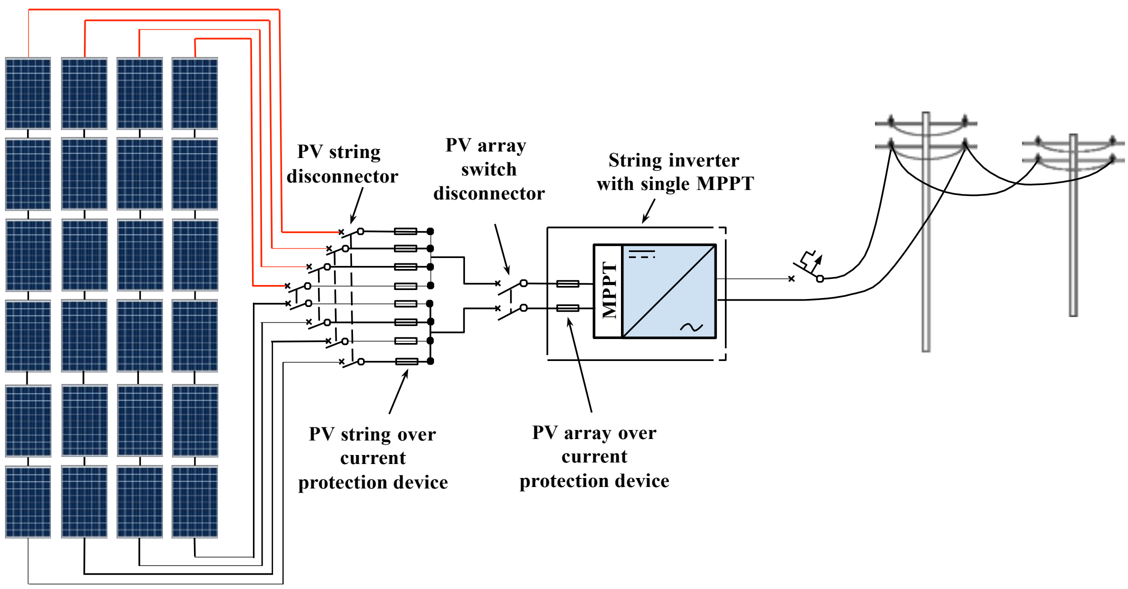


Figure 42: PV array connected with string inverter

The number of modules connected in parallel will be dependent on the input current rating of the inverter and the output current rating of the modules as well as the number of modules connected in each string. This is because the power rating of the array must be suitable for the power rating of the inverter as well as being within the current and voltage limits of the inverter.

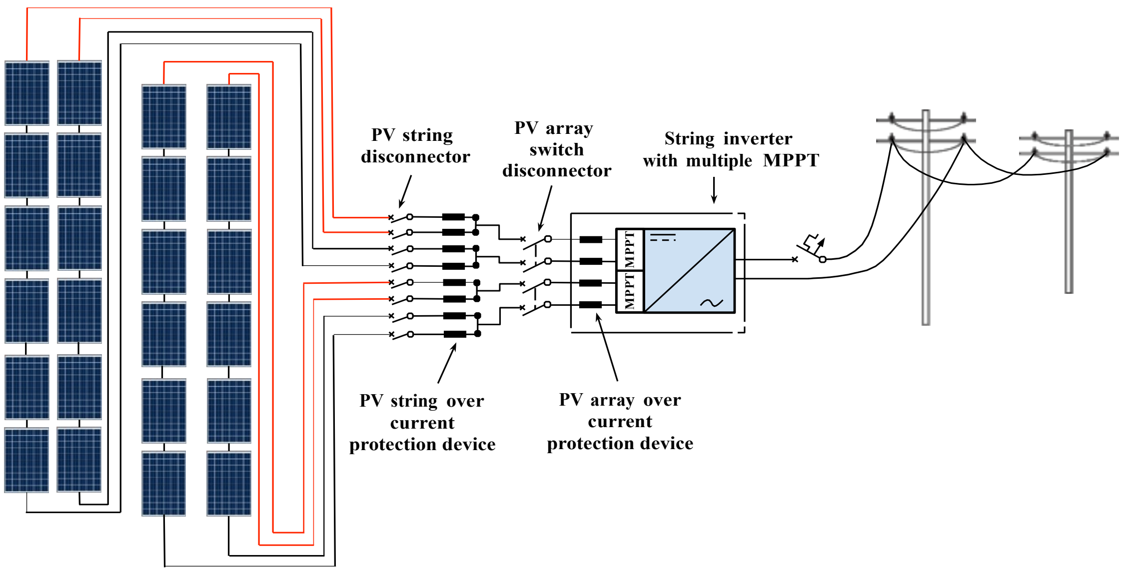


Figure 43: PV array connected with multi-string inverter

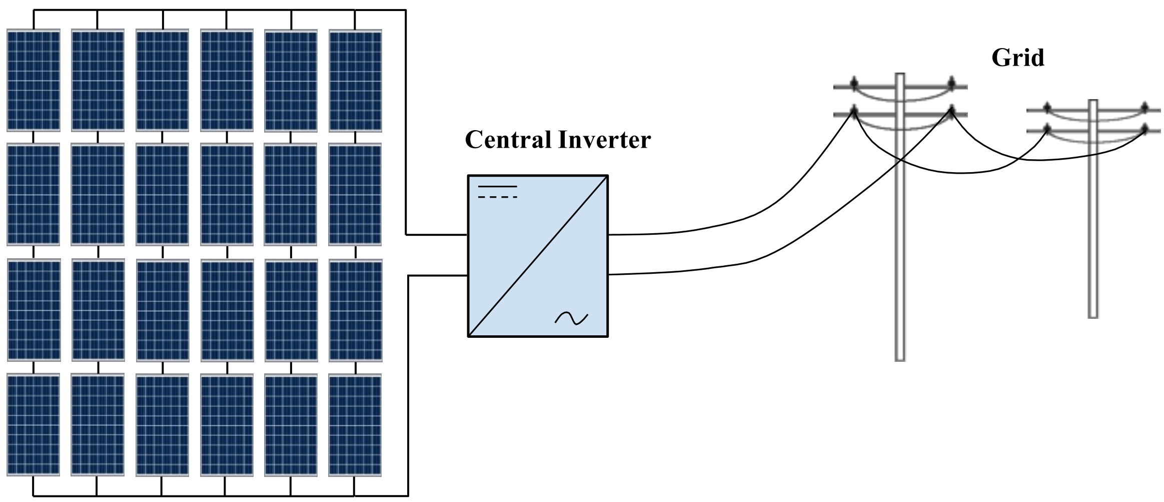


Figure 44: PV array connected with central inverter

The array configurations are also dependent on the number of MPPT algorithms of the inverter. According to IEC 62548 PV array design requirement, when inverters have multiple MPPT inputs, overcurrent protection of the section of the array may be treated as a separate PV array and each PV array shall have a switch disconnector to provide isolation of the inverter.

Where an inverter has a single MPPT and multiple input circuits are internally paralleled onto a common DC bus, each PV section connected to one of those inputs will be treated as a sub-array and each PV sub-array will have a switch disconnector to provide isolation of the inverter.

Array mounting structure design

Support structures and module mounting arrangements should comply with applicable building codes regulations and standards and module manufacturer's mounting requirements.

The following aspects are to be considered in designing array mounting structure:

Thermal Aspects

PV modules generally have aluminum frames and are mounted on metal frames that may contract and expand under different operating conditions. Therefore the design of the mounting structure must consider this aspect as per the manufacturer's recommendation.

Mechanical Loads

The PV array support structures should comply with international standards, industry standards and regulations with respect to loading characteristics. Particular attention should be taken when installing PV array systems in areas of high wind speeds and regions with lots of snowfall.

Corrosion

The metals used in the structure should be made from a corrosion resistant or appropriate protective coating should be applied so that the structure is free from corrosion throughout its life. Special care must be taken when using metals of two dissimilar metals to avoid bi-metallic corrosion.

Wind

PV modules, module mounting frames and the methods used for attaching frames to buildings or to the ground will be rated for the maximum expected wind speeds at the location according to IS 875 (Part 2).

Material Accumulation on PV array

Snow, ice or other material may build up on the PV array and should be accounted for when selecting suitably rated modules, calculating the supporting structure for the modules and likewise, when calculating the building capability to support the array.

Safety issues- personal and system safety

Protection against electric shock

For protection against electric shock, the requirements of IEC 60364-4-41 and Central Electricity Authority (CEA) - Measures relating to safety and electric supply 2010 will apply.

According to IEC 62548: Photovoltaic array design requirement PV arrays for installation on buildings shall not have maximum voltages greater than 1000V DC.

Protection against Overcurrent
PV modules are current limited sources but can be subjected to over currents because they can be connected in parallel and also connected to external sources. Overcurrent within a PV array can result from earth faults in array wiring of from fault currents due to short circuits in modules, in junction boxes, combiner boxes or in module wiring.

PV system architecture for earthing

The relation of a PV array to earth is determined by whether any earthing of the array for functional reasons is in use, the impedance of that connection and also by the earth status of the inverter.

Protective earthing of any of the conductors of the PV array is not permitted. Earthing of one of the conductors of the PV array for functional reasons is not allowed unless there is at least simple separation from mains earth provided either internally in the PCE or externally via a separate transformer.

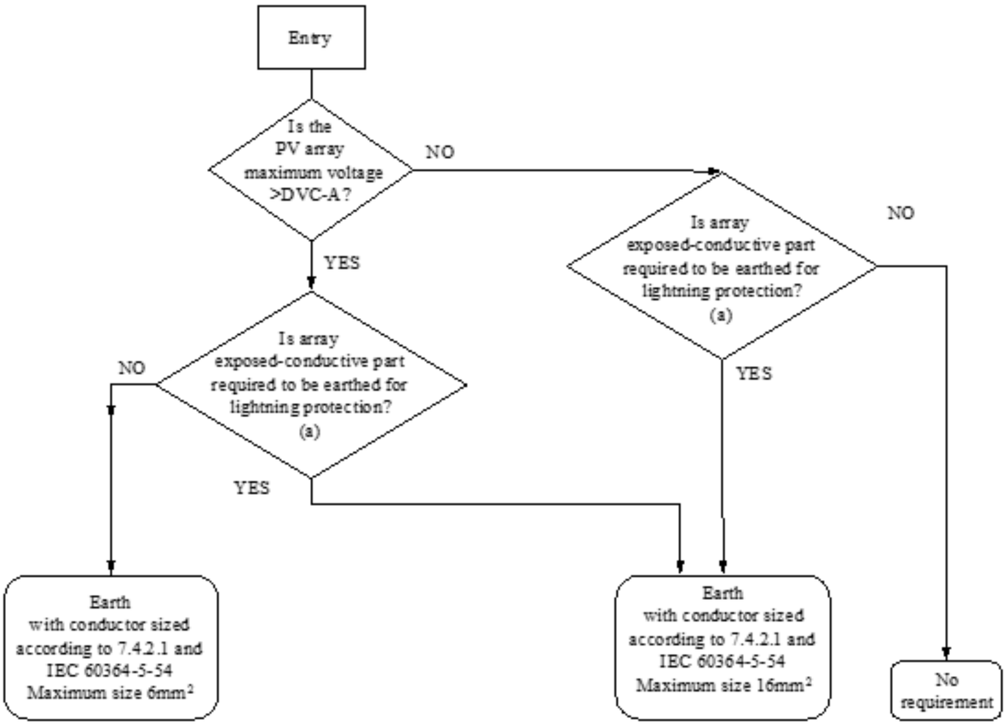
A connection of one conductor to earth through internal connections inherent in the inverter via the neutral conductor is allowed in a system without at least simple separation.

Array Configuration	Inverter Type	Is there Functional Earthing?	Is Equipotential Bonding Required?
Functionally Unearthed array	Isolated Inverter	No	Yes
Functionally unearthed array	Non – isolated inverter	No	Yes
Functionally earthed array	Isolated inverter	Yes	Yes
Functionally earthed array	Non- isolated Inverter	This configuration is NOT permitted.	

Table 3: Earthing based on Array configurations

As per IEC 62548 Photovoltaic array design requirement, a functionally earthed array shall NOT be connected to a transformer-less (non-isolated) inverter. The configuration is not permitted due to the high probability that the inverter will introduce direct current into the AC electricity grid.

Figure 45 lists the different types of system configurations and the corresponding requirement for equipotential bonding.



Source: IEC 62548

Figure 45: PV array functional earthing decision tree

Lightning protection for rooftop system

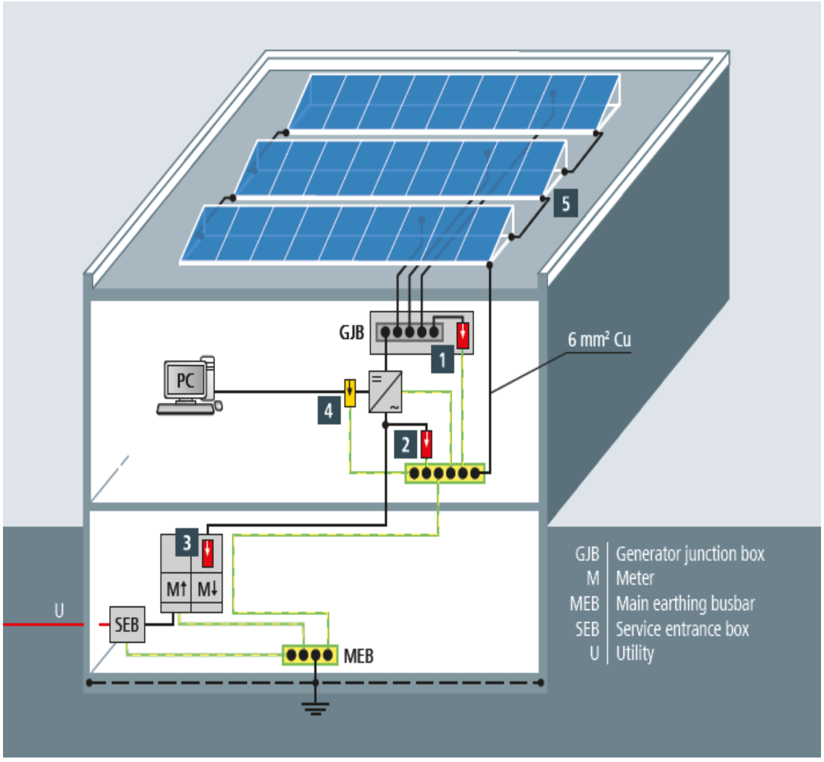
The installation of a PV system has no direct relation to the probability of lightning strikes, but in case the system is installed in regions where thunderstorms are of common occurrence, it is recommended to install a lightning protection system as per the standards in IEC 62305-3.

To protect the system as a whole, surge protection devices can be fitted between the active conductors and earth at the inverter end of the DC cabling and the array. To protect specific equipment, surge protection devices may be fitted as close is practical to the device.

Based on the necessity and the available area, lighting surge protection devices can be arranged based on the configurations given below:

Case 1: Building without external lightning protection system

If a PV system is installed on a new or on an existing building and no external lightning protection system is installed according to a risk analysis in line with the IEC/EN 62305-2 standard, it is not required to install an external lightning protection system. However, in such case, according to EN 62305-3 standard, a type 2 surge protective device (SPD) shall be installed on the DC and AC side to protect PV systems against inductive and conducted interference pulses. The number of SPDs depends on the distance between the device to be protected and the SPD. Additional SPDs will be required if the distance exceeds 10m.



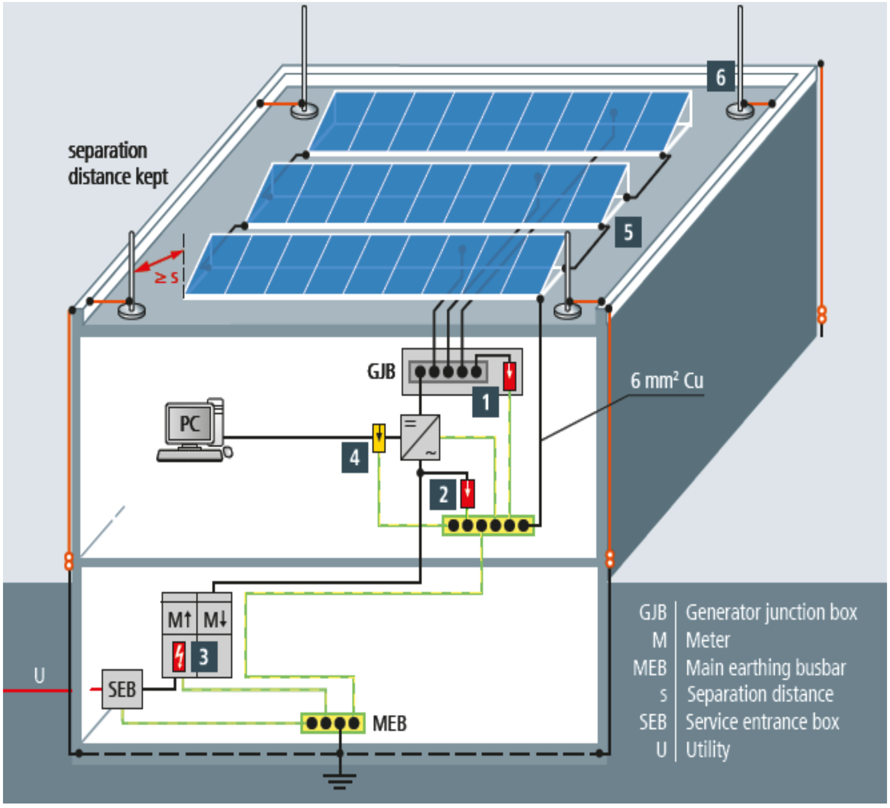
Source: www.dehn-international.com

Figure 46: Installation of a rooftop PV system without lightning protection

Case 2: Building with external lightning protection system and adequate separation distance

If the building has (or requires) an external lightning protection system according to risk analysis as well as national regulations, and separation distance are kept between lightening arrestor and PV array structure, a lightning protection system should be preferred which is not directly connected with the PV power supply system. The modules must be located in the protected zone of the isolated air-termination system.

If the separation distance calculated according to the IEC/EN 62305-2 standard is maintained, type 2 arresters must be used to protect the inverter on the DC side and the modules. The number of SPDs depends on the distance between the device to be protected and the SPD. If this distance exceeds 10m, additional SPDs are required. The AC side is protected by installing a combined arrester at the grid connection. If the distance between the grid connection and the inverter exceeds 10m, it is advisable to install an additional type 2 arrester on the AC side of the inverter.



Source: *www.dehn-international.com*

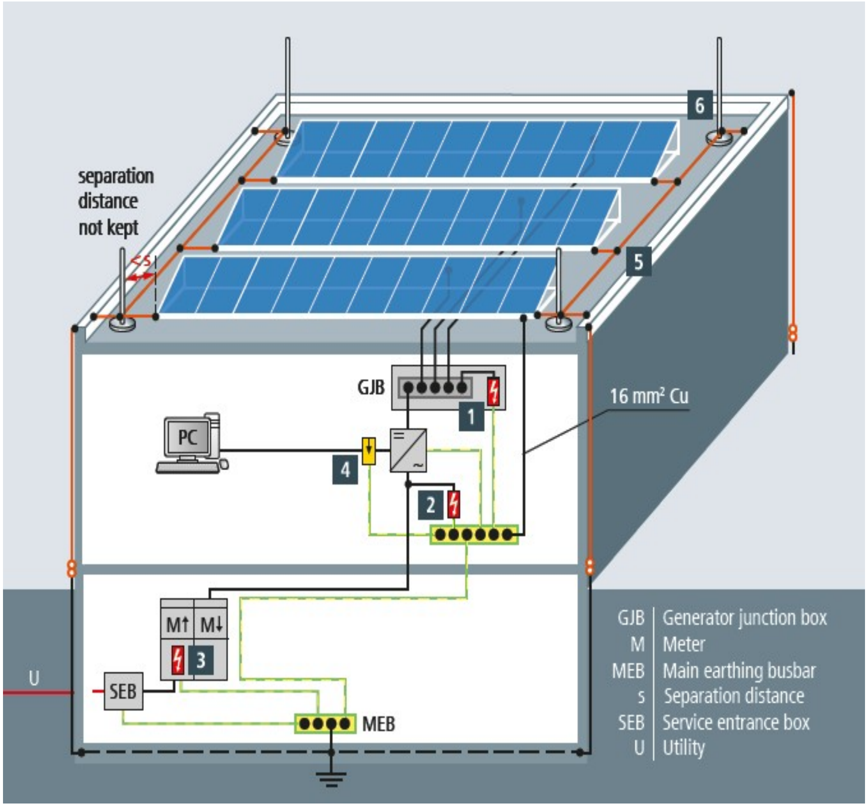
Figure 47: Installation of a rooftop PV system with a LPS (ample roof space)

Case 3: Building with external lightning protection system without adequate separation distance

If the building has (or requires) an external lightning protection system according to risk analysis as well as national regulations, a lightning protection system should be preferred which, if the required separation distances are kept, is not directly connected with the PV power supply system.

If the separation distance calculated according to IEC/EN 62305-2 cannot be maintained, for example in case of metal roofs, lightning equipotential bonding must be established.

Type 1 combined arresters must be provided to protect the inverter on the DC side and the modules. The number of SPDs depends on the distance between the device to be protected and the SPD. If this distance exceeds 10m, additional SPDs are required. The AC side is protected by installing a combined arrester at the grid connection. If the distance between the grid connection and the inverter exceeds 10m, it is advisable to install an additional type 1 arrester on the AC side of the inverter.



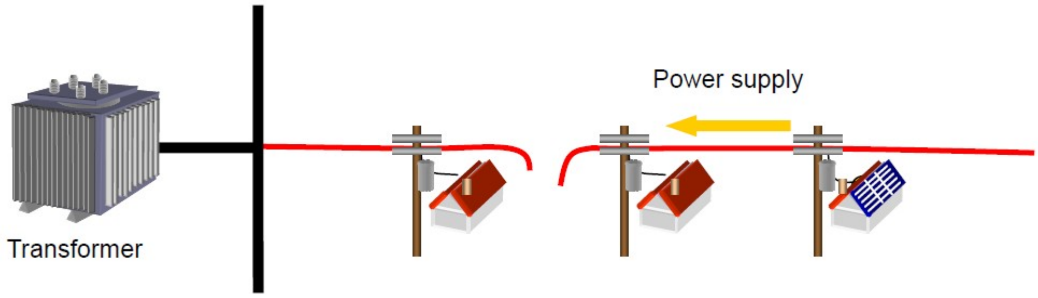
Source: www.dehn-international.com

Figure 48: Installation of a rooftop PV system with a LPS (limited roof space)

Grid protection – unintentional islanding

One of the major concerns about unintended islanding is the "increased risk of accident". In the case of grid fault or planned grid maintenance, the network operators must repair the distribution lines as soon as possible. Before starting the work, it must be confirmed that the lines are disconnected from the main grid, in other words, out of electricity. However, if PV systems or other distributed power generators are still supplying power to the lines, it could lead to electric shock of workers. It has also been pointed out that since the power is continuously supplied to the fault point, the public is exposed to the risk of electric shock. In addition to physical injury, studies indicate that unintended islanding could also damage grid/end-users' devices.

Another unintended islanding problem is the "risk of overcurrent" during the breaker reclosing process. With the main grid and the distribution line operating independently during unintended islanding, the voltages are not in synchronized operation and could be out of phase. If the breaker is reclosed with a large voltage phase difference, a strong current will flow into the line, which is very dangerous [Overcoming PV Grid Issues in Urban Areas, IEA 2009: Japan].



Source: Overcoming PV Grid Issues in Urban Areas [IEA 2009: Japan]

Figure 49: Unintended islanding condition

The grid protection must disconnect the inverter from the grid when:

- The power supply from the grid is disrupted.
- The grid goes outside the preset parameters of the inverter.

The inverters disconnect from the grid in either of the above situations to avoid 'islanding' through two types of internal protection called passive and active protection.

Passive protection: the inverter disconnects if it detects grid conditions which are over or under the voltage and/or over or under the frequency settings of the inverter.

Active protection: the inverter will either include frequency or voltage drift - such that when the inverter is disconnected from the larger grid, the voltage or frequency will drift to the point where the passive protection will cause the inverter to trip.

According to IEEE 1547 and CEA (technical standards for connectivity of the distributed generation resources) Regulation 2013 - for an unintentional island the grid tied inverter shall detect the island and cease to energize within two seconds of the formation of an island.

According to IEEE 1547 the grid-connected rooftop soar system shall include and adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the grid voltage and frequency restored. As per CEA Regulation 2013 delay in reconnection shall be at least 60 seconds.

In case another power generation source such as a DG set in the consumer facility is operated when grid is not available, the inverter may sense the grid availability and if operation parameters are within the working range it will start functioning and will start feeding to the DG grid – depending on the regulation.

Selection of PV module and array BOS components

PV array maximum voltage
According to IEC 62548, all components, shall be rated for DC use, have a voltage rating equal to or greater than the PV array maximum voltage determined in section 7.2 of IEC 62548 and have a current rating equal to or greater than that shown in Table 6 of IEC 62548.

Lowest expected operating temperature (^{o}C)	Correction factor
24 to 20	1.02
19 to 15	1.04
14 to 10	1.06
9 to 5	1.08
4 to 0	1.10
-1 to -5	1.12
-6 to -10	1.14
-11 to -15	1.16
-16 to -20	1.18
-21 to -25	1.20
- 26 to -30	1.21
-31 to -35	1.23
-36 to -40	1.25

IEC 62548

Table 4: Voltage correction factors for crystalline modules

Qualification of PV modules
Crystalline silicon modules shall comply with IEC 61215. Thin film PV modules shall comply with IEC 61646. Systems with voltages above 50 V DC should include bypass diodes. Only Class A and Class C modules shall be used for grid-connected PV systems according to IEC 61730-1 and IEC 61730-2. Class B modules shall not be used for grid connected systems.

Class A: Modules rated under this class may be used in systems operating at greater than 50V DC or 240W as per safety requirements in IEC 61730 – 1 and IEC 61730.

Class C: Modules rated for use in this application class restricted to systems operating at less than 50V DC and 240W, where general contact access is anticipated

Class B: Modules shall not be used (Modules rated for Class B are restricted to systems protected from public access by fences, location, etc.).

Qualification of combiner boxes
PV array and PV string combiner boxes exposed to the environment shall be at least IP 54 compliant in accordance with IEC 60529, and shall be UV resistant.

PV array and PV string combiner boxes, which contain overcurrent and or switching devices, should be easily accessible for inspection, maintenance or repairs without necessitating the dismantling of structural parts, cupboards, benches or the like.

Qualification of Cables
DC cables must be rated at temperature 40˚C or above, and should be double insulated, UV-resistant, and water resistant. If they are to be exposed to an environment with salt, then the cables need to be made of tinned copper, and be multi stranded in order to reduce degradation of the cable over time.

Installation of isolator

Isolators are used as protective devices which help isolate elements of the system during high current flow caused either due to fault or due to external elements such as lighting storms, etc. Another functionality of breakers is that if there is any maintenance work to be done, they can be used to disable a part of the system while still connected to the load (hence they are also termed load breaking) so that maintenance can be performed.

Based on their position in the system, DC and AC isolators are used mainly at the connections between the PV array junction box (to protect the inverter from excess current from the array) and after the inverter respectively (to disconnect the entire system in case of grid fault).

PV Array DC Isolator:
A double-pole, load breaking, DC rated isolating (disconnect) switch should be installed on the DC side of the inverter. It should be rated appropriately for the voltage and current of the PV system.

Inverter AC Isolator:
CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 require an inverter AC isolator to be installed on the output of the inverter.

A main switch, lockable in off position, is required to be installed in the switchboard, which is located at a height of at-least 2.44m above the ground level. This allows the PV system to be disconnected from the mains power supply. This main switch may not be rated for load break nor may have feature of overcurrent protection.

Cable management at array

Wiring of PV arrays shall be undertaken with care to protect the cables from any mechanical damage. It is important to note that damage of cables may cause line-to-line or line-to-earth fault which can cause arc and possible fire.

All connections must verify for tightness and polarity during installation to avoid risk of faults and possible arcs during commissioning, operation and maintenance.

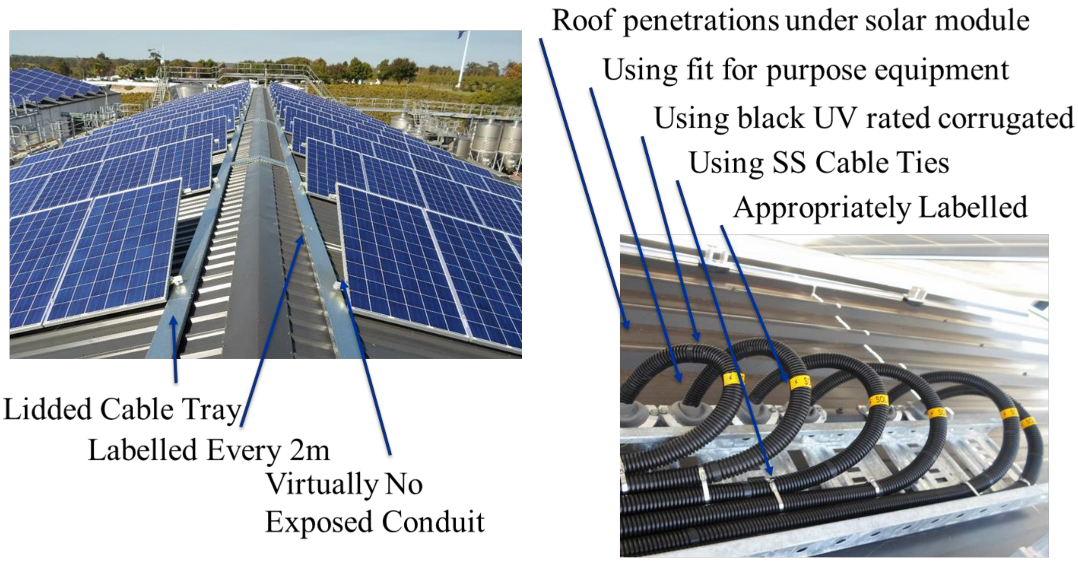


Photo credit: GSES

Figure 50: Example of good cable management

Cabling and interconnection

PV array should be laid in such a way that area of conductive loop is minimized. This will reduce the magnitude of lightening-induced overvoltage and disturbance to communication network under the building.

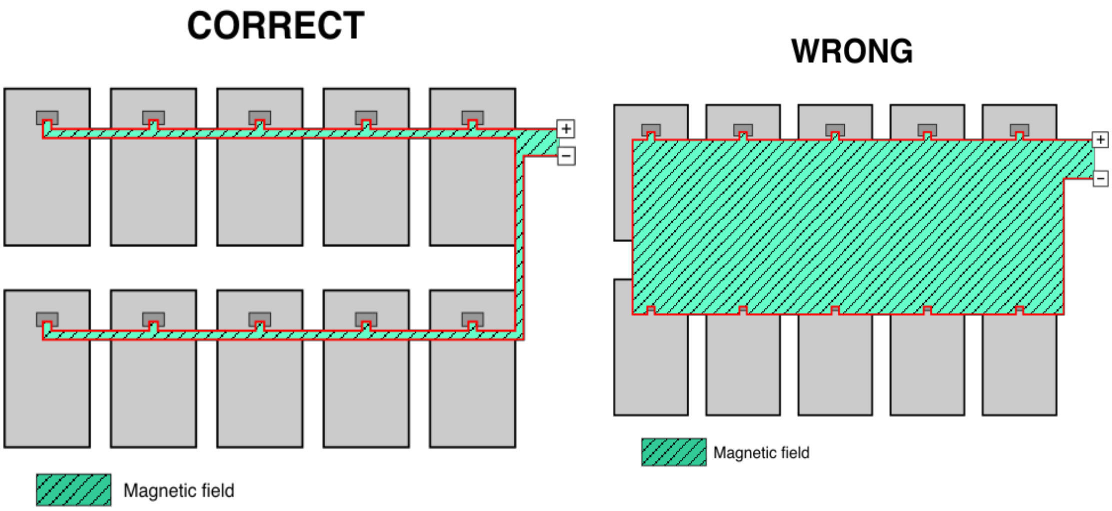


Figure 51: Example of good cable interconnection

Documentation

As per IEC 62446: Grid-Connected Photovoltaic Systems - Minimum Requirements for System Documentation, Commissioning Tests and Inspection, the required documentation includes:

- System data
- Nameplate data – rated power, manufacturers, models and quantities of PV modules and inverters
- Cover page data - contact information for the customer, system designer and system installer, relevant project dates
- Wiring diagrams (single line diagram with equipment information)
- Data sheets (Module and inverter)
- O&M information
- Test results and commission data

Chapter 5: Metering, Grid Connectivity And Test Procedure

Metering arrangement

The gross and net metering arrangements are illustrated in Figure 52.

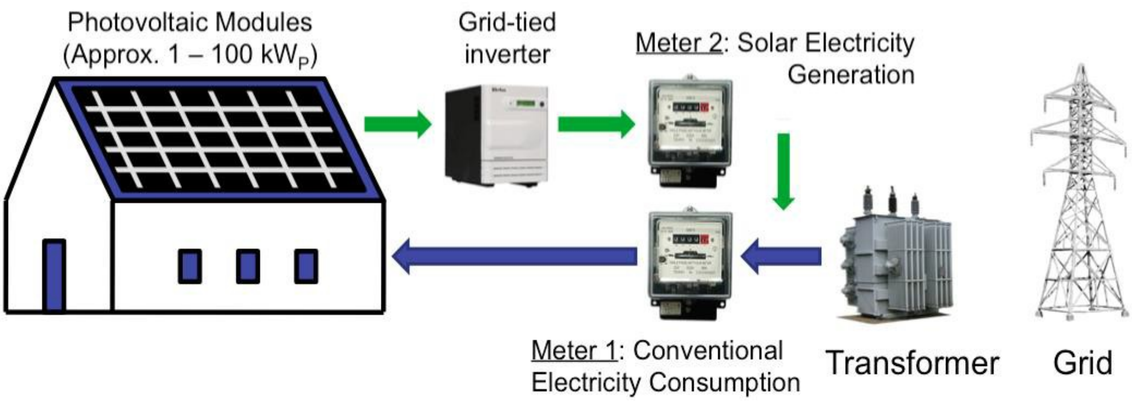


Figure 52: Gross metering arrangement

Gross metering arrangement: Energy generated from rooftop system is exported to the grid. Energy for self -consumption is imported from the grid. The user gets two line items on their bills, one of energy consumption and another for exported energy, which are completely independent of each other.

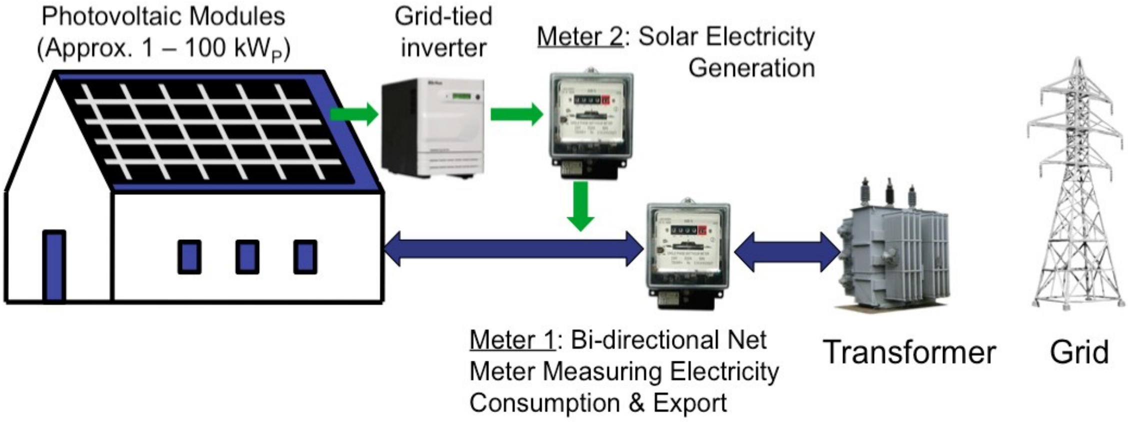


Figure 53: Net metering arrangement

Net Metering Arrangement: Energy generated by the rooftop system is first used internally and excess electricity is exported to the grid through a bi-directional meter. The bill received by consumer is net of electricity imported from the grid minus electricity exported to the grid.

Grid connectivity

Grid connectivity, inspection and approval mark the final steps within the rooftop solar PV project process. A successful connectivity and inspection procedure requires adherence to certain standards, regulations and guidelines which are designed to commission a technically safe and compliant project, ensuring that the system is operational.

The standards and regulations relevant to the grid connectivity and inspection procedure are listed below. These standards detail the requirements related to performances, operation, testing, safety and maintenance of grid connectivity and inspection activities.

These standards can either be purchased or sourced from the web. Full text description of the standards is beyond the scope of this training manual. However, general principles of these standards are summarized in the following sections.

Applicable standards and regulations

- Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013
- IEEE 1547 – Standard for Interconnecting Distributed Resources with Electric Power System, 2003
- Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations, 2010
- Central Electricity Authority (Technical Standards for Connectivity to the grid) Regulations 2007
- IEEE 519: Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, 2014

Interconnection technical specification and requirements

As mentioned previously, the interconnection process is guided by specific standards and procedures, which outline the technical specifications to which an interconnection process must adhere.

The requirements outlined in the specifications shall be met at the point of interconnection, although the instruments used to meet these requirements can be located away from the point of interconnection. However, all the interconnection system--hardware and software--that affects the grid is required to meet the standard regardless of their location within the electric power system.

These requirements apply to interconnection of either a single rooftop solar PV system or multiple PV systems.

The following section highlights the key specifications of an interconnection process. Please note that the specifications have been separated on three conditions of operations – general requirements, response to abnormal conditions, and power quality.

General requirements:

- **Voltage Regulations –** The distributed resources shall not actively regulate the voltage at the point of interconnection.

- **Synchronization –** The distributed resource synchronised with electric system shall not cause a voltage fluctuation at the point of interconnection greater then ±5 percent.

- **Monitoring Provision** – Each distributed resource of 250 kVA or more at a single point of interconnection shall have provisions for monitoring its connections status, real power output, reactive power output and voltages at the point of interconnection.

- **Isolation Device** – As per CEA Regulation 2013, there must be a manually operating isolating switch between distributed generation resource and electric system, which shall meet following requirements:

    - Allows visible verification that separation has been established
    - Indicates clearly the closed and open positions
    - Be capable of readily accessible and be capable of being locked in open position
    - May not be rated for load-break
    - Be located at height of 2.44 m above ground level

Interconnect integrity

- Interconnection system shall have the capability to withstand electromagnetic interference
- Paralleling device shall withstand 220 percent of interconnection system rated voltage
- Interconnection system shall have the capability to withstand voltage and current surge (in accordance with the environments defined in IEEE Std. (C62.41.2 – 2002 or IEEE Std. C37.90.1 – 2002)

Response to abnormal conditions:

- **Voltage –** Inverter must have over and under voltage trip functions if voltage reaches above 110 percent or below 80 percent respectively with clearing time up to two seconds.

- **Frequency –** Inverter must have over and under frequency trip functions if frequency reaches 50.5 Hz and below 47.5 Hz with a clearing time of 0.2 seconds.

- **Islanding –** Inverter must have function to prevent formation of unintended island, and cease to energise the electricity system within two seconds.

Power quality:

- **Limitation on DC injection –** The rooftop solar and its interconnection system shall not inject dc current greater than 0.5 percent of the full rated output current.

- **Limitation of flicker –** The distributed resource shall not cause objectionable flicker on the electric system (IEC 61000).

- **Harmonics –** The distributed resource shall not inject harmonic current greater than 5 percent (in some cases state regulators have limited this to 3 percent) at the electric system (IEEE 519).

Interconnection voltages

In India, the State Electricity Regulatory Commissions (SERCs) specify and regulate the interconnection voltages for connecting rooftop solar PV to grid.

The specifics and technical details of connecting voltage requirements might vary from state to state. A general guideline on rated capacity and connecting voltages are summarized in Table 5. These capacities usually fall under grid codes of respective states.

System Capacity	Connecting Voltage
Less than 4 kW (or 5/6/7/10 kW in some states)	240 V_{AC}, 1φ, 50 Hz
More than 4kW (or 5/ 6/7/10 kW in some states) but less than 50 kW (or 75/100/112 kW in some states)	415 V_{AC}, 3φ, 50 Hz
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)	11 kV_{AC}, 3φ, 50 Hz

Table 5: System capacity and connecting voltage:

Interconnection parameters

The grid is a complex system comprising various electrical and magnetic properties associated with an AC electrical supply system. Traditionally, the grid has been used to transmit power produced at centralized generation plants, and already has established norms and performance standards for power quality, safety and service.

The introduction of grid-connected rooftop solar PV systems creates multiple power injection points within the electrical supply system, thus exposing the grid to the risk of destabilization in the event of lack of interconnection guidelines and standards.

The interconnection process, therefore, needs to comply with the established standards regulating various electrical supply parameters. This is to ensure the safety, quality and stability of the grid.

The relevant electrical supply parameters, their prescribed standards and requirements within those standards have been listed in Table 6.

Parameter	Reference	Requirement
Overall conditions of Service	State Distribution/Supply Code	Reference to State Distribution Code
Overall Grid Standards	Central Electricity Authority (Grid Standard) Regulations 2010	Compliance
Equipment	BIS/IEC/IEEE	Compliance
Meters	Central Electricity Authority (Installation & operation of meters) Regulation 2006 Amendments thereof, OERC Generic Tariff Order 2013	Compliance
Safety and Supply	Central Electricity Authority (measures of safety and electricity supply) Regulations, 2010	Compliance
Harmonic Current	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	Harmonic current injections from a generating station shall not exceed the limits specified in IEEE 519
Synchronization	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	RTPV System must be equipped with a grid frequency synchronization device. Every time the generating station is synchronized to the electricity system. It shall not cause voltage fluctuation greater than +/- 5% at point of connection
Voltage	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	The voltage operating window should minimize nuisance tripping and should be under operating range of 80% to 110% of the nominal connected voltage. Beyond a clearing time of 2 seconds, the RTPV System must isolate itself from the grid.
Flicker	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources)	Operation of Rooftop Solar PV System should not cause voltage flicker in excess of the limits stated in IEC 61000

	Regulation 2013	standards or other equivalent Indian standards, if any.
Frequency	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	When the Distribution system frequency deviates outside the specified conditions (50.5 Hz on upper side and 47.5 Hz on lower side), There should be over and under frequency trip functions with a clearing time of 0.2 seconds.
DC Injection	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	RTPV System should not inject DC power more than 0.5% of full rated output at the interconnection point 1% of rated inverter output current into distribution system under any operating conditions
Power Factor	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	While the output of the inverter is greater than 50%, a lagging power factor of greater than 0.9 should operate.
Islanding and Disconnection	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	The RTPV System in the event of fault, voltage or frequency variations must disconnect itself within IEC standard stipulated period.
Overload and Overheat	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	The inverter should have the facility to automatically switch off in case of overload or overheating and should restart when normal conditions are restored
Paralleling Device	IEEE 519 CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulation 2013	Parallel device of RTPV System shall be capable of withstanding 220% of the normal voltage at the interconnection point.

Table 6: Interconnection parameters

Component inspection checklist

A sample checklist which can be used to validate the components used within the grid-connected rooftop solar PV installation at an interconnection inspection schedule is provided below. The checklist is a guide only and can be amended to suit an organization‘s specific requirements.

Sr. No.	Item Type	Yes	No
1	Installation Layout – is it as per drawing?		
2	Inverter IEC standard qualified		
3	PV Panel IEC standards qualified		
4	PV Isolators/ PV cables IS/IEC standards qualified		
5	AC disconnect manual switch provided with locking arrangements		
6	Meters approved by concerned authority		

Table 7: Component inspection checklist

Grid connected functional safety checklist

A sample checklist, which can be used to validate the functionality of components used within the grid connected rooftop solar PV installation during an interconnection inspection is provided in Table 8. The checklist is a guide only and can be amended to suit an organization‘s specific requirements.

Sr. No.	Item Type	Yes	No
1	Check whether solar generation stops automatically when the distribution company (DISCOM) supply shuts off (procedure detailed below)		
2	Confirm Bi-directional flow recorded on net meter		
3	Check ‘Consumption (Import) only’ mode operation		
4	Check operation of Solar (Generation) meter		
5	Check all Protections and Earthing points		
6	Confirm Solar and Bi-directional meter tested & sealed by DISCOM meter testing lab		
7	Confirm the manual isolating switch is installed at accessible location and is with locking arrangement		
8	Check whether manual isolating switch stops feeding supply in grid when in OFF position		

Table 8: Grid-connected functional safety checklist

Interconnection test specification and requirements

After completion of the grid interconnection process, testing and approval of the interconnection circuits is required to ensure that they are adhering to the technical specifications of relevant standards. Tests are done on the following points of the interconnection system:

- **Isolation device** – A system design verification shall be made to ensure that the requirements have been met.

- **Monitoring provision** – A system design verification shall be made to ensure that the provisions for monitoring are in accordance with the requirements.

- **Grid fault** – A system design verification shall be made to ensure that in case of grid fault the solar inverter shall cease to energize the grid to which it is connected.

- **Grounding integration with grid** – A system design verification shall be made to ensure that solar inverter shall not cause over voltage and shall not disrupt the coordination of the ground fault protection connected to the grid.

Commissioning tests

Commissioning tests are critical to ensure proper working of the system. The parameters of a well-managed commissioning test are:

- All commissioning tests shall be performed based on written test procedures of equipment manufacturer/system integrator.

- A visual inspection shall be made to ensure that the system earthing is adequate as per standard/regulation.

- A visual inspection shall be made to confirm the presence of the isolation device as required by standard/regulation.

- The following initial commissioning tests shall be performed on the installed solar system and grid-connected inverter prior to the initial parallel connection to the grid.

    - Operability test on the isolation device
    - Unintentional-islanding functionality
    - Cease to energize functionality

Unintentional islanding functionality test

Unintentional islanding can have undesirable impacts on customer and utility equipment integrity. If the unintentional island is sustained for a significant period of time, personnel safety could become a cause for concern. Even if the unintentional islanding period is short, the potential degraded power quality could still be a concern. For these reasons, the risk of unintentional islanding must be kept low. To manage these risks, a series of functionality tests are required.

- This test must be conducted during noon time in a sunny day.
- PV system shall produce more than 20 percent of the rated output of the PV array or the inverter – whichever is less.
- If there is more than one inverter, tests should be carried out for each inverter.

Test 1: Inverter must cease supplying power within two seconds of a loss of mains

STEP 1: Keep DC supply from the solar array connected to the inverter.
STEP 2: Place the voltage probe in the inverter side of the AC main switch.
STEP 3: Turn OFF the AC main switch through which inverter is connected to grid.
STEP 4: Measure the time taken for the inverter to cease attempting to export power with a timing device and record.

Test 2: Inverter must not resume supplying power until mains have been present for more than 60 seconds.

STEP 1: Keep DC supply from the solar array connected to the inverter.
STEP 2: Place the current probe in the inverter side of the AC main switch.
STEP 3: Turn ON the AC main switch through which inverter is connected to grid.
STEP 4: Measure the time taken for the inverter to re-energise and start export power with a timing device and record.

Periodic interconnection tests

- All interconnection-related protective functions shall be periodically tested at intervals specified by the manufacturer, system integrator or the authority that has the jurisdiction over the SRTPV interconnection.

- Proper record of periodic test reports shall be maintained.

CHAPTER 6: ROOFTOP SOLAR PV BUSINESS MODELS

Business Models for Grid-connected Solar PV

A business model, in simple terms, can be described as an interaction of business activities, vendors, customer, cost and revenue streams, through which a company "makes money." Typically, development of the rooftop solar PV market across the globe has taken the following routes:

1. **Utility driven solar project development:** These projects are typically on Megawatt (MW) scale, and can be either constructed on land or on rooftops. One of the key drivers for developing these projects is the Renewable Purchase Obligation (RPOs) requirement, legislated in many countries to create a market for RE.

   These projects can either be developed by utilities themselves or by third parties. The project generates revenue typically from long term power purchase agreements, usually entered with state or central power authorities.

2. **Customer driven solar project development:** This term is typically used for small-scale projects which are developed by consumers on their own rooftops. This model is more common currently in the Indian solar rooftop marketplace. The rooftop solar plant in this model can either be owned outright by the customer or owned by the installer and leased to the customer.

   These projects are driven by declining costs of solar energy, availability of financial incentives such as feed-in-tariff (FiT), subsidies, tax rebates and increase in the cost of grid-based electricity.

   Revenue in this model is either through the sale of engineering, installation and maintenance services to customer, or long term power purchase agreements of solar lease at a rate agreed between the company and the consumer.

Several hybrids of the above routes have emerged in specific markets, depending on the regulations, market opportunities and role of intermediaries.

These project development models have been summarized in Figure 54.

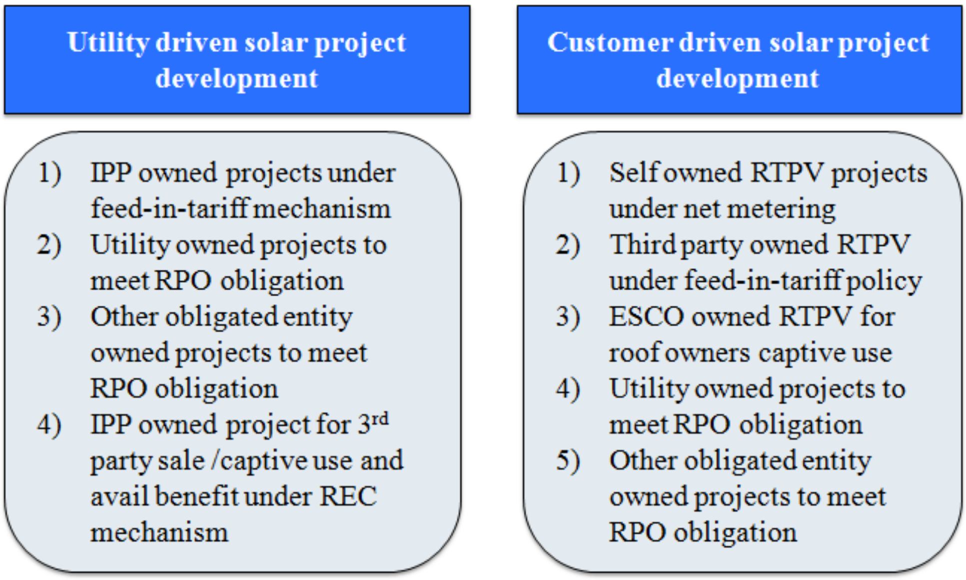


Figure 54: Rooftop solar power program implementation model

Customer Side Business Model – Options, Interface, Variations

The customer side business model is essentially commissioned in two ways: self-owned and third party-owned.

In case of the self-owned business model, the end user of solar energy is responsible for financing and selection of service providers to install a rooftop solar PV system on their property. The project developer or system integrator gets revenue from direct sale and/or operation and maintenance of the system over a suitable period of time.

In the case of a third party-owned business model, as the name suggests, a third party, who is 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 electricity which may be sold to the utility or to the rooftop owner. Typically, this transaction is done through the following agreements:

- Solar Leasing – The rooftop owner signs a lease agreement with third party, under which the rooftop owner agrees to make a monthly lease payment to the third party over a mutually agreed period of time. Electricity generated by the solar PV system is used by the consumer, resulting in reduction in the amount of electricity purchased from main grid. The monthly lease repayments are fixed, and do not depend on the amount of electricity produced by the system.

  The ownership of the solar rooftop system remains with the third party until the end of the lease period, after which, the rooftop owner as the option to purchase the PV system, extend the lease agreement or remove the system from the roof.

The project developer or system integrator gets revenue from the steady cash flow in form of lease rental and also benefits from government incentives such as tax credits and deprecation benefits.

The underlying requirement for success of this model is that the cost of monthly lease rental should be less than the savings generated from reduced electricity bills of the customer.

- Solar Power Purchase Agreement (PPA) – This model is fundamentally similar to solar leasing, except that the repayments are tied to the amount of electricity generated from the system. Consequently, the project developer or system integrator also takes over the operation, maintenance and monitoring of the system to ensure that it is performing optimally as a poor performing system will create a loss of revenue.

  Revenue is generated in this model through sale of electricity at the rates which match the grid, and also benefits from government incentives such as tax credits and deprecation benefits.

Revenue from the aforementioned business models also depend on the design parameters of solar PV system, consumption profile of the user and prevailing metering regime.

For example, if gross metering scheme is available in the project location, the system can be designed to leverage additional revenue from sale of surplus electricity to the utility.
In case of net metering scheme, the system may be sized to meet maximum possible self-consumption and avoid export altogether, as it will not be a cost effective design. However, there still may be periods of export, such as on weekends or holidays when the facility operation is closed.

In situations where design priority is to create 100 percent self-consumption, with no export to the grid, a captive generation plant is installed. This can work with or without grid interconnection; however, the later will require a battery bank, which increases the cost of ownership of solar PV system.

The parameter and variations discussed in the above section is summarized in Table 9.

Parameter	Variations	Explanation
Project Ownership	• Self-owned • Third party-owned	The system can be owned by the customer, purchased outright, or, owned by a third party, who will sell services to customer in form of solar lease or PPAs.
Type of metering	• Without Grid Feed • Net Metering • Gross Metering	Subject to the available rooftop area and energy demand, the solar PV system can either be sized entirely for self-consumption (captive) i.e. no feed to the grid, or, if schemes like net metering and gross metering are available, the customer can export excess electricity to grid. The exported electricity may attract a higher export tariff under gross metering scheme, or can be credited against electricity imported from the grid in case of net metering scheme.

Parameter	Variations	Explanation
Type of rooftop	• Individual • Third party or utility • Combined	The system can be installed entirely on owner's rooftop, of a third party rooftop or a combination of the two.

Table 9: Various rooftop PV business models

The business models characterized and shown in the sections above are intended to capture the most basic types. For each of the models described, variations exist in the market.

Some of the most popular examples within the customer-side solar PV business model are listed in Table 10.

Type of customer side business model	Example
Self-owned; Without Grid Feed (captive) and Individual roof	Early solar PV system offerings in the Indian marketplace
Self-owned; Net metering and Individual roof	Japanese Rooftop Solar PV Net metering model
Self-owned; Gross metering and Individual roof	German Rooftop Solar PV feed-in-tariff model
Third Party-owned Rooftops with Captive Consumption – No Grid Feed	SunEdison-Walmart Rooftop Solar PV project
Third Party-owned Rooftops; Net metering and individual roof	California Rooftop Solar PV leased system for residences
Third Party-owned Rooftops; Gross metering and combined roof	Pilot project under Gandhinagar Rooftop Program

Table 10: Customer rooftop PV business models

A summary of the characteristics, variations and options of the customer side business model is further illustrated in Figure 55. Each of the examples provided within the customer side business model are further illustrated and discussed in the following sections.

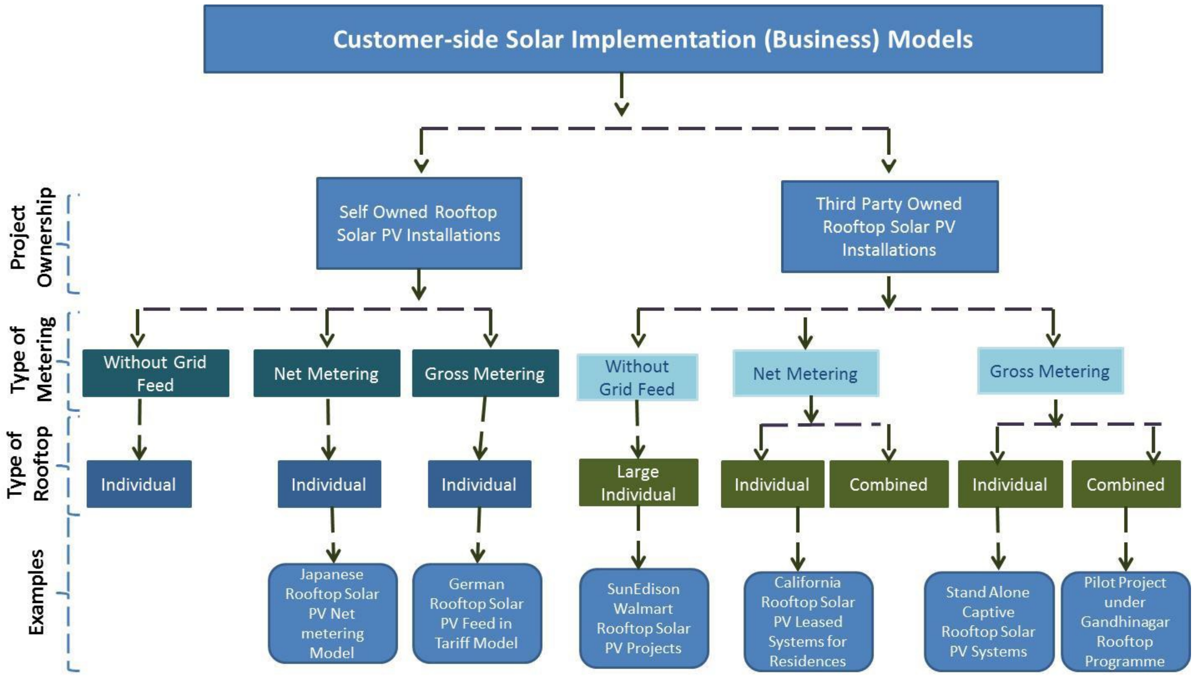


Figure 55: Customer-side solar business models

Self-owned; Net Metering and Individual Roof

Similar to the earlier process diagram, this diagram shows the flow of values and key transactions between the main stakeholders in its most basic configuration. Variations of this basic model are found in the market.

The key difference here is the presence of a stable grid, which in turn avoids use of a battery or diesel generator backup in the system architecture, leading to lower installation costs. This project is commissioned under a net metering scheme, where the consumer is billed on the net amount of electricity imported from the grid, after adjusting self-consumption and occasional export.

This is still a first generation business model, where the rooftop owner generally manages the various aspects of the installation and commissioning process such as, appointment of EPC (Engineering, Procurement, and Construction) Contractor, sourcing finance, interconnection with the utility, coordinating application process for the rebates and other incentives and potential sale of Renewable Energy Certificates (RECs).

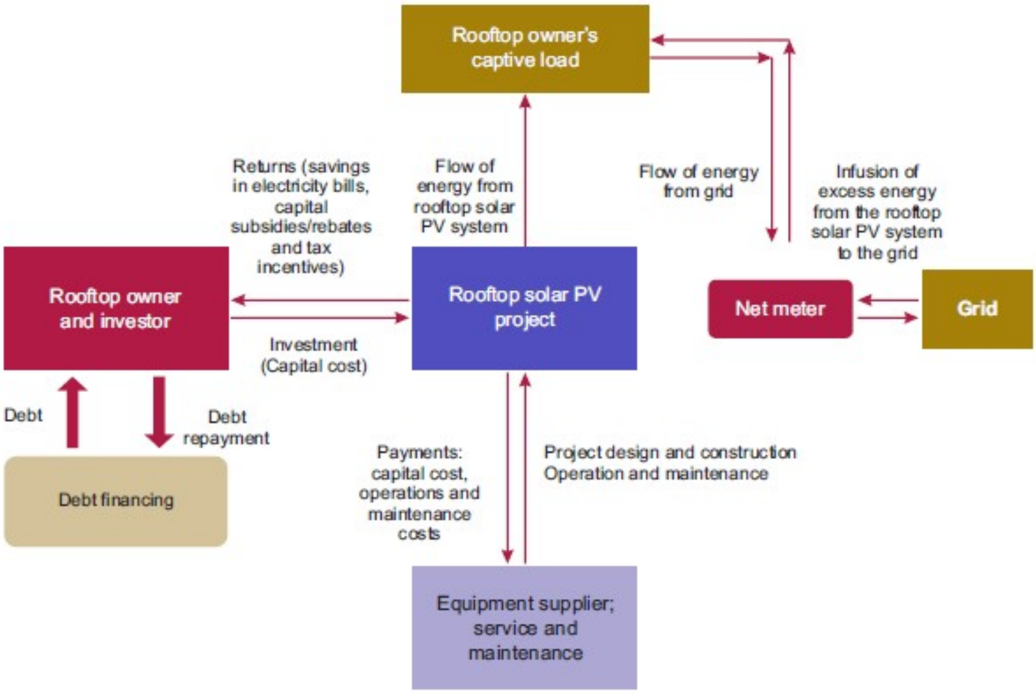


Figure 56: Self owned; Net metering and individual roof

Self-owned; Without Grid Feed (captive) and Individual Roof

The process diagram for the customer-side self-owned; captive and individual roof model is shown in Figure 57. The diagram shows the flow of values and key transactions between the main stakeholders in its most basic configuration. Variations of this basic model are found in the market.

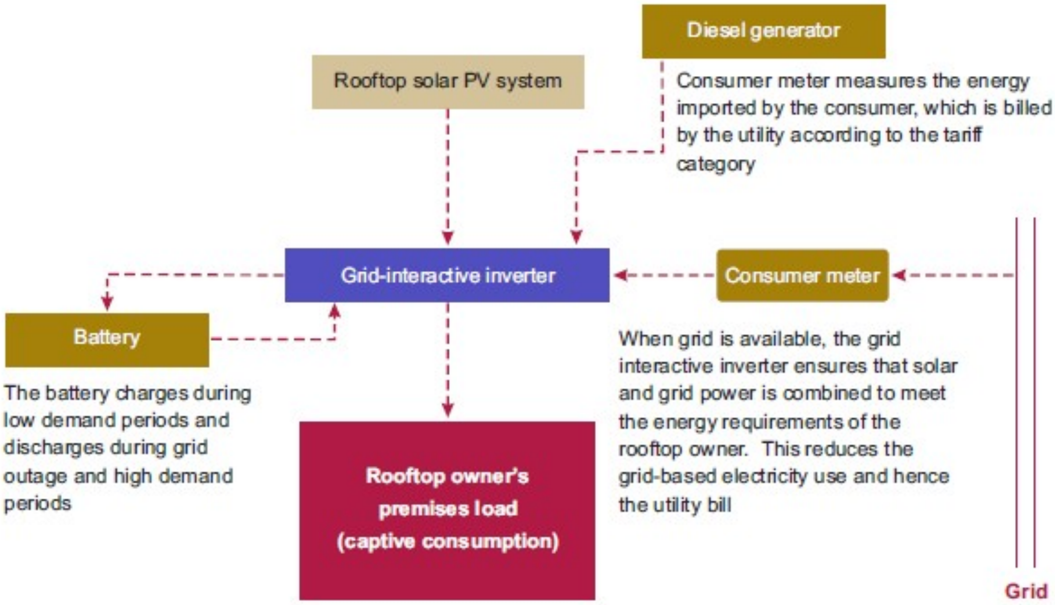


Figure 57: Self-owned; Without Grid Feed (captive) and Individual roof

Self-owned; Gross Metering and Individual Roof

The relationships and workings within this model are very similar to the one described above, except that the project is commissioned under gross metering mechanism. In this case, the consumer may be paid a premium tariff for the electricity which has been exported to the grid.

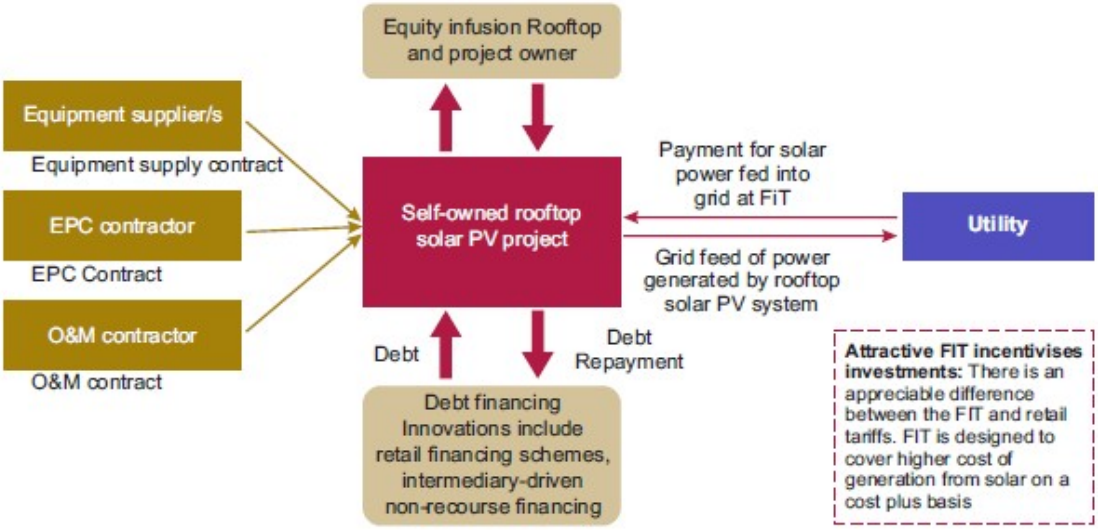


Figure 58: Self-owned; Gross metering and individual roof

Third Party-owned Rooftops with Captive Consumption – No Grid Feed

For the third-party-owned model shown in Figure 59, the most striking difference with the previous models shown is the third-party as the central player, managing all aspects of the installation and then taking on the long-term ownership, operation, and maintenance of the system. The end-user is involved by way of providing roof space and purchasing the electricity that is generated from the system.

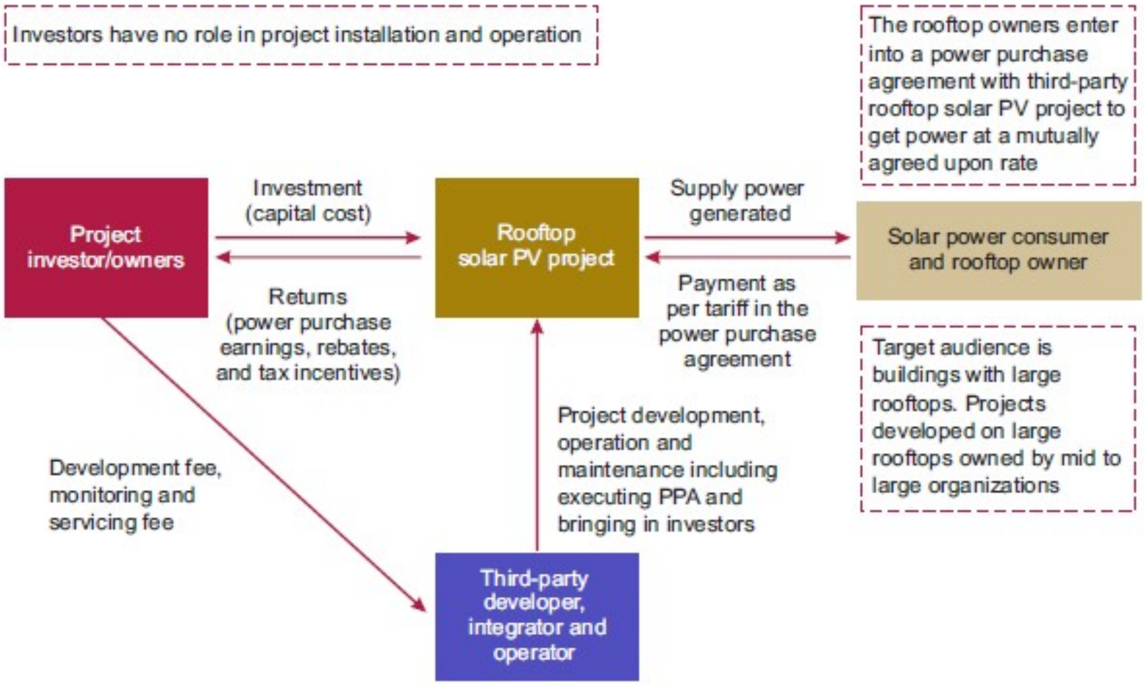


Figure 59: Third party-owned rooftops with captive consumption

Third Party-Owned Rooftops; Grid Feed and Combined Roof

The mechanisms of this model are similar to the one previously described, except that this model is commissioned under a metering scheme (Gross or Net).

Also, the rooftops can be sourced from a combination of sources, such as either at the property where energy consumption will be taking place, or leased from other property owners, different from the site of energy use.

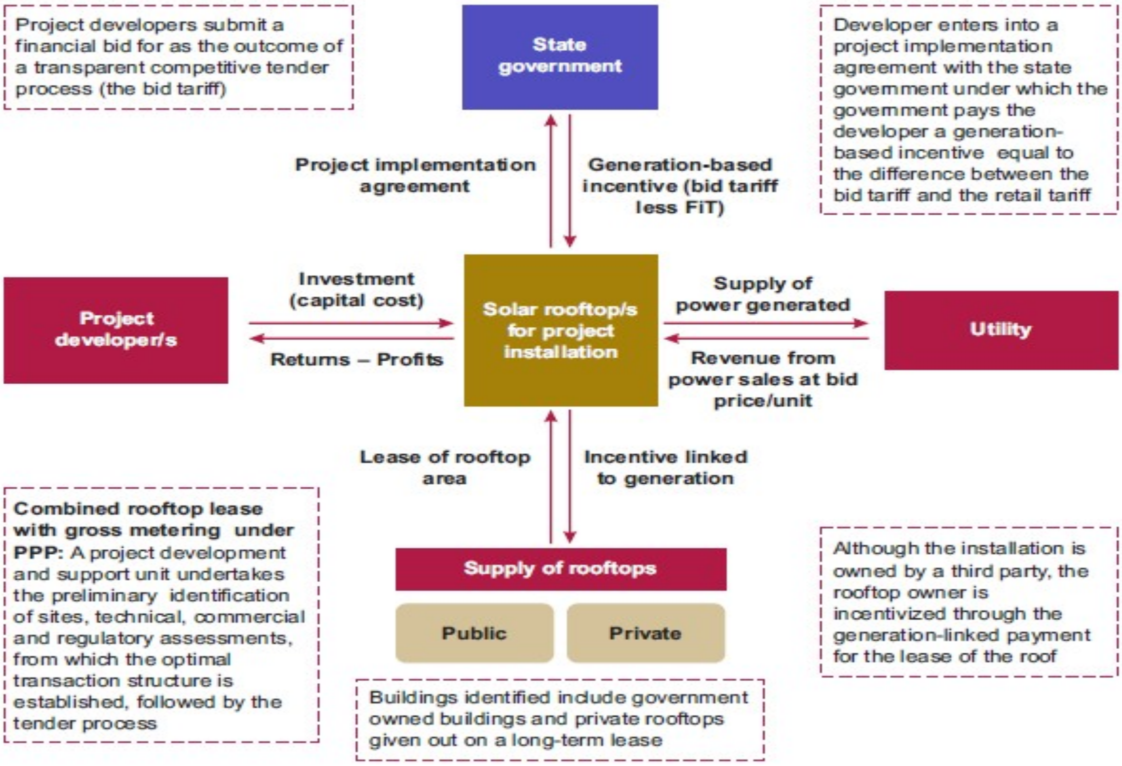


Figure 60: Third party-owned rooftops; Grid feed and combined roof

Customer Side Business Model – Case Study, Gandhinagar

In 2014, the Government of Gujarat commissioned a 5 MW rooftop solar PV project in Gandhinagar (initiated in 2010). The project was based on the third party-owned rooftop model, as illustrated above. A 25 year concession was issued to two private companies, which were selected to install solar PV panels on the rooftops of selected public buildings (80 percent of the installed capacity) and private residences (20 percent).

The developers were responsible for installing the panels, connecting them to the grid, and injecting the power generated from these panels into the grid. In turn, the firms received a feed-in tariff (FiT) determined during the bid process. The project was commissioned under the gross-metering mechanism, where the entire amount of power generated is supplied directly to the local grid at declared FiTs.

The participating roof owners were also paid a minimum generation-based incentive as specified by the Government of Gujarat.

The operational mechanism of the Gandhinagar case study is illustrated in Figure 61.

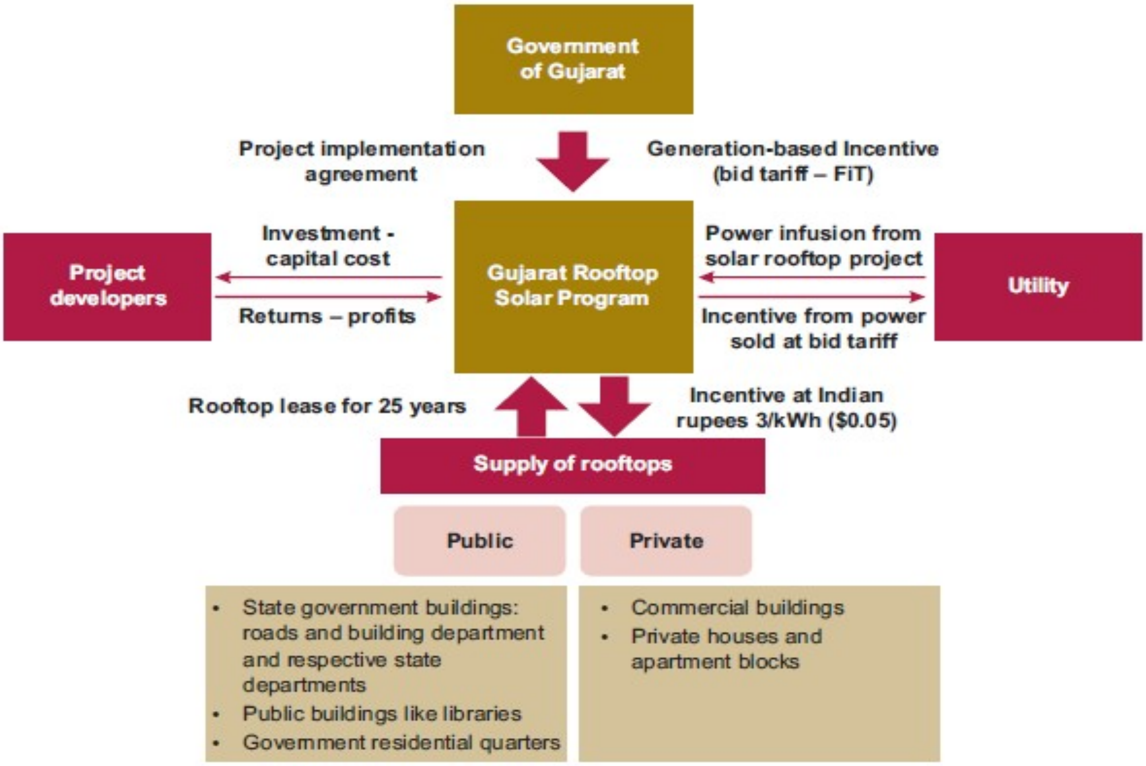


Figure 61: Customer side business model – Gandhinagar model

Utility-based Business Models

The utility-based business models are characterized by a greater level of involvement from the utilities, compared with the customer side business model as discussed earlier. It looks very similar to the third party-owned business models in terms of process flow.

In this model, the utility turns into the central player, managing all aspects of the installation and then taking on the long-term ownership, project financing, operation, and maintenance of the system. The end-user is involved by way of providing roof space and purchasing the electricity that is generated from the system. It can also happen that the utility leases rooftop from a third party, sells electricity to the end user, and pays rent to the roof owner, similar to the Gandhinagar model, described above.

Similar to the other business models, variations of its basic model can be found in the market. Few of the possible variations and their examples have been illustrated in Figure 62.

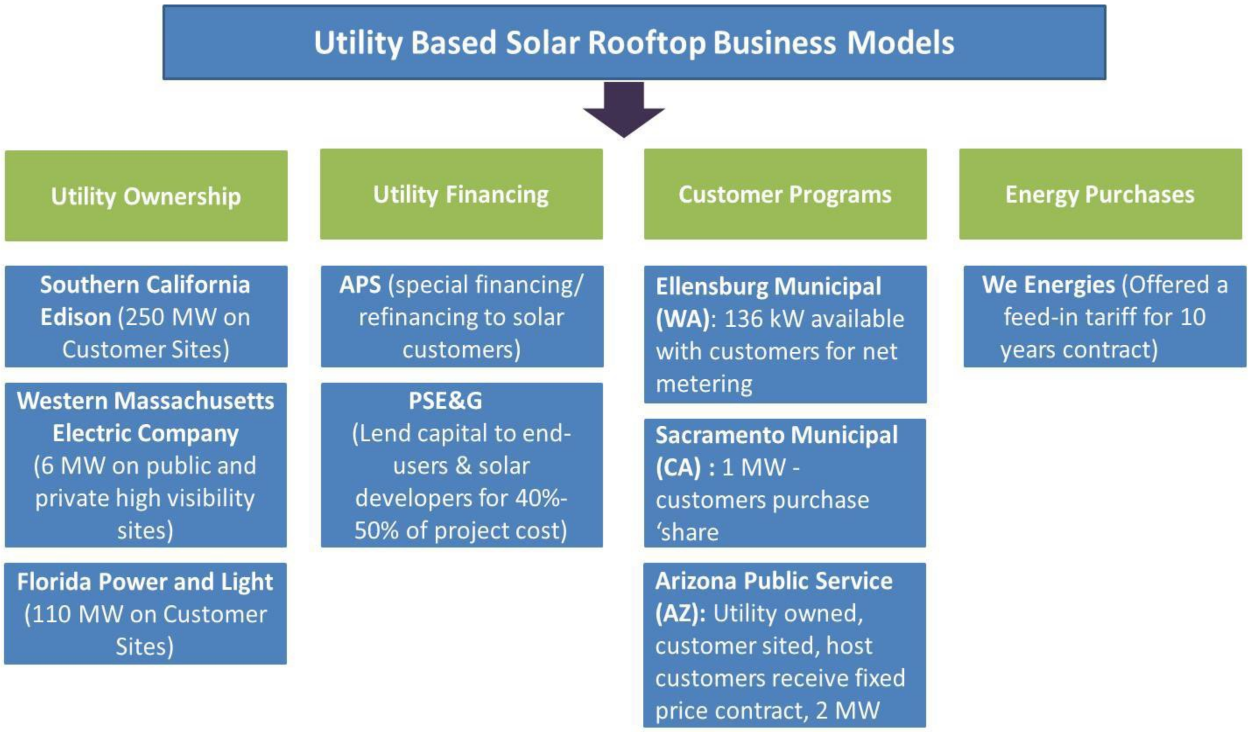


Figure 62: Utility based business models

Community-based Business Models

The community business model is very much similar to the utility-based model, except that a community group or cooperative takes the role of a utility here.

The financing usually comes from a community cooperative and a third party developer takes on the long-term ownership, operation, and maintenance of the system. The end-user is involved by way of providing roof space for a rent as well as purchasing the electricity that is generated from the system.

Electricity produced from the solar PV plant is traded between the participants through the principle of Virtual Net Metering (VNM). The VNM concept allows a household or business to receive the net metering credits equal to the amount of electricity generated by their share of investment in the community-owned solar PV plant. These credits are applied to the customer's electricity bills usually received from the utilities. For example, every unit (kWh) of electricity generated by the community solar farm will effectively reduce the participant's power bill on a one-for-one basis. If the participant's share in a 100 kW plant produces 5 kWh of electricity on a given day, they will receive 5 kWh of solar net metering credits on their power bill.

A basic representation of the community based business model is illustrated in Figure 63.

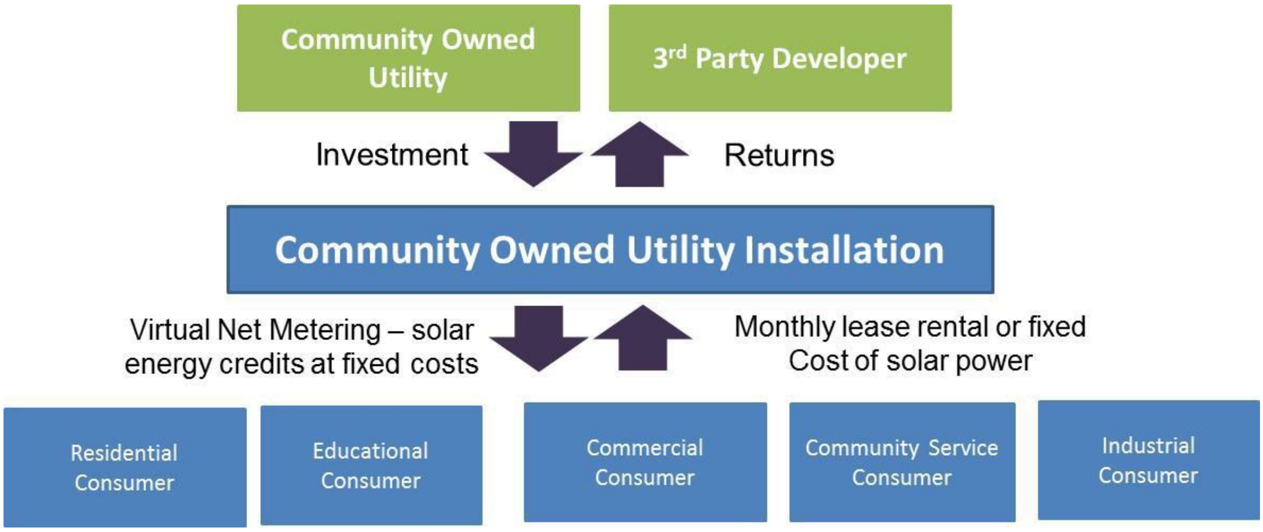


Figure 63: Utility-based business models

Comparing Business Models – Self-owned vs. Third Party-owned, Revenue

Each of the aforementioned business models is unique in the way it delivers value to the end user. A comparison of these business models and associated value propositions is summarized in Table 11.

As can be seen, projects with gross metering or large rooftops are generally more attractive to investors.

Implementation Model	Sub-model	Metering	Feed-in-tariff	High retail tariff	Tax rebates & incentives	Time-of-day metering	Suitability for project financing
Self-Owned	Captive with no grid feed	Not Mandatory		□	□	□	
	Grid feed (gross metering)	Gross	□				□
	Grid feeding (Net metering)	Net		□	□	□	
Third party owned	Large rooftops with no grid feed	Not Mandatory		□	□	□	□
	Leased systems with grid feed (net metering)	Gross		□	□	□	
	Combined leased rooftops with feed into the grid (gross metering)	Net	□				□

Table 11: A comparison of business models

Figure 64 provides further examples on the type of third party solar projects, potential consumers of power generated from the projects, and revenue sources for project developers. Long term PPAs are one of the most used instruments of generating revenues. Other sources of revenue are RECs needed for RPO compliance.

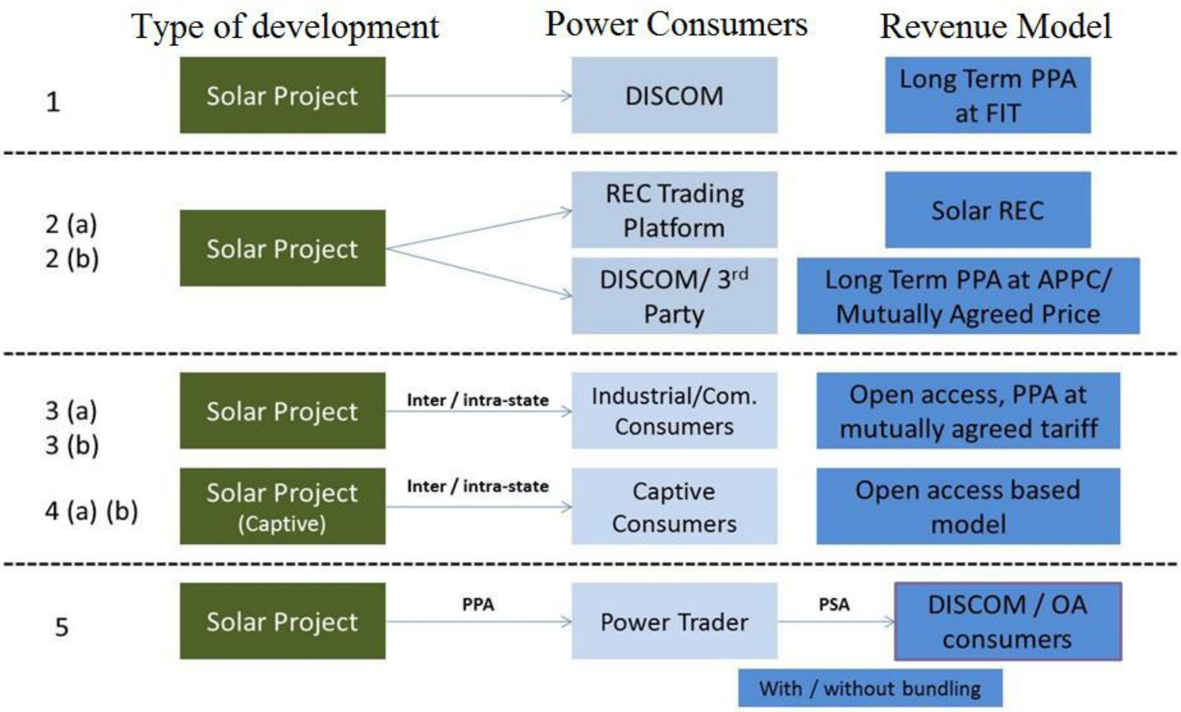
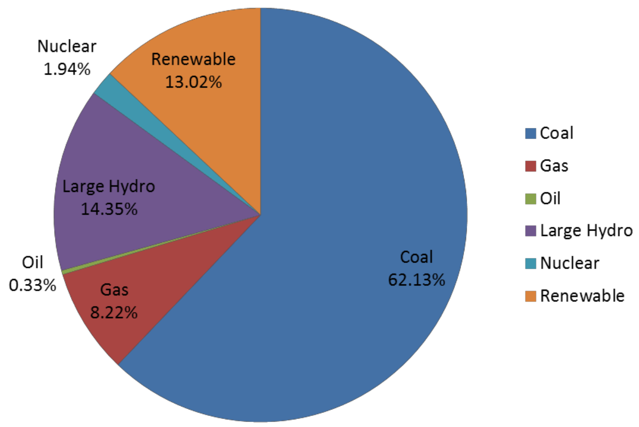


Figure 64: Utility-based business models

CHAPTER 7: POLICY & REGULATORY FRAMEWORK AND INCENTIVES

India's Energy Scenario

RE, excluding large hydropower, is approximately 13 percent of the total energy mix in India, while fossil fuel based sources account for almost 70 percent of total sources of generation.



Installed Capacity by source(MW)	
Total Thermal	210675
Coal	185172
Gas	24508
Oil	994
Large Hydro	42783
Nuclear	5780
Renewable	38822
Total	298059

Installed Capacity by sector(MW)		% Share
State Sector	101761	34%
Central Sector	76297	26%
Private Sector	120003	40%
Total	298060	100%

***As per CEA March 2016 Report**

Figure 65: Share of RE in Indian power sector

Of all forms of RE in India, solar PV technology has received a great level of interest from the government and private sectors as one of the solutions to India's energy challenges. Solar energy currently accounts for only about 15 percent of India's installed RE capacity, and has a vast potential for growth.

Another important driver of promoting distributed energy sources such as rooftop solar PV projects is to reduce the power deficit facing the growing economy of India. According to an executive summary report published by the CEA, India is facing the power supply deficit of 1.5 percent and peak demand deficit of 1.7 percent, as of March 2016.

Legal and Institutional Framework for RE In India

The energy sector, including RE, is on the concurrent list in India. It means that both the central and state governments share responsibilities in managing this sector at the levels of policy, regulation, program and implementation. Within the legal and institutional framework for the RE deployment, including solar PV, different central and state government organizations are responsible for the following activities:

- Framing of law and policies to create market for RE
- Formulation of regulations to facilitate deployment of RE programs

- Implementation of policy on-ground realization on projects
- Implementation of REC trading for RPO compliance
- Scheduling of energy dispatching across the national grid system and ensure that grid stability in not compromised

A summary of these responsibilities and the relevant central and state government institutions are provided in Figure 66.

Law and Policies	**Central**:Ministy of Power, Ministry of New and Renewable Energy **State**: State Energy Departments
Regulations (National)	**Central**: Central Electricity Regulatory Commissions **State:** State Electricity Regulatory Commissions
Policy Implementation	**Central:** Solar Energy Corp. of India, Solar Energy Centre **State:** State Nodal Agencies
REC Mechanism Implementation	**Central:** National Load Dispatch Centre (NLDC) **State:** State Nodal Agencies
Scheduling	**Central:** National Load Dispatch Centre **State:** State Load Dispatch Centre

Figure 66: Legal and institutional framework for deployment of RE

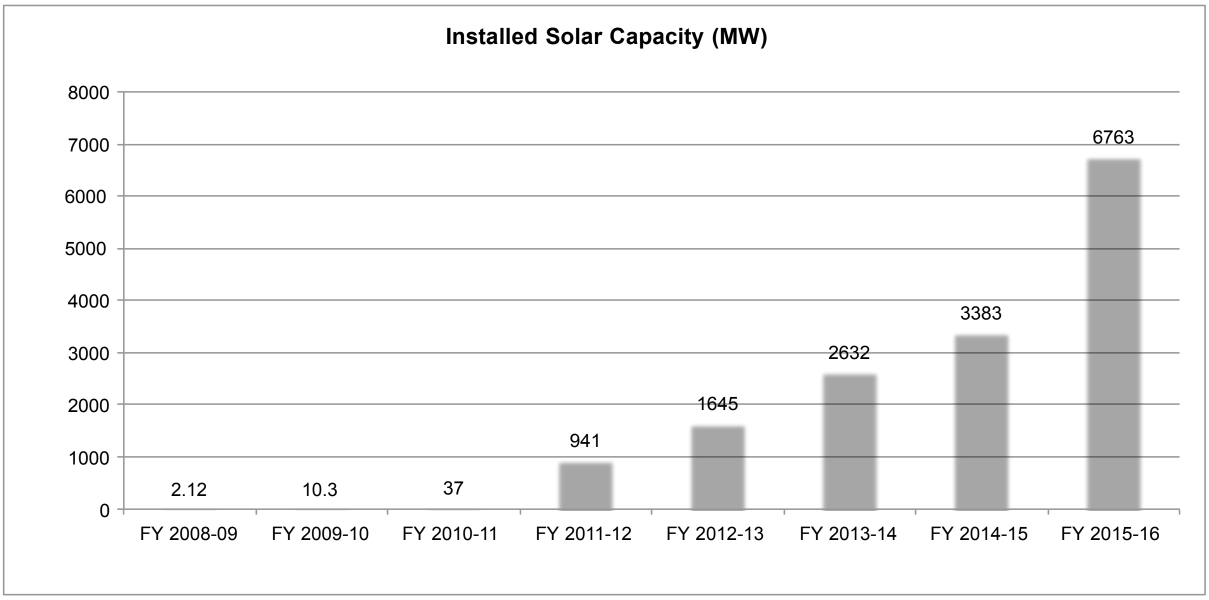
Evolution of Solar Power Market in India

India's solar market, especially solar PV, has seen significant growth after the launch of the Jawaharlal Nehru National Solar Mission in 2010, with an installed capacity of over 6 GW in just six years. The Government of India is determined towards achieving 100 GW of interactive solar power capacity by 2020, of which 40 GW would be deployed through decentralized and rooftop-scale solar projects.

Use of solar power as a supplementary source to traditional grid-based electricity is relatively recent in India. The Generation-based Incentive (GBI) scheme, announced in January 2008, was the first step by the government to promote installation of grid-connected solar power plants.

Additionally, in 2008, the Indian Government announced the National Action Plan for Climate Change, which also marked the commencement of National Solar Mission (NSM). The NSM set national and state level targets, and provided policy guidelines and financial incentives to support the growth of solar power in India. The states also followed this up by progressively rolling out their own solar policies and RE regulations.

Under the NSM, the installed capacity of solar power in India has propelled from just over 2 MW in 2009 to 2632 MW in 2014. As on March 31, 2016, this capacity has swelled to 6,763 MW.



Source: Ministry of New and Renewable Energy, Government of India

Figure 67: Installed solar capacity (MW) in India

Solar PV Policy and Regulatory Initiatives from Key Indian States

The solar energy sector is slowly picking with the involvement of an increasing number of states in India. A collection of solar PV policy and regulatory initiatives from some of the key Indian states is provided in Table 12.

Key Initiatives / State →	Andhra Pradesh	Karnataka	Madhya Pradesh	Tamil Nadu
Solar tariff Order	✗	✓	✓	✓
Solar RPO Regulations	✓	✓	✓	✓
REC Framework	✓	✓	✓	✓
RPO Compliance Monitoring	✗	✗	✗	✗
Concessional OA charges	✗	✓	✓	✓
Banking	✓	✓	✓	✓
Net Metering Framework	✓	✓	✗	✓

Table 12: Solar policy and regulatory initiatives in key Indian states

Solar Rooftops - Governing Regulatory framework

As highlighted earlier, both the central and state governments' institutions share responsibilities in governing the solar PV sector in India. A summary of the governance level, relevant institutions and their respective regulatory orders is provided in Table 13.

<table>
<tr><th>Governance Level</th><th>Governing Bodies</th><th>Regulatory Order</th></tr>
<tr><td rowspan="3">Centre</td><td>Forum of Regulators</td><td>• Draft Model Regulations for grid-tied rooftop solar-based on Net Metering, (August 2013)
• Model Regulations on Forecasting, Scheduling and Deviation Settlement of Wind and Solar Generating Stations at the State level</td></tr>
<tr><td>Central Electricity Authority</td><td>• Technical Standards for connectivity of Distributed Generating Resources, Regulations, 2013
• Installation and Operation of Meters, Regulation 2006 (2nd amendment 2014)
• Measures of Safety and Electricity Supply, Regulations, 2010</td></tr>
<tr><td>CERC</td><td>• REC regulations and RE Tariff Regulations for renewable energy</td></tr>
<tr><td>State</td><td>State Electricity Regulatory Commission (CERC)</td><td>• Net Metering regulations, Solar tariff order, RPO regulations, State Metering Regulations, State Supply Code, Grid code (Over the past one year around 16 SERCs have issued regulations for solar rooftop in their jurisdiction.)</td></tr>
</table>

Table 13: Solar rooftop – governing regulatory framework

Successful development of rooftop solar PV technology into a mature and established market requires a multilateral, coordinated approach, engaging and working with interest of all the stakeholders adopted the technology, in presence of a strong policy and regulatory framework, incentive structures and implementation framework.

Together, they should be able to communicate the overall goals of the rooftop solar PV program, provide incentives or other forms of support to develop the solar PV market into a mature stage, establish mechanisms for settlement of these incentives and enable proper interconnection process to ensure contribution of grid-connected solar rooftop systems in the distribution system.

A summary of the key regulatory parameters within which the solar PV sector operates in India and their related technical aspects is provided in Table 14. A consistent definition and application of the suggested regulatory parameters at the governance level is critical for the growth of the solar PV market in India.

Regulatory Parameter	Technical Aspects
Metering Mechanism	**Net metering or gross metering**
Eligible Consumer	**The consumer class eligible for installing solar rooftop**
Project Capacity	**The limit (minimum or maximum capacity) of SRTPV allowed under the framework**

Regulatory Parameter	Technical Aspects
Aggregate Capacity	**Cumulative capacity of rooftop solar PV systems connected on the feeder or distribution transformer**
Connection Levels	**The voltage level at which the rooftop solar PV projects will be connected**
Excess Generation	**Quantum of excess generation allowed and the settlement of excess generation**
Settlement Period	**Period for settlement of excess generation i.e. yearly or half yearly**
RPO/REC	**Applicability of RPO and REC on solar energy generated from the SRTPV**
Metering	**Metering provisions, standards, accuracy etc.**
Other Charges	**Applicability of wheeling, banking, cross subsidy, surcharge, etc.**

Table 14: Solar Rooftops – Key Regulatory Parameters for kW scale

Incentives for Solar PV Projects – Central and State Government

The Central and State Governments in India have come up with policies to accelerate the deployment of rooftop solar PV projects. This section provides details of the financial incentives made available by both the center and some of the key state governments.

1. Incentives from Central Government

- **Accelerated Depreciation (AD)**

Accelerated depreciation of 80 percent is available under the Income Tax Act for rooftop solar PV systems. This can provide significant savings to a solar plant developer who has a taxable asset base and has sufficient profits against which the depreciation can be charged. This is illustrated in Table 15.

Item	Rs.
Cost of a 100 kW rooftop solar plant (A)	70,00000
Accelerated depreciation @80%	56,00000
Corporate tax rate	34.61%
Tax saved through depreciation (B)	19,38,160
Net cost of rooftop solar plant (A)-(B)	50,61,840

Table 15: Example of Accelerated Depreciation

- **Viability Gap Funding (VGF)**

In the past 1,000 MW of grid-connected solar power projects by central public sector undertakings (PSUs) and the Government of India organizations would be carried out under various Central/State Schemes/Self-use/Third party sale/Merchant sale with VGF under batch-V Phase-II of the NSM in a span of three years.

Particulars	Description
Target	Setting up of solar power projects with 1,000 MW of solar capacity addition in a span of three years from 2014-15 to 2016-17
Applicability	The PSUs and Government of India organizations
Implementation Agency	Solar Energy Corporation of India (SECI) on behalf of MNRE
Domestic Content Requirements	It is mandatory to procure cells and modules from domestic manufacturers to avail the benefits of the scheme
MNRE support	VGF of Rs. 1 Cr./MW at fixed rate will be provided for projects where domestically produced cells and modules are used. The VGF will be managed and released by SECI on behalf of MNRE for which SECI will be given fund handling fee of 1 percent.
Tariff for sale of Power	No tariff defined. The project developers can have their own PPA agreement and can sell power to third party as well.

Table 16: Eligibility criteria for viability gap funding

Later on, implementation of 2,000 MW of grid-connected solar PV projects was approved under Batch III, Phase II of the NSM with VGF from the National Clean Energy Fund. Recently, in the wake of falling solar tariffs and increasing capacity addition, the Union Cabinet approved setting up 5,000 MW of grid-connected solar PV power projects on a build, own and operate basis under the VGF scheme.

- **Power Bundling**

During Phase 1, NTPC Vidyut Vyapar Nigam Limited (NVVN) sold solar power by bundling it with coal power generated under the unallocated quota.

The bundling reduced the average purchase cost of energy for distribution companies to a rate between Rs. 5.5 per kWh and Rs. 6.0 per kWh. Although considered a success during Phase 1, bundling solar was not continued in Phase 2, Batch 1 guidelines.

Responding to stakeholder feedback, the Phase 2, Batch 2 draft guidelines propose bringing back bundling.

- **Subsidies**

No Central Finance Assistance (CFA) will be provided for commercial and industrial establishments in the private sector as they are eligible for other benefits such as AD, custom duty concessions, excise duty exemptions and tax holiday.

For all other sectors, the CFA will be 30 percent of benchmark cost for general category States/UTs and 70 percent of benchmark cost for special category states i.e., North Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Lakshadweep, and Andaman and Nicobar Islands.

- **Tax Holiday**

This was announced in the budget for the financial year 2014-15. The ten years income tax holiday (section 80 IA) on solar projects has been extended till March 2017.

In addition, companies engaged in the business of generating power from grid-connected solar PV projects should be exempted from payment of Minimum Alternate Tax under Section 115JB of the Income Tax Act.

- **Excise Duty Exemptions**

Machinery equipment which is imported to India and used to manufacture solar thermal components has been exempted from customs duty since July 2014. The products' exempt status was announced by the Finance Minister, on July 11, 2014 during his presentation on the annual Union budget for 2014-15.

It is an amendment to the Central Excise Notification No. 15/2010 dated February 27, 2010. The notification had exempted importers of machinery equipment from paying excise and basic customs duty for solar electricity projects.

- **Custom Duty Concessions**

Custom duty exemption exemptions are available on:

Solar cell/modules: Machinery and equipment required for initial setting up of a solar power generation or solar energy production project.

EVA sheets **and solar back sheets** and specified inputs used in their manufacture and manufacture of PV ribbons.

Solar tempered glass used in the manufacture of solar PV cells and modules; and

Flat copper wire for the manufacture of PV ribbons for use in solar cells and modules.

2. Incentives from Key State Governments

Examples of incentives and power selling mechanisms from few of the state governments in India is summarised in the following tables. More details on the eligibility and workings of these schemes can be sourced from the implementation agencies of respective states.

State: Madhya Pradesh

Project Features	Details
Competitive Bidding	Selection of projects to sell power to DISCOMs will be through tariff-based competitive bidding process.
Sale through REC	For grid-connected projects, there is no capacity limit for sale through REC.
Sale to DISCOM	The Government of Madhya Pradesh will promote setting up of solar power projects for direct sale to MP DISCOMs/MP Power Management Company Ltd. (MPPMC). The total capacity under this category will be as per the RPO targets specified by the Madhya Pradesh Electricity Regulatory Commission (MPERC).
Off-take Arrangement :	
Power Purchase Agreement	This will be signed for projects when the sale is to third party, to DISCOM, captive use, sale through REC and for projects under the NSM.
Sale through REC	The PPA, as required, will be executed between solar power producers and the procurer as per the regulations/orders of the Central Electricity Regulatory Commission (CERC) and/or MPERC.
Sale to DISCOM	Through competitive bidding route
Sale to Third party/outside state	PPA between producer and procurer
Incentives : Madhya Pradesh	
Banking Charges	Banking of 100 percent of energy in every financial year
Electricity Duty	All solar power projects (including captive units) will be eligible for exemption from payment of electricity duty and cess for a period of 10 years from the date of commissioning of the project.
Industrial Grant	The solar projects implemented under this Solar Policy will have the status of industry and will be eligible for all benefits under Industrial Promotion Policy.
Octroi/ entry tax	The equipment purchased for installation of solar power plants under the policy shall be exempted from VAT and entry tax.
Stamp Duty and Registration charges	In case the developer purchases private land for the project, they will be eligible for an exemption of 50 percent on stamp duty.
VAT Refund	The equipment purchased for installation of solar power plants under the policy shall be exempted from VAT and entry tax.
Wheeling and Transmission Charges	Facility of wheeling will be available to all solar power projects through Madhya Pradesh Power Transmission Company/MP DISCOMs, as case may be, as per wheeling charges specified by MPERC.

State: Tamil Nadu

Capacity Target and Period : Tamil Nadu	
Generation Based Incentive (GBI)	500 MW
Rooftop PV and Small Solar	350 MW
Sale through REC	1150 MW
Sale to DISCOM	1500 MW
Off-take Arrangement:	
Sale through REC	REC mechanism promotes trading of solar power to meet RPO. All the obligated entities committed to meet SPO will necessarily have to either produce solar power (captive) or buy solar power from the Tamil Nadu Generation and Distribution Corporation Limited or purchase Solar RE Certificates for an equivalent quantity through the Power Exchange from the promoters who have tradable RE Certificates. Under this mechanism, solar power promoters are eligible to possess one tradable REC wheeled to the DISCOM or to any other licensee.
Incentives : Tamil Nadu	
Banking Charges	The banking charges for wheeling of power generated from the solar power projects, to the desired locations for captive use/third party sale within the state, will be as per the orders of the Tamil Nadu Electricity Regulatory Commission.(NIL)
Electricity Duty	Exemption from electricity tax to the extent of 100 percent of electricity generated from solar power used for self-consumption/sale to utility will be allowed for five years.
Tax Exemption	100 percent exempted for projects with investment above 3000 Cr. Creating an employment of 500 in seven years as per TN Industrial Policy will be allowed.
Wheeling and Transmission Charges	The wheeling charges for wheeling of power generated from the solar power projects, to the desired locations for captive use/third party sale within the state, will be as per the orders of the Tamil Nadu Electricity Regulatory Commission. (30 percent of the conventional charges as on date.)

State: Rajasthan

Capacity Target and Period: Rajasthan	
Captive Use	**Unlimited**
Competitive Bidding	550 MW
Generation Based Incentive (GBI)	5 MW – MNRE
Rooftop PV and Small Solar	50 MW

Sale to DISCOM	600 MW by 2017
Solar Power Plants along with Solar PV manufacturing plants in Rajasthan by 2013	200 MW
SPV	500 MW/Year
Incentives: Rajasthan	
Electricity Duty	Yes
Industrial Grant	Yes
Land Allotment	Yes
No grid connectivity charges	Yes
Solar Park	Yes
Water availability for power	Yes
Wheeling and Transmission Charges	Yes

State: Chhattisgarh

Capacity Target and Period: Chhattisgarh	
Captive Use	**500-1000 MW**
Sale through REC	Projects to be developed for sale of power through REC Mechanism as per the orders/regulations of the state commission.
Offtake Arrangement	
Sale to Captive	The state will promote solar power developers to set up solar powe plants for captive use or sale of power to third party or other states ir India.
Sale to DISCOM	This policy will promote the sale of power to DISCOM to fulfill RPO.
Sale to Third party/outside state	The state will promote solar power developers to set up solar power plants for captive use or sale of power to third party or other states in India.
Incentives: Chhattisgarh	
Energy Banking facility	Energy banking facility is allowed at mutually agreed terms and wherever required approval of appropriate regulatory commission shall be obtained.
Land Allotment	It is the responsibility of the developer to acquire land for the SPP. Depending on the availability, the government land will be allotted as per prevailing state policy on obtaining all statutory clearances.
REC	Projects under this policy are eligible to claim REC benefits. Injection of electrical units into the dedicated grid for its captive use by a solar generation plant shall be considered for issue of RECs as per CERC guidelines.

Wheeling and Transmission Charges	Wheeling and Transmission charges for sale will be as per Chhattisgarh Electricity Regulatory Commission charges.

State: Uttar Pradesh

Capacity Target and Period : Uttar Pradesh	
Grid Connected	500 MW by March 2017
Offtake Arrangement :	
Power Purchase Agreement	Will be signed between UPPCL and successful bidders (developers) for a period of 10 years
Sale to Captive	
Sale to DISCOM	Power can be sold to Uttar Pradesh Power Corporation Limited (UPPCL) through competitive bidding
Sale to Third party/outside state	Project developers who want to set up projects under this policy and do not want to sign a PPA with distribution utility of UPPCL and want to sell power to a third party, can set up plants under this policy without a bidding process but will not be allowed to sign a PPA even at a future date with distribution utility of UPPCL.
Incentives : Uttar Pradesh	
Additional benefits under Central Government and Respective State government	All the incentives provided under the Uttar Pradesh State Industrial Policy, 2012 will be applicable on the power plants based on solar energy.

CHAPTER 8: MARKET TRENDS & BUSINESS POTENTIAL

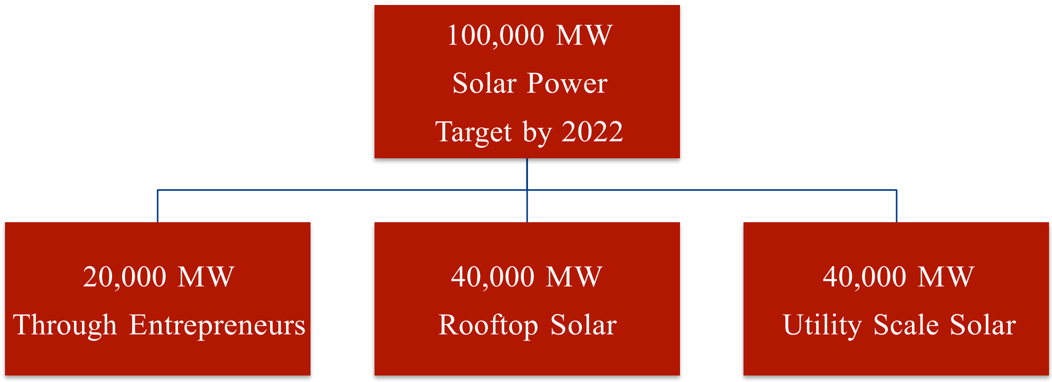
Target under National Solar Mission

The NSM is a Government of India initiative implemented by the State Governments. It commenced in 2009 to address India's energy security challenges while promoting ecologically sustainable growth. The NSM will be a major contribution to India's intended commitment to meet its share of climate change mitigation and adaptation activities as agreed within the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is an international treaty, established to coordinate international efforts in addressing the challenges of climate change.

The overall objective of the NSM is to make solar power cost completive with fossil fuel-based energy options by 2022 through the following actions:

1. Long term policy,
2. Large scale deployment goals,
3. Aggressive research and development; and
4. Domestic production of critical raw materials, components and products.

Following up on the objectives of the Mission, the Government of India announced ambitious targets for grid-connected solar power in 2015. Under these targets, a total of 100,000 MW of grid-connected solar power is to be installed across India by the year 2022. Utility-scale solar and rooftop solar will contribute 40 percent each towards this target, while entrepreneurs will get an opportunity to meet 20 percent of this target as well, with a focus to promote local job creation and skill development. A detailed breakdown of this target is illustrated in Figure 68.



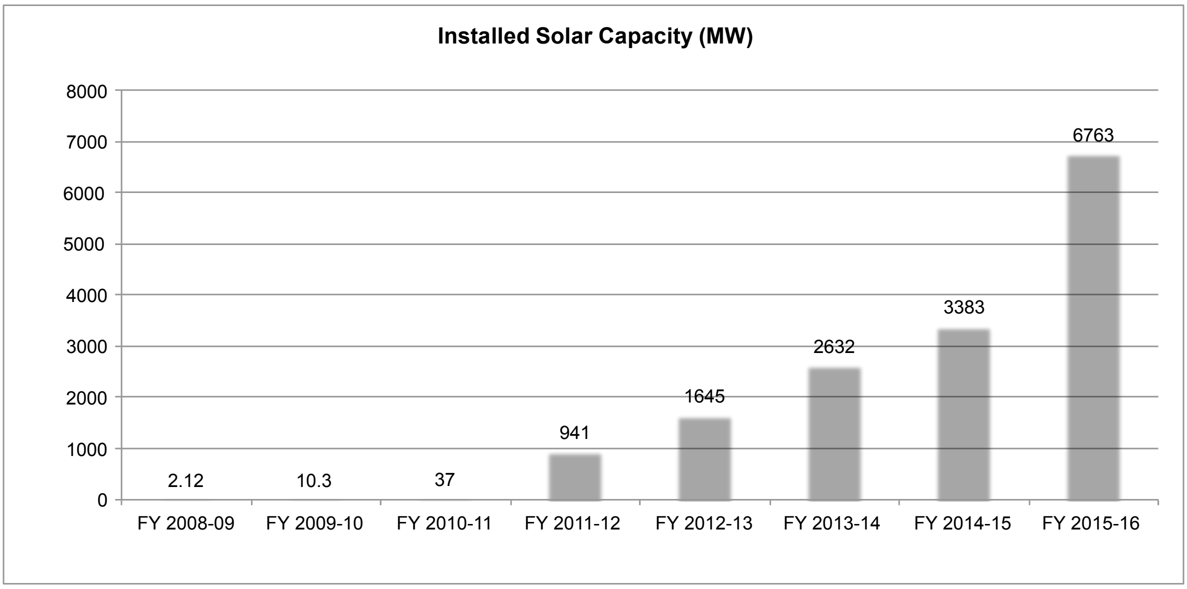
Source: Ministry of New and Renewable Energy, Government of India

Figure 68: Targets under India's National Solar Mission

Category	Scheme	Allocated Capacity (kWp)
Category 1	Solar rooftops	40,000
Category 2	Schemes for distributed solar energy projects by unemployed youth and farmers	10,000
	PSUs	10,000
	Large Private Sector/IPPs	5,000
	SECI	5,000
	Under State Policies	20,000
	On-going programs	10,000
	Total	**100,000**

Table 17: Overview of National Solar Mission and Sectors

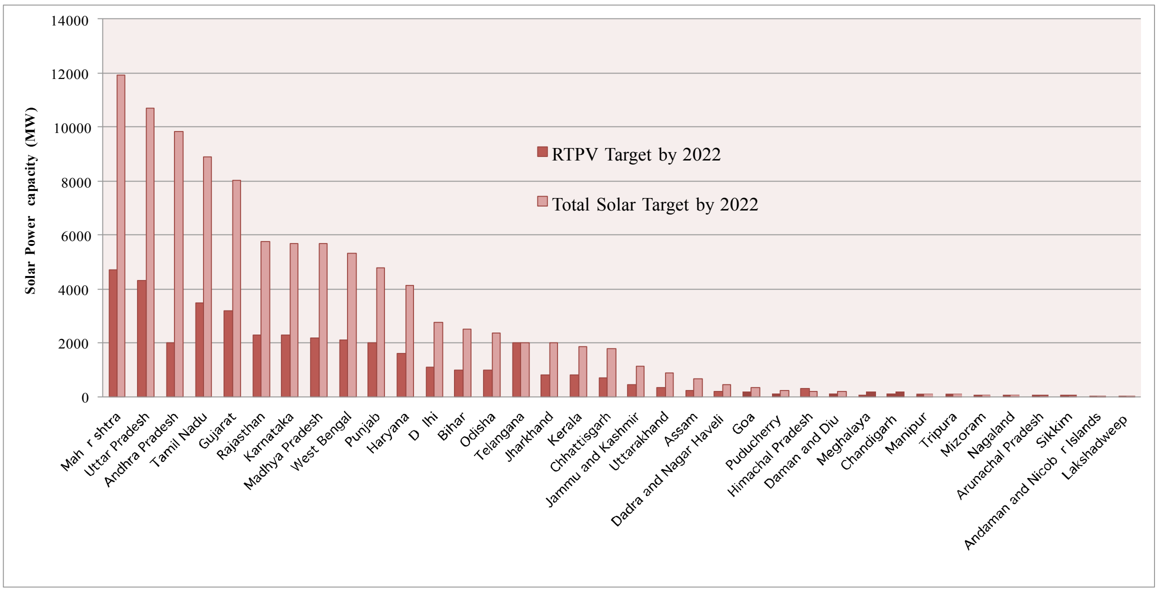
RTPV systems have been targeted on the huge roof spaces available across government buildings, institutions and properties with public sector units.



Source: Ministry of New and Renewable Energy, Government of India

Figure 69: Growth of solar sector in India

Allocated targets for all Indian states are presented in Figure 70.



Source: Ministry of New and Renewable Energy, Government of India

Figure 70: States with targets by 2022

MNRE has identified approximately 124 GW of market potential within Indian solar energy sector, which is significantly more than the 2022 target set by it. Implementing such a large-scale program will require large resources, logistics and infrastructure, which may not be present immediately at this stage in India; However, as the industry's knowledge and capacity improves and grows, things may look different in the future.

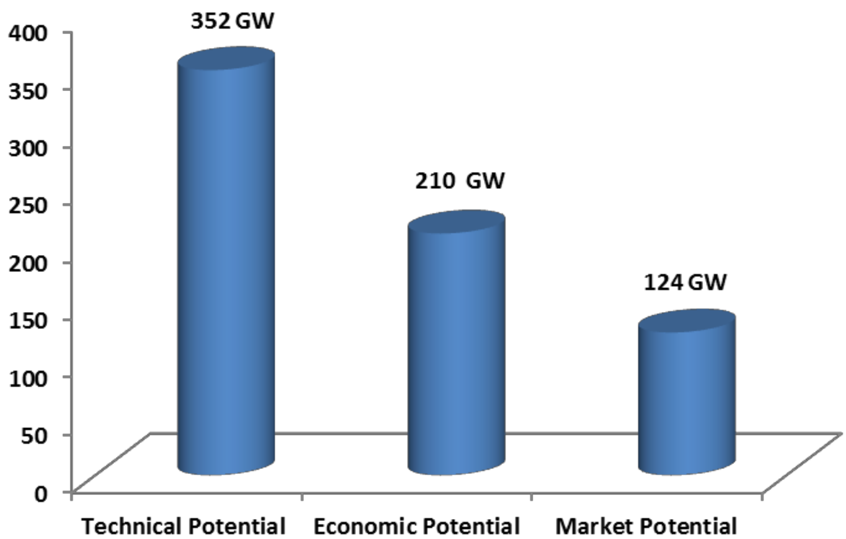


Figure 71: Technical, economic and market potential of RTPV

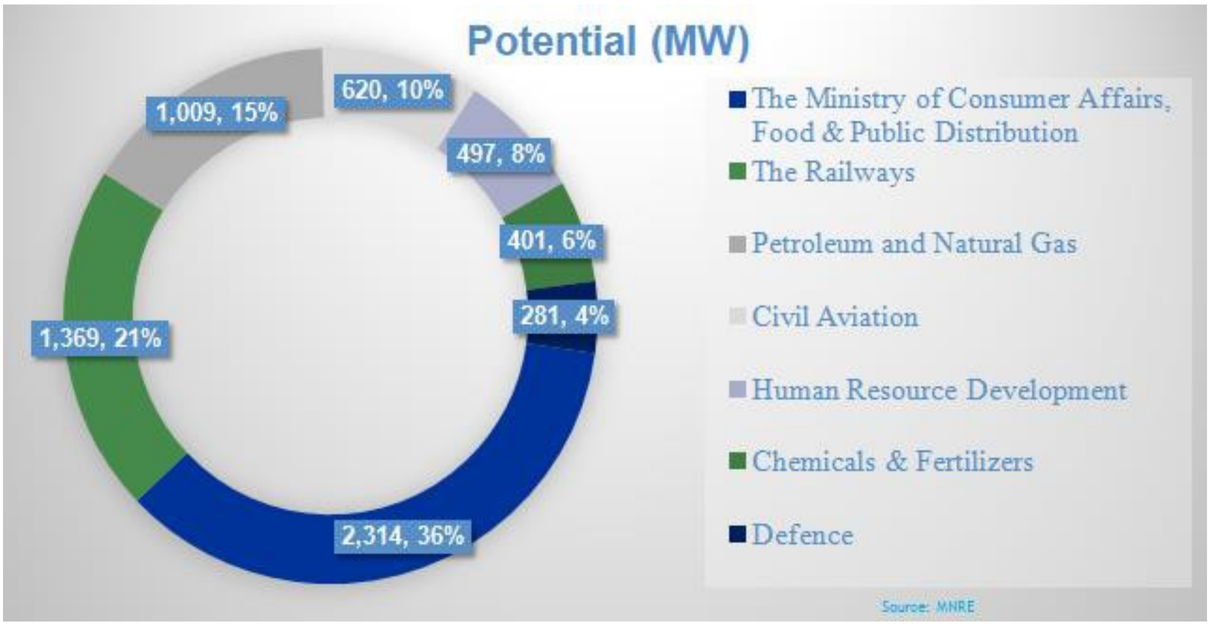


Figure 72: Estimated potential of rooftop PV on government buildings

NSM progression over the years

The NSM has undergone from initial trial and testing period, which included small-scale, captive installations to a developed stage of large-scale grid-connected installations. An illustration of this progression is provided in Figure 73.

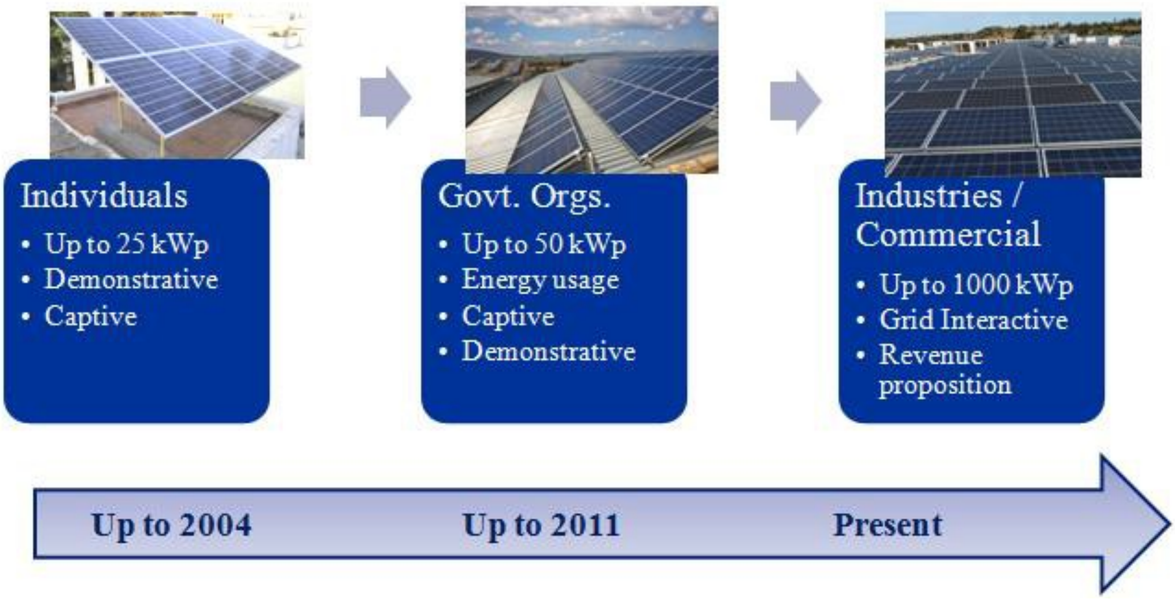
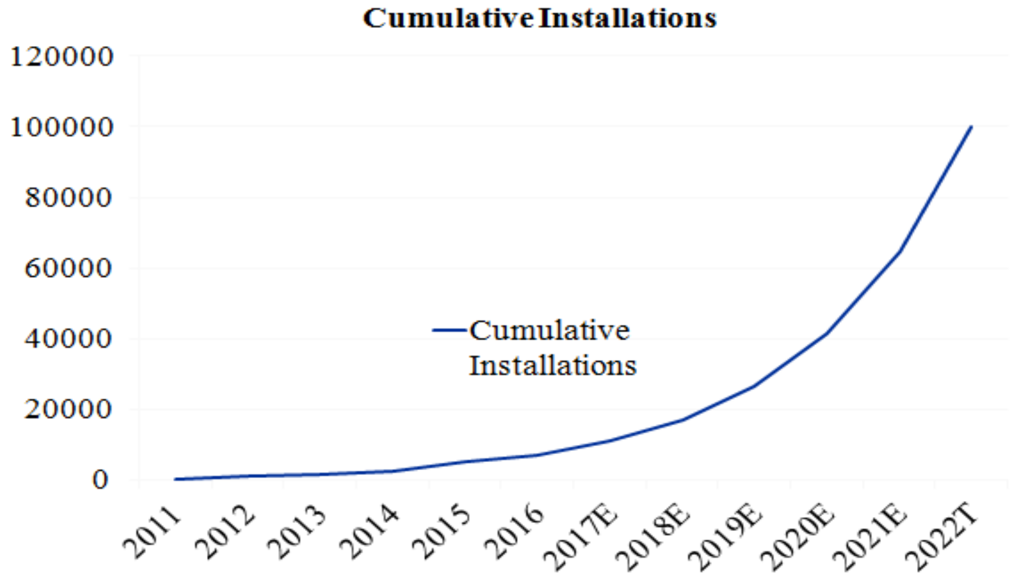


Figure 73: NSM progression over the years

An illustration of actual cumulative capacity addition of solar PV plants within the Phases 1 and 2 until 2016, and estimated growth required through the years until the 2022 target year is provided in Figure 74.



E – Estimated, T- Target

Figure 74: NSM – cumulative capacity addition over the years

The NSM has clearly helped in establishing and growing the solar power sector in India. The mission has successfully achieved its targets under Phase 1. Some of the challenges and key learning has been summarized below.

Key challenges faced during Phase 1:

- High capital costs of modules and balance of system components, recurring replacement costs making solar PV economically unviable.
- Negligible awareness about PV technology; so the basic aim was to prove the concept.

Some of the factors which worked in making the first phase a success include:

- Availability of subsidy, making projects attractive for developers.
- Smaller project sizes; hence low capital cost, and lower investment risks.
- Involvement of limited decision makers, mainly the owner of the project.
- Low emphasis on optimum output as there was generally low level of awareness of the technology.

The success of Phase1 had increased the level of interest in the solar energy sector from multiple sources. While this is good for the industry, it also presents some challenges which are fundamentally different to the ones faced earlier.

- Large number of stakeholders; and so, decision makers, increasing levels of complexity and timeframes within a project.
- Interest in large capacity projects typically requiring large investments and convincing of financing institutes for investment.

- Low knowledge levels within the industry; there is currently entry of all types of operators in the market. Low quality work can reduce the project profitability and negatively impact technology's reputation.

Some of the factors which may work in making the Phase 2 a success include:

- Grid-connected solar PV now makes economic sense.
- Revenue guaranteed for many years with good system design and choice of components.
- Grid-connected systems can avoid using battery; thereby reducing recurrent costs.

Recent Developments in RTPV Market

Grid-connected RTPV projects are increasingly becoming a viable alternative for sourcing power using the otherwise unused roof spaces. Many states now have clear policies, mandates and regulations for net metering, thereby improving investor confidence and consumer awareness. Industries and businesses with large unused roof spaces on the factories are increasingly willing to invest in solar PV to generate energy and to save on increasing tariffs and energy costs.

In addition, more than 15 states across India have announced rooftop programs, mainly under net metering framework. Corporations like Delhi Metro initiated projects on stations and other buildings. More than three states have announced distributed grid-connected power generation programs.

As regards other developments in the RTPV sector, various municipal corporations have made RTPV compulsory for certain real estate projects (like solar water heating few years ago), such as nursing homes, educational institutions, new buildings, etc.

Banks and oil companies have also started to pursue deployment of RTPV, and have announced programs to install RTPV on rural bank branches and oil dispensing stations.

Some of the key developments in the RTPV market include:

- Indian Railways has launched the first 50 MW pilot program for utilizing all premises for RTPV installations.
- Warehousing Corporation/Food Corporation of India have also announced similar programs for RTPV on their properties.
- Several PSUs have committed to implement ambitious RTPV programs.
- The 100 Smart cities program has RTPV as an integral component.

Market segments

Table 18 provides an example of typical market segments which can be approached by an entrepreneur with a RTPV project offer. The entrepreneur may consider becoming a specialized service provider for a particular segment, thus creating a niche market.

Market Segments	Example
Commercial	Theatres, office complexes or individual offices, warehouses, housing societies, banks, hospitals, airports, etc.
Industrial	Factories, workshops, garages, etc.
Educational Institutions	Government and private schools and colleges, etc.
Individual Households	Bungalows, apartments, apartment flats, farm houses, etc.
Government Establishments	Institutes, factories, offices, hospitals, airports, railway stations, etc.

Table 18: Solar rooftops – market segments

Market Research Strategies

Starting a new business is always challenging, especially in a new market like the RTPV, where rules of business are still being established and supply chain is still at an early stage of development. As like any early stage market, acquiring quality information on several aspects can prove to be a difficult task and may create barriers for entry of new entrepreneurs. Lending institutions or investors may also perceive new entrepreneurs within the solar sector as an investment risk, thus access to finance for a faster scale up can be a challenge. There would be few other 'unknown' challenges which may appear in course of business development.

While there may not be a silver bullet to resolve all the existing challenges, business start-up strategies such as market research and business plan can help in understanding the context of the market sector and anticipate any potential challenges. Some of the market research strategies to enter into the rooftop solar PV sector in India have been listed in Table 19. This list is not exhaustive and is intended to provide a few starting points to the entrepreneur. It is recommended that the entrepreneurs should carry out their own research and develop strategies which suit their individual circumstances and business objectives.

Market research activities	Research areas	Potential sources of information
Study and understand all applicable	• Central and State government programs • Incentives to different customer types • Tax benefits • Subsidies	MNRE, state nodal agencies (SNAs), Indian Renewable Energy Development Agency (IREDA), lending institutions such as Yes Bank, State Bank of India, MUDRA, IREDA, etc.

Market research activities	Research areas	Potential sources of information
	• Soft /concessional loans • Restrictions and limitations	
Prepare standard offers, including	• Technical features of the system • Outputs to the user • Competitive pricing • Commercial aspects • Economics and profitability	MNRE, technical handbooks and trainings from relevant institutions, manufactures, wholesalers, distributors, system integrators, etc.
Building an Organisation	• Sourcing manpower – numbers, qualifications, designations, experience, roles and responsibilities, and retention • Employment vs. on-the-job-basis contracting	State chamber of commerce, business coaches, industry professionals, etc.
Product sourcing	• Identify, study, shortlist suppliers for material • Decide vendors and contractors • Each component of the system should have more than three possible vendors shortlisted by the entrepreneur	Manufacturers, wholesalers, distributors, etc.
Making sale	• Salesmen – employ limited number as employees • Dealers – exclusive or non-exclusive • Distributors – as stocking and forwarding agents; once the company reaches certain level • Commission agents – existing service companies dealing with particular market segments where you have possibilities	Manufacturers, wholesalers, distributors, typical customer segments, typical industry partners like architects, builders, etc.
Product Pricing	• Market intelligence and competitors pricing • Cost plus or market driven	Market intelligence reports, websites, tender reports, MNRE, etc.

Table 19: Market research strategies

Market entry – Empanelment/Certifications/Approvals

The following activities can be undertaken to enter into the market:

- **Empanelment/certifications/approvals**

The NSM implementation agencies such as the MNRE, SECI, and the National Institute of Solar Energy empanel channel partners, either in form of new entrepreneurs of businesses which have been running for a minimum of three years. Usually, a credit rating agency issues certificates based on organisation’s creditworthiness. The organisation can them approach the MNRE for its empanelment. More details on the qualification criteria, timelines and processes can be found on MNRE’s website.

- **MNRE empanelment for a particular category**

Within its empanelment process, the MNRE categorizes the organisations at different levels, depending on their annual turnover and capacity. There are 25 levels of rating which determines the magnitude of project which can be given to a channel partner for implementation. More details on the empanelment processes can be found on MNRE's website.

- **SNA registration wherever applicable and necessary**

Similar to MNRE, the SNAs also look for channel partners to deliver projects within the respective states. More details on the registration processes can be found on the respective SNA's website.

- **Product testing, approvals and certificates**

Entrepreneurs looking to establish the manufacturing or assembling units should follow up with MNRE for information on the certifications and approvals required to launch the product in the market.

- **Special certificates**

Public sector units such as the Research Design & Standard Organisation (RSDO), Defence and Telecom have also made commitments to install solar PV plants on the rooftop of their properties. However, participating in their projects will require special certificates and approvals. More details can be found on the respective organization's websites and with the Contracts Departments of these organisations.

Promotional activities

Promotions are of great value in getting your company or product to your customer, especially in the start-up stage of your company. Some of the key steps which can be taken to promote the business include:

- Attend and participate in exhibitions
- Organize or participate in events
- Print brochures detailing product offerings, special features of the products and customer service
- Ready catalogues for presentation – technical specifications, certifications
- Have presence on Internet, build website and social media networking
- Publish handouts and inserts in newspapers
- Install hoardings at appropriate places

There could be many other innovative ways to promote your business which are not covered in the above list however it gives a rough idea on what could be done to get your business out there, to your customers.

Service – Pre and Post Sales

Rooftop solar PV installations are very much centred on quality of customer service. Being a design and engineering-based product/solution, quality of data collection and engineering calculations are of very high importance as they decide the final quality of a system. For example, a site visit to the customer's property without proper data capturing will lead to a poor system design, and will damage the reputation of your business in the longer run.

Similarly, without having proper contracts in place (in writing) the business is left open to disputes originating from customers.

It is therefore important to build an organisation with a capacity to provide service to customers, both during pre and post sales phase. Some of the aspects an entrepreneur could consider in building their capacity to provide both pre and post-sale services to customers are listed Table 20.

Aspects of pre sales service	Aspects of post sales service
Site survey Critical for good designs which will save disappointments and legal risks later on.	**Service centres** Point of contact for customers for maintenance callouts at the time of system underperformance or failure or any hazard
Offer submission Critical for winning a competitive procurement bid	**Service personnel** Manpower resources for attending to maintenance callouts
Negotiations Critical for winning a competitive procurement bid	**Spares stocks** To immediately replace any broken parts
Contract signing and payments Critical for business continuity	**Preventive and Curative (repairs)** Regular checks as part of operation and maintenance scheduling

Table 20: Service – Pre and post sales

Warranties and Guarantees

Either as a service provider or as a manufacturer, the entrepreneur must be able to provide the following warranties and guarantees:

- Warrantees on design and engineering
- Guaranties on workmanship, usually with a defects liability period
- Module performance warranty, usually in agreement with the manufacturer. It is important to source modules form manufacturers with established business history.
- Guarantees for other components such as inverters, mounting systems and energy performance. All of these require partnerships with reputed manufacturers.

Financing and Offers

The entrepreneur must be aware of means and ways a client can finance their system. This may prove to be very useful in converting a lead to a sale, especially where high upfront cost is usually cited as a barrier. Some of the typical ways of financing a project are:

- **Client own financing –** Customer provides 100 percent finance.
- **Client own and debt financing** – Debt sourced from Indian and foreign banks on a client's equity. For example – 70:30 debt to equity ratio.
- **Equity participation –** A type of loan where the lender shares a proportion of the revenue generated from the system. This typically applies to a large volume of project, or a long term PPA.
- **Supplier's Credit –** Credit which is usually provided by the exporting vendor from whom a product is sourced. The credit can then be refinanced by the importer through credit insurance.
- **Energy Service Companies–** Selling energy rather than the hardware (system), typically applies to a long term PPA.
- **Sharing of benefits from AD,** typically applies to a long term PPA.
- **Sharing subsidy** by handling the entire application process.

These ideas are indicative only and their application will depend on the individual circumstances and business goals of the entrepreneurs. The entrepreneurs are encouraged to carryout adequate research on financing option which will fit the business and customer's needs.

CHAPTER 9: PROJECT COSTING AND ECONOMICS

Project cost components

The solar PV industry has in recent time experienced a sharp decline in the cost of solar PV modules and rapid growth in the volume of output produced and shipped worldwide. Together with a worldwide surge in the investment into RE technology, the solar PV industry has grown with a compound annual growth rate (CAGR) of 44 percent from 2000 to 2014, thus making its growth highest among all the installed new energy generation sources.

System equipment capital cost

Table 21 provides a breakdown of the cost of a typical 10 kW grid-connected solar PV rooftop system. It should be noted that the PV modules comprise about 50 percent of the cost of the installed PV system, thus making the most expensive item in a project. On the other hand, all other equipment (also known as BoS) and associated works are equally critical as they can also collectively have about 50-60 percent impact on the cost of the PV system.

Sl. No	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

Table 21: Cost of components for a typical 10 kW grid-connected system

The total cost of the PV system indicated in Table 21 will vary with respect to size of the system, combination of inverters used to reach the desired capacity, type of mounting used for the PV modules and so on. While the 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.

Site-related cost

Site-related costs include all the additional expenditures for implementing a PV project before its actual installation. These may consist of:

Roof rent: In case of third party lease arrangement, the licensee should incur monthly expenses for utilizing the roof on which the PV system has been installed.

Strengthening of roof: Some sites may require that the roof area be reinforced in order to increase the overall stability of the structure before the rooftop PV system could be installed.

New roofing: In some cases, a complete new roofing structure should be incorporated since it may not meet the mandatory requirements (IEC 62548) in order to install the PV system. In such case, additional expenses should be considered which may contribute to the pre installation costs.

Operation & Maintenance costs: Operation and maintenance cost generally involve regular maintenance of the system which includes cleaning of PV modules, investigating equipment and checking their performance with data sheet specifications.

Administrative charges: These costs relate to the application/registration/sanctioning of the project.

Utility charges: Utility costs are incurred while consuming power from the utility grid in times when the PV system is not in operation. A typical load curve graph for a given day may peak early in the mornings and late in the evening whereas a typical PV generation graph peaks in the afternoon. Therefore if there is no battery storage system incorporated, energy will be consumed from the utility grid at these times, thus contributing to fixed cost over time.

Components that affects project cost

There are a number of variables which may affect the final cost of a project, and must be kept in mind when scoping and quoting for a job.

- **Choice of structure – Aluminum framing or Galvanized Iron (GI)**

  Aluminum structure tends to be of lower cost than the GI framing for larger scale projects; however, variations of GI structure is widely available at project sites, saving time and money in logistics for smaller scale projects. Also, aluminum is lighter, anti-corrosive and easier to clean which can make it a preferred choice, depending on local site conditions.

- **Surface – Flat/Sloping RCC/Sloping Tinned Roof/Super Structure**

  The surface of the roof will determine the specifics of the mounting structure to be used. For example, preferring a flat mounting over tilted mounting could translate into more money spent on modules and lesser on mounting systems. However, this should be weighed against energy generated from a flat mounted system verses a system mounted on tilt or more closely aligned orientation.

- **Interconnection voltage level – 230 V / 415 V / 11 KV / 33 KV**

  Availability of interconnection point at client's premises, either LT or HT, determines the type of inverters, switchgears, or step-up transformers to be used. Generally, the higher the connecting voltage, the more investment is needed in sophisticated and high capacity balance of system components as well as documentation for grid connection approvals, thus increasing the project costs.

- **Interconnection point distance from inverter**

  The further away the interconnection point from inverter, the more investment is needed in cable runs. These cables should be appropriately sized to avoid voltage loss, to prevent loss of power delivered power the load. Loss of power from the system means loss of revenue for client and should be avoided. The accepted upper limit of voltage loss in a system is about 3 percent.

- **String inverters/central inverters**

  Inverters are the single largest cost hardware item after solar PV modules in project. The choice between string inverters and central inverters is typically governed by price of technology, available space, installation costs, type of cables required, maintenance costs, inverter efficiency and MPPT inputs. Typically, the central inverters tend to have a lower DC watt unit cost, however, the string inverter have lower installation, maintenance costs and higher energy output. The pros and cons of both these technologies must be compared, within the context of project's objective, before a choice is made.

- **Fixed structure/tracking (single axis/double axis)**

  Presence of single or double axis trackers can increase the energy output of a project by up to 30 percent, depending on the site. However, this increased output must be evaluated against the increase in component and operation and maintenance costs. Generally, if space is not a constraint, it is more cost effective to add more solar modules to the system design.

Project Financing and Revenues

Solar rooftop projects, like other RE 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 upfront costs of such projects may prove to be a major challenge as compared to their conventional energy counterparts.

Financing instruments play an important role in spreading the cost of owning a rooftop solar PV system over a period of time, and hence improve the cash flow of the owner, be it the end user, or a third party project developer.

There are three methods financing methods which are popularly used with solar PV projects.

1. **Debt**
   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.

2. **Lease Financing**
   Lease financing is a commercial arrangement between a financial institution (FI) and the project developer where the former purchases equipment and other components (usually equivalent to 70 to 80 percent of the project cost) and leases them to the latter.

3. **Equity Financing**
   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 Indian context, a debt to equity ratio of 70: 30/75: 25 is observed as normal financing norms for banks.

The equity can either be sourced from own equity or, own and private equity or own and community sourcing. Debt for solar PV projects can be sourced from public sector banks, private banks, non-banking FIs, IREDA, foreign institutional or foreign individuals. A list of banks providing debt to solar PV developers in listed in the next chapter.

Project financing and revenue generation are key component of rooftop solar PV value chain for an entrepreneur. For a successful project, the cost of financing should be lower than the project revenue. This is true for both the third party developers as well as end user, who purchase the system outright. Few variables which affect generation of revenue from a project include:

- **Tariff and its pattern – constant/increasing**

The tariff can either be kept fixed over the agreed contract period, or applied with an escalation at interval of few years, to account for the CPI, inflation, external variables and reduction in output from the system. The structure of the tariff can be a combination or any of the following:

- **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 steady cash flow for the project developer. However, the disadvantage is that, the power purchaser may find the solar tariffs relatively high during the initial years of the agreement.

- **Independent Escalation:**

A variable tariff can be developed with a constant or variable annual escalation (e.g. to the tune of three-five percent per year). The PPA may predefine 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 bear the brunt of high upfront solar tariffs. However, in the longer term, the conventional power tariffs may not follow the same escalation rates as defined in the PPA, which may result in either:

a) The project developer selling cheaper solar power than its actual value or
b) The consumer paying a higher tariff than the conventional tariff, both these situations can put the PPA at risk.

- **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 honor the PPA. The disadvantage is that if the conventional tariff does not escalate substantially, then the project developer may not receive high return. However, such a tariff arrangement may balance out the risks in the long term.

- **Energy Generation**

Estimation of energy generation is fundamental to tariff determination process. Energy generation estimates from a solar PV system depend on location of site, climatic factors, site azimuth and relative orientation of PV arrays, presence of existing and future shadow causing object or plant growth.

In case of grid-connected systems without battery storage, poor quality of grid as well as incidents of grid outage will reduce the amount of energy delivered to consumer, and hence loss of revenue for developer. In the event of grid downtime, the inverter loses its 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 DISCOM 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

- **Debt (term loan) interest rate, repayment period of debt and moratorium**

The conditions of sourcing debt also play in important role in revenue generation. The longer the debt term, the higher is the interest repayments. The repayment period should be designed in a way that the lifetime revenue from solar PV system is more than the cost of debt.

- **Possibility of availing AD benefit**

ADbenefits are available to owners of solar PV systems, reducing the taxable profits of owners.

These variables should be considered when developing the solar project, and setting long term PPAs.

Tariff Determination by the Regulators

The CERC publishes order for RE tariffs and is either adopted by the State Electricity Regulatory Commission (SERCs) or some changes are made based on state specific conditions.

These tariffs are normally announced for a control period of five years, but may change on annual basis. Public comments are usually invited on draft tariff order.

The tariffs are based on “Cost Plus” methodologies and calculated on certain assumptions. The tariff is tariff designed to provide project investors a market based motivational return of investment.

The CERC tariff determination process provides a good working snapshot of variables that should be considered when developing the solar project, and setting long term PPAs.

Table 22 provides an example of a tariff order released in March 2015. Please have a look at the pricing parameters are associated values. These values are provided for a 1 MW solar PV project, with 19 percent capacity utilization factor, a 25 year useful life with 70:30 percent debt to equity ratio.

Assumptions for Solar PV Power Project Parameters					
S.No.	**Assumption Head**	**Sub-Head**	**Sub-Head (2)**	**Assumptions**	**Unit**
1	Power Generation	Capacity	Installed Power Generation Capacity	1	MW
			Auxiliary Consumption	0	%
			Capacity Utilization Factor	19	%
			Useful Factor	25	Years
2	Project Cost	Capital Cost	Power Plant Cost	605.85	Rs. Lakhs per MW
3	Financial Assumptions		Tariff Period	25	Years
		Debt Equity	Debt	70	%
			Equity	30	%
			Total Debt Amount	424.10	Rs. Lakhs
			Total Equity Amount	181.76	Rs. Lakhs
		Data Component	Loan Amount	424.10	Rs. Lakhs
			Moratorium Period	0	Years

			Repayment Period(Moratorium period included)	12	Years
			Interest Rate	13	%
		Equity Component	Equity amount	181.76	Rs.Lakhs
			Return on Equity for first 10 years	20	% p.a.
			Return on Equity 11th year onwards	24	% p.a.
			Weighted average of ROE	22.40	
			Discount Rate	10.81	
4	Financial Assumptions	Fiscal Assumptions	Income Tax	33,9990	%
		Depreciation	Depreciation Rate for first 12 years	5.83	%
			Depreciation Rate 13th year onwards	1.54	%
5	Working Capital	**For fixed charges**	% of O&M expenses		
		O&M charges		1	Months
		Maintenance charges		15	%
		Receivables for Debtors		2	Months
		For variable charges			
		Interest on working capital		13.50	%
6	Operation & Maintenance	O&M Expenses (2015-16)		13	Rs.Lakhs
		O&M Expenses Escalation		5.72	%
		O&M Expenses (2012-13)		11	Rs.Lakhs

Table 22: Assumptions for solar PV power project parameters

Units Generation	Unit	Year →	1	2	3	4
Installed Capacity	MW		1	1	1	1
Gross generation	MU		1.664	1.66	1.66	1.66
Anniversary Consumption	MU		0	0	0	0
Net Generation			1.6644	1.664	1.664	1.664
Fixed Cost	Unit	Year →	1	2	3	4
O&M Expenses	Rs. Lakhs		13.00	13.74	14.53	15.36
Depreciation	Rs.Lakhs		35.32	35.32	35.32	35.32
Interest on term loan	Rs.Lakhs		52.84	48.24	43.65	39.02
Interest on working capital	Rs. Lakhs		3.58	3.52	3.46	3.40
Return of Equity	Rs. Lakhs		36.35	36.35	36.35	36.35
Total Fixed Cost	Rs. Lakhs		141.09	137.17	133.30	129.48
Levelized COG						
Per Unit Cost of generation	Unit	Levelized	1	2	3	4
O&M Expenses	Rs./ kWh	1.24	0.78	0.83	0.87	0.92
Depreciation	Rs./ kWh	1.76	2.12	2.12	2.12	2.12
Interest on term loan	Rs./ kWh	1.52	3.17	2.90	2.62	2.35
Interest on working capital	Rs./ kWh	0.20	0.22	0.21	0.21	0.20

Return of Equity	Rs./ kWh	2.32	2.18	2.18	2.18	2.18
Total COG	Rs./ kWh		8.48	8.24	8.01	7.78
Discount Factor			1	0.902	0.814	0.735
Levelized Tariff	Rs./ Unit	7.04				

Table 23: Step-by-step tariff determination

The levelized cost of energy, which is the sum of all project costs, including material, labor, financing and operation and maintenance costs divided by total energy generated over system life, comes to be Rs. 7.04/kWh.

It is important to note the assumptions in the above tariff determination process, as it may not be applicable to individual cases of rooftop solar PV project. This tariff determination is for a utility-scale project hence working parameters and system needs will be different.

- The auxiliary consumption is taken as NIL, implying that no additional source of energy is need on cloudy days.
- No de-rating considered in solar modules, implying the output will be constant over system life.
- The Capacity Utilization Factor (CUF) considered on limited experience in India or within a state, and may change.
- Interest rate on loan (debt) considered based on the State Bank of India.
- Charges to utilities not considered.

Business case

In preparing business cases for clients or financial institutions to obtain finance, few variables affect the process of creating project financials, and are subject to the business model used by the entrepreneur, as summarized below. These business models have been explained in detail in Chapter 5.

- On premises Captive
- Net metering
- Open access – Third party sale
- Open access – Captive consumption

Largely, the building block of project financials is common for most of the models. However, the results will vary from changes in corresponding parameters.

Table 24 provides an illustration of developing project financials for a 2 MWp solar PV. Note that this information is from a utility-scale project and is intended to provide as a guide only.

Project Cost Details	Basis	Year 1
Permits & Licenses	Policy	150,000.00
EPC Cost	Market prices	120,000,000.00
Contingency	1%	1,200,000.00
Pre-operative cost and preliminary expenses	1%	1,200,000.00
Total Plant Cost **(Rs.)**		122,550,000.00

Table 24: Cost breakdown of 2 MWp Open Access project

Please note that EPC by large is the major cost, at about 97 percent of the total spend.

The above project is commissioned under the Open Access model, and is financed on a 70:30 percent debt to equity ratio.

Project mode - Captive in Open Access			
Project Capacity	Kilowatt-Peak		2000.00
Project Capacity	Megawatt-Peak		2.00
Project Cost	Rs. Lacs		1,225.50
Equity	Rs. Lacs	30%	367.65
Term Loan	Rs. Lacs	70%	857.85

Table 25: Financing parameters of 2 MWp Open Access project

Once capital costs and financing costs are accounted, the project's operating costs need to be calculated, as mentioned in Table 26.

Operational Cost Details	Basis	Year 2
Base Operation & Maintenance Cost	LS	1,800,000.00
Annual Insurance Cost (0.05% of Project Cost)	0.05%	61,275.00
Contingencies (0.05% of Project Cost)	0.05%	61,275.00
Spare Parts (0.05% of Project Cost)	0.05%	61,275.00
Remote Monitoring	LS	50,000.00
Administration Fees	LS	50,000.00
Annual Inflation Rate	5%	
Inverter component replacement cost (12th year)	50% of inverter cost	9,191,250.00

Table 26: Operational cost of 2 MWp Open Access project

The cost of financing is calculated next, in terms of debt repayments, interest rates.

Debt Schedule (Figures in Rs.)				
Year	Basis	1	2	10
Principal Amount		85,785,000	81,127,770	13,990,513
Annual Interest Paid	13%	11,152,050	10,546,610	1,818,767
Annual Principal Payment to Loan	10	4,657,230	5,262,669	13,990,513
Annual Payment to Loan	15,809,280	15,809,280	15,809,280	15,809,280
Remaining Amount of Loan		81,127,770	75,865,101	(0)

Table 27: Cost of financing of 2 MWp Open Access project

The building blocks of financial models are same until the above point. In case of captive use, there are no wheeling charges or transmission charges applied by the utility, however, these charges are applied to open access or third party consumers (where electricity is generated away from the place of consumption), affecting the cash flow and other financial indicators.

This fee and charges also depends on connecting voltage. In this case, the connecting voltage is 33 KV.

Operational Cost Details	Basis	Utility Charges	Remarks
Wheeling Charges	0.11	0.11	33KV
Transmission Charges	0.49	0.49	RE
Cross Subsidy Surcharge	0.00%	5.09	Commercial
Wheeling Losses	6.00%	6%	33KV
Transmission Losses	4.08%	4.08%	33KV

Table 28: Utility Charges of 2MWp Open Access project

Accounting for all the financial variables illustrated in Table 28 give the following business case model. Note the expenses paid to the utility for Open Access model. It is the single highest operational expenses for first few years of project.

Year	Basis	1	2	3	4	5
Units Generated (in Lakh kWH)		32.26	31.94	31.62	31.30	30.99
Utility Grid Losses (Wheeling)		1.94	1.92	1.90	1.88	1.86
Net Units saved		30.32	30.02	29.72	29.42	29.13
Tariff of saved units (Rs.) with inflation	5%	8.25	8.66	9.10	9.55	10.03
Revenue from saving of energy		250.18	260.06	270.33	281.01	292.11
Operational Cost		0.00	20.84	21.88	22.97	24.12
Operational Charges to Utility		19.36	19.16	18.97	18.78	18.59
Inverter replacement cost (12th year)		0.00	0.00	0.00	0.00	0.00
Total expenses		19.36	40.00	40.85	41.76	42.72
Gross Earnings	(1,225.50)	230.82	220.06	229.48	239.25	249.39
Repayment of Term Loan		46.57	52.63	59.47	67.20	75.93
EBIDTA		184.25	167.43	170.01	172.05	173.46
Cumulative EBIDTA	1,225.50	184.25	351.68	521.69	693.74	867.20
Interest on Term Loan		111.52	105.47	98.62	90.89	82.16
Total expenses and repayments		177.45	198.09	198.94	199.85	200.81

Table 29: Cash flow model of 2 MWp Open Access project

Another variable affecting financial performance of a project is availability of Accelerated Depreciation as tax benefit for the developer. A summary of various project financials with and without availing AD are provided in Table 30.

Equity Payback Estimate		NO	NO	NO	NO	YES
Equity Payback (years)	4					
Equity IRR	29%					
Project Payback Estimate		NO	NO	NO	NO	NO
Project Payback (years)	7					
Project IRR	21%					
Depreciation	80%	980.40	196.08	39.22	7.84	1.57
Tax amount saved	33%	323.53	64.71	12.94	2.59	0.52
Cumulative tax saved		323.53	388.24	401.18	403.77	404.29
Equity Payback Estimate		YES	YES	YES	YES	YES
Equity Payback (years)	0					

Table 30: Effect of AD on equity payback for 2 MWp Open Access project

Note how equity payback changes from 'No' to 'Yes' after availing AD.

Revenue for a project is generated from sale to the third party as provided in Table 31, after paying charges to utility and revenue lost to wheeling losses.

Year	Basis	1	2	3
Units Generated (in Lakh kWH)		16.00	15.84	15.68
Utility Grid Losses (Wheeling)		0.96	0.95	0.94
Net Units sold		15.04	14.89	14.74
Tariff of sold units (Rs.) with inflation	5%	6.50	6.83	7.17
Revenue from sale of energy		97.76	101.62	105.64
Operational Cost		0.00	10.27	10.78
Operational Charges to Utility		29.96	29.66	29.36
Inverter replacement cost (12th year)		0.00	0.00	0.00
Total expenses		**29.96**	**39.93**	**40.14**

Gross Earnings	(510.50)	67.80	61.70	65.49
Repayment of Term Loan		19.40	21.92	24.77
EBIDTA		48.40	39.77	40.72
Cumulative EBIDTA	510.50	48.40	88.17	128.89
Interest on Term Loan		46.46	43.93	41.08
Total expenses and repayments		**95.82**	**105.78**	**106.00**

Table 31: Revenue from sale of power for 2 MWp Open Access project

Table 32 provides a hypothetical comparison of six different solar PV project cases. The models differ on the rate of their tariff and rate of agreed increment (or no increment) in the PPA each year. Note that how the variables change the payback and IRR of both the project and equity.

Scenarios	Case 1	**Case 2**	Case 3	**Case 4**	Case 5	**Case 6**
Tariff of sold energy in the First year	11.00	**9.00**	11.00	**10.00**	10.00	**8.00**
Increment in tariff every year	4%	4%	**0%**	**3%**	**0%**	**5%**
Total Revenue in first year	330.88	270.72	330.88	300.80	300.80	240.64
Total Expenses in first year	59.92	59.92	59.92	59.92	59.92	59.92
Gross in hand in first year	270.96	210.80	270.96	240.88	240.88	180.72
Repayment of Debt in first year	151.76	151.76	151.76	151.76	151.76	151.76
Net in hand in first year before taxes	119.20	59.04	119.20	89.12	89.12	28.96
Equity Payback Estimate						
Equity Payback (years)	3	5	3	4	5	8
Equity IRR	37%	25%	28%	28%	21%	22%
Project Payback Estimate						
Project Payback (years)	5	8	7	7	10	10
Project IRR	24%	19%	19%	20%	16%	18%

Table 32: Comparison of 6 hypothetical PPA case studies

As can be seen from the above discussion and financial indicators creating a profitable solar PV project depends on several variables. Reducing capital cost is not the key parameter if increasing returns from a project.

Energy generation is probably the most important factor for good financial performance over project life. Other variables include quality of components used, workmanship and performance over life.

Terms loan interest rate and period another important factor. Low interest loans or increased self-contribution assists in creation of better IRRs. Focus on tariff in the first year in itself not as important as its pattern over the years.

Making the tariffs attractive to customer in the first year to adopt solar is an important factor for finishing the sale.

In summary, solar is long term investment project. One should expect continued returns over 25 years, but at lower rates than some other businesses, at the present moment. However, trends suggest that these are changing quickly.

Chapter 10: Rooftop Solar Project Financing

Green Energy Commitment made by FIs

A total of 29 FIs have made commitments to lend to RE projects. These include non-banking financial companies (NBFCs), public and private sector banks and private NBFCs. Collectively, their commitments amount to financing 70 GW of RE projects. A list of all the FIs and their respective commitment is provided in Table 33.

Sl. No	Name of Financial Institution	Funding in (Crores)	Capacity (in MW)
1	State Bank of India	75,000	15,000
2	ICICI Bank		7,500
3	L&T Finance Holdings Ltd.		6,500
4	Indian Renewable Energy Development Agency Ltd.	30,000	6,000
5	PTC India Financial Services Ltd.	30,000	6,000
6	Yes Bank Pvt. Ltd.		5,000
7	Indian Infrastructure Finance Co. Ltd.	20,000	4,000
8	IDBI Bank Ltd.	14,700	3,000
9	Power Finance Corporation	15,000	3,000
10	Bank of Baroda	12,500	2,500
11	Axis Bank	10,000	2,000
12	Bank of India	10,000	2,000
13	Union Bank of India	7,500	1,500
14	Bank of Maharashtra	7,500	1,500
15	Andhra Bank	5,000	1,000
16	South Indian Bank Ltd.	3,000	600
17	HDFC Bank	2,000	400
18	Indian Overseas Bank	2,000	400
19	Punjab National Bank	2,500	500
20	Canara Bank	1,600	320
21	State Bank of Mysore	2,000	285
22	Indian Bank	1,000	220
23	Dena Bank	1,000	200
24	United Bank of India	1,000	200
25	Vijaya Bank	1,000	200
26	Lakshmi Vilas Bank	1,000	200
27	State Bank of Patiala	500	100
28	Oriental Bank of Commerce	240	80
29	Bhartiya Mahila Bank	250	50

Table 33: List of FIs with green lending commitment

Lending Guidelines of key FIs

The lending guidelines of key FIs are listed below. These FIs have been categorized into three groups, A, B and C, as per their capacity.

The information is relevant at the time of writing this handbook. It is recommended that the users follow up with relevant FIs to check the currency these guidelines when developing a project plan.

CATEGORY A: Government-backed NBFCs

1. **IREDA**

IREDA has played the critical role of a catalyst for RE development in India and has funded a large number of such projects all over the last several years.

The scheme is available to all grid-connected/ interactive solar PV projects located on rooftops wherein the applications can be submitted into two categories, namely:

a) **Aggregator Category**

- Application can include either single project or aggregate multiple projects
- Minimum project capacity to be submitted shall be at least 1000 kWp
- Minimum capacity of sub projects under this mode shall not be less than 20 kWp

b) **Direct Category**

- Applicants shall include projects from single roof owners only
- Minimum project capacity to be submitted shall be at least 1000 kWp

Eligible entities/categories as per IREDA norms include:

- PSUs/firms
- Central PSUs
- State utilities/ DISCOMs/ transmission companies/generation companies/ corporations
- Joint sector companies

2. **Power Finance Corporation (PFC)**

PFC provides financial assistance in case of grid-connected solar PV private sector power generation projects, inter alia, subject to following minimum eligibility conditions:

- The minimum size of the project to be considered for appraisal/financing of all grid-connected solar PV private sector power generation projects shall be 1 MW.
- Debt equity ratio of the project shall not exceed 70:30 (i.e. equity not lower than 30 percent of project cost).
- The entire equity portion shall be brought upfront by the borrower.
- The PPA for the entire generation should have been signed upfront for a period not lower than PFC's loan repayment period.
- Requirement of collateral securities shall be as applicable to private sector generation projects with rating of IR-5 (where PFC is the lead FI).

3. **Rural Electrification Corporation (REC)**

Financing norms for RE projects include:

a) Moratorium Period: The moratorium period for principle repayment would be six months after Commercial Operation Date (COD) for all type of power generation projects. Moratorium period for all types of projects shall be COD + six months, subject to maximum of following duration from the date of first disbursement:

- 1.5 years for Solar PV, Wind
- 2.5 years for Biomass
- 4 years for Solar Thermal
- 6 years for Small Hydro Projects

b) Minimum Equity Contribution: The debt equity ratio proposed for private sector borrowers or the REC is 70:30. Where the lead FI is funding on the basis of a different debt equity ratio, REC would follow the debt equity ratio being considered by the lead FI, subject to maximum of 3:1.

CATEGORY B: Public Sector Banks (PSBs)

1. **SBI and Associates**

- The interest rates usually provided by SBI are as 11 - 12 percent.
- Minimum capacity eligible for the process is of 30 kWp rooftop solar PV.
- Maximum repayment period is of eight years.

2. **IDBI Saurya Shakti**

- Individuals/joint individuals are eligible for loan up to 60 percent of the project cost subject to maximum of Rs. 10 lac per borrower.
- The cost of 5 KWp plant ideal for a three bedroom house is about Rs. 5 lac and around Rs. 6 lac with battery backup.
- Out of which Rs. 60,000 will be subsidy @ Rs. 12000 per KW and bank will finance Rs. 3 lac.
- The maximum repayment period will be seven years and repayment will be in equated monthly instalments.

3. **National Bank for Agriculture and Rural Development (NABARD)**

- Capital subsidy/refinance scheme for installation of solar off-grid under the NSM.
- Solar water heating system.
- Capital subsidy scheme for solar lighting and small capacity PV systems.
- Capital subsidy scheme for installation of 68,000 s PV lighting systems and small capacity PV systems under NSM.
- MNRE’s scheme for installation of 10,000 solar PV water pumping systems for irrigation purpose implemented through NABARD.

CATEGORY C: Private Sector Banks (PSBs)

1. Yes Bank

- YES BANK successfully issues India's first Green Infrastructure Bonds.

- Amount Raised : INR 1000 Crores (including green shoe of INR 500 Cr)

- Tenor : 10 Years – Bullet Repayment

- The issue launched on February 16, 2015 for INR 500 crores plus green shoe option witnessed strong demand from leading investors including insurance companies, pension and provident funds, foreign portfolio investors, new pension schemes and mutual funds, resulting in a total subscription of INR 1000 crores and was closed on February 24, 2015. The bonds are for a tenor of 10 years. YES BANK's Sustainable Investment Banking and Debt Capital Markets team acted as arranger to the transaction.
- KPMG, India will be providing the Assurance Services annually, on the use of proceeds in accordance with the Green Bond principles.

2. Axis Bank

Axis Bank's environmental management efforts are inclined towards resource conservation, renewable energy and energy efficiency. Through its Green Banking Initiative, the bank:

- Encourages adopting green building concept for its office space (Bank's corporate office 'Axis House' is designed and constructed as a Platinum LEED-Certified "Green Building") and many other similar activities.

- Initiated solar-based UPS for ten ATMs under its Independent ATM Deployment (IAD) model

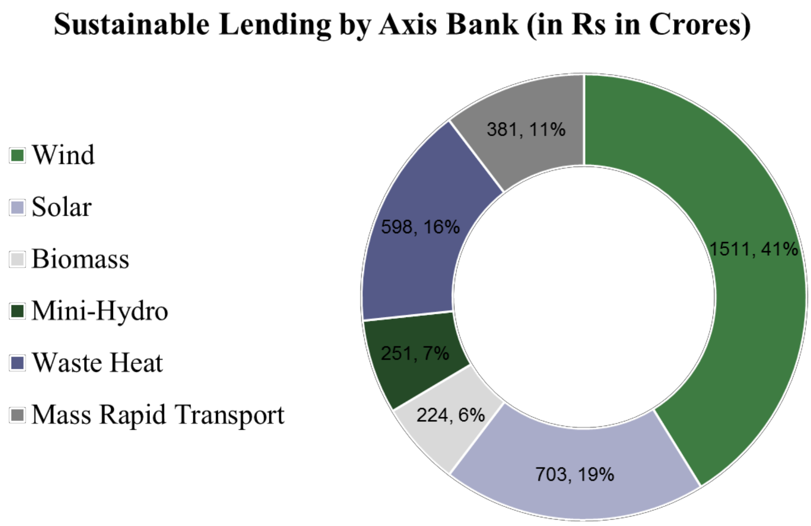


Figure 75: Sustainable lending by Axis Bank

Summary of lending schemes of few FIs

Table 34 provides a summary of all lending schemes discussed in the above sections.

Sl. No.	Banks/FIs	Minimum Capacity (kWp)	Interest Rate (%)	Repayment Period (Years)
1	IREDA	1000	10.05-10.90	9
2	IDBI	5	9.9-10.75	7
3	SBI and Associates	30	11-12	8
4	Yes Bank	50	10.5-115	10
5	Power Finance Corporation (PFC)	500	10.5-11.5	10
6	Rural Electrification Corporation (REC)	5	9.8 – 10.7	10
7	NABARD	50 Wp to 200 Wp	9.6-10.75	5

Table 34: Summary of lending schemes

Financing of Rooftop Solar PV as Home Improvement Loan

The MNRE, in a notification, has advised all banks to encourage home loan/home improvement loan seekers to install rooftop solar PV and include the cost of such equipment in their home loan proposals just like non solar lighting, wiring and other such fittings.

These rooftop solar PV plants will be set up in residential, commercial, industrial, institutional sectors in the country ranging from 1 kWp to 500 kWp capacity.

Other FIs Financing Solar Projects

In addition to the nationalized banks, the following financial investment banks have also made commitments to invest in solar projects:

- L&T Finance, SBI capital markets, Bank of America, Barclays Capital, BNP Paribas, Lazzard and Credit Suisse
- Export credit agencies/Investment insurance agencies
- US EXIM Bank, Euler Hermes Kreditversicherungs- AG (Germany), China Export & Credit Insurance Corporation (China), Nippon Export and Investment Insurance (Japan)
- Development Finance Institutions –
- Asian Development Bank (ADB), the International Finance Corporation (IFC), Overseas Private Investment Corporation (OPIC), Germany's KfW & DEG

Micro Units Development & Refinance Agency Ltd. (MUDRA)

MUDRA is a lending scheme where Rs. 212 crores value of loan would be given to 1 lakh small entrepreneurs. The scheme has three products namely 'Shishu', 'Kishore' and 'Tarun' based on the stage of growth of the business and funding needs of the beneficiary micro unit.

a. **Shishu:** covering loans up to Rs.50,000
b. **Kishore:** covering loans above Rs.50,000 and up to Rs.5,00,000
c. **Tarun:** covering loans above Rs.5,00,000 and up to Rs.10,00,000

CHAPTER 11: TENDER PREPARATION AND EVALUATION TECHNIQUES

Approach

Submitting a tender is common for businesses supplying goods or services to other businesses or the public sector. The format of a tender proposal varies widely by industry, but all have the same basic requirements. The most important part of any tender response is the deadline.

When submitting a tender it is important to remember that it is a highly competitive process, so it is imperative to provide the best possible quote.

Applying for tenders provides a good learning experience. Even if one does not win the work, writing a tender can clarify an organisation's aims, strengths and weaknesses and one can learn for next time by asking for feedback on the bid. It raises a company's profile with the customer and helps one learn about customers' needs.

Before applying for the tender, it is important to spend time on working out the following details, which may be useful in preparing for a tender submission.

- Firstly, **understand the client,** their needs and expectations from the project as well as the drivers and motivation behind a project. This can be done by attending the pre-bid meeting and asking questions/clarifications from the client.

- **Understand the objective of the assignment** and assess whether you have the skills to deliver the job or you need to collaborate (form a consortium) with someone in the industry.

- **Understand qualification criteria and check whether your company qualifies in the tender by meeting all criteria** before applying for the tender.

- **Understand scope of work or services/Terms of Reference.** Ignoring this may lead to costs which may have to be borne by the tenderer.

- **Establish credential for the required assignment** by participating in shared projects, building networks with skilled people within the industry.

- **Prepare methodology and approach.** The client seeks to understand the depth of understanding and capacity of the tenderer to deliver the work. A detailed methodology and approach gives confidence to the client in tenderer's ability.

- **Work Plan** detailed to task breakdowns, timeline targets and resource allocation. It must include **Manpower Plan,** including details such as **skill matrix, task assign, CVs of key persons, etc.**

- **Management Plan – Organisation structure, quality control, backstopping** providing confidence to the client in tenderer's ability to deliver the work.

- **Budget allocation for manpower, expenses, contingencies.** Plan the bid including these cost items.

- **Terms and Conditions** which work to protect your business from any breach of contract, force majeure or any error on client's part.

Qualification Criteria

The tender documents are advertised with qualifying requirements that determines the eligibility of a tenderer. While the requirement may be specific to each tender process, some of the most commonly listed requirements include:

- **Legal status** of the Organization, i.e Company, Partnership, Proprietorship, Joint Venture

- **Overall experience and credential** in the area of works.

- **Experience of organization specific to the project type and capacity**.

- **Multitasking capability and experience** to handle non engineering side of works.

- **Financial status of the** organization **as per the project requirement, and solvency certificate** to evaluate the financial capacity of the tenderer.

- Details on **joint venture or partnership/consortiums.**

- **Proof of association with materials suppliers** to get assurance on the ability of the tenderer to meet timelines.

- **Proof of commitment from supplier to supply required quantity within stipulated time.**

- **Performance certificates of similar projects done the by the bidder,** to evaluate experience and reference checks.

- **Manpower availability and CVs of key persons** to evaluate the knowledge base and capacity of the organization.

- **Tax clearance certificate** to evaluate the financial health of the tenderer.

Tender preparation

Tender specification documents will probably include a response template that has sections for the tenderer to fill in. These sections may have word limits and also may require certain file formats. By accurately following all of the requirements in the response template, one will make it easy for the tender review panel to consider their offer.

Always take the time to carefully evaluate tender opportunities. A well-researched tender, followed by a planned response, increases chances of success and reduces time-wastage and costs to the business.

The following is a suggested step-by-step method for organising a tender response:

Step 1: Examine the site requirement
This should typically include the following activities:

- Location of the project and grid connectivity facilities
- Availability of transportation and conveyance means for logistics purposes
- Topography and soil of the ground-mounted site and types of roofs for RTPV plants
- Surrounding and neighborhood of the site
- Evacuation and grid interface option
- Power availability to determine
- Infrastructure and facilities available, including access to roofs

Step 2: Examine the technical requirement
Activities within this step include the following:

- Identify and associate with the vendors of specified PV modules and inverters, electrical equipment, control and monitoring equipment, and mechanical equipment.
- Identify and plan for the extent of civil work required by the client.
- Acquaint oneself with the specified codes and standards, and plan for the means of compliance.

Step 3: Project Execution planning
The next stage of planning is to plan for executing the works. Within this step, the tenderer should aim to provide a strategic execution plan indicating the strength and availability of execution team for each activity, and procurement and installation schedule for components, sub components and consumables with a clear time frame.

This is achieved by:

- Creation of a construction schedule showing week-by-week targets for all activities.
- Providing update on the status and explaining any critical activity that may not meet the scheduled deadline.

The tenderer should guarantee to complete the work as per schedule. On failure to do so, the tenderer may have to accept the penalty as applicable.

Step 4: O&M Plan and Training
Almost every tender will ask for an O&M Plan and training for maintenance staff post project completion. The tenderer has to propose an Operation and Maintenance Plan for at least five years (or as required in the tender) from the date of commission of the plant and suggest facilitating maintenance for the rest of the solar PV power plant's life.

The tenderer should also provide an indicative training plan for technical and managerial staff of client for operation and maintenance of the power plant.

Step 5: Guarantee
Tenderer should work with its vendors to organise the process of servicing of warranty claims, which will be used in the tender response. At the customer's end, the tenderer shall provide guarantee commitments for the material and workmanship of all components.

The operation of the equipment shall meet the requirement of the specification. Should the performance test result at works deviate from the guaranteed values, including the specified tolerance, the vendor shall correct their equipment at no extra cost and repeat the performance tests within a reasonable period as agreed to the client.

Step 5: Manpower, tools and equipment
In the project schedule submission, provide qualification and relevant experience of engineering and technical team to be engaged in the project.

Also provide a list of plant and machines, tools and tackles including measurement and safety equipment intended to be used in the work as per the instruction in the tender document.

Step 6: Documentation
Check the documentation before submitting a tender response. Also, plan for creating handover documents (as necessary after completing the project) in anticipation of getting the tender. Typically, in a solar PV project, the following is needed to be provided to the client post completion.

- All electrical drawings
- All civil engineering drawings
- Plant layout drawings
- Structural drawing
- Test certificates of electrical and mechanical equipment
- Pre-commissioning tests report
- Instruction manual for all operation and maintenance
- Maintenance procedures
- Precautions to be taken during operation and maintenance work (typical Do's and Don'ts)

Please note that these requirements will vary based on type and size of project.

Bid Evaluation

As a tender, it is useful to understand the evaluation process followed by the tender evaluation panel at the client's side. This will assist in pitching the tender submission to the level of the client's need and expectation.

Generally, from the point of view of clients, a contract is categorised as:

- **Critical contracts -** High value and High Risk
- **Secure contracts -** Low value, but High Risk
- **Drive contracts -** High value, but Low Risk
- **Routine contracts -** Low value and Low Risk

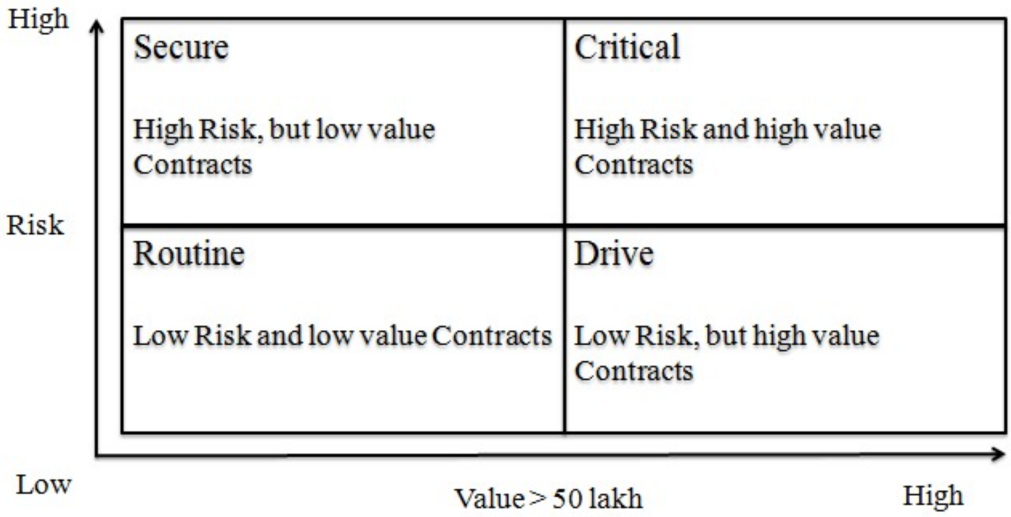


Figure 76: Procurement Risk Matrix

In all of the contracts, bids of lowest value do not necessarily secure a contract, as they may be evaluated also on non-cost factors. These include technical capacity of the tenderer to deliver the project on time and budget.

While in a high risk tender, the non-cost evaluation criteria may account for as high as 85 percent of the weighting, a low risk tender may have the non-cost criteria at a much lower level, generally at 50 percent.

A summary of ranges of technical and financial weightings for various types of contracts are provided in Table 35.

Type of Purchase	Non Cost Ratio/ Weighting
Critical/ Secure contracts	Between 50 percent and 75 percent, in exceptional circumstances this may go up to 85 percent
Drive/ Acquisition contracts	Up to 50 percent, but this must be fully justified

Table 35: Summary of bid evaluation - Technical/Financial Weighting

An example of the application of bid evaluation process is listed below.

For a tender, weighting of technical offer is 70 percent and that of financial offer is 30 percent. To evaluate the bids for this tender, the client will use the following formula to evaluate the overall ranking of the qualified tenders.

$$Overall\ Score = \frac{Score\ of\ Technical\ Bid\ x\ 70}{Highest\ Score\ of\ Best\ Technical\ Bid} + \frac{Lowest\ Financial\ Bid\ x\ 30}{Price\ of\ Financial\ Bid}$$

Table 36 illustrates the score from tender evaluation using the above mentioned formula.

Tenderer	Score in Technical Offer	Price of Financial Bid	Overall Score	Overall Rank
Company A	90	480	98.75	First
Company B	80	470	91.58	Third
Company C	80	460	92.22	Second

Table 36: Example – technical/financial weighting

As can be seen, even as Company C has submitted the lowest price, and Company A the highest, the later still wins the tender as the evaluation panel provided higher weighting to the technical offer in the bid.

It is therefore imperative to read through the bidding details of a tender process, to make sure all the time and effort is not wasted in preparing a response that does not meet a client’s criteria.

CHAPTER 12: CONTRACT STRUCTURES AND AGREEMENTS

Key Agreements in a Solar PV project

Subject to the choice of business model, there can be a range of agreements which bind the stakeholders within a solar PV project. For customer driven, self-owned business models, typical agreements may include the product and workmanship warranties, system performance warranties, and operation, maintenance and replacement contracts.

For business models centered on third party providers, the important agreements include PPAs and rooftop lease.

This chapter will provide details on the key agreements within the third party business models as these models are getting more popular with large-scale rooftop projects in India.

Power Purchase Agreement
A PPA is the contract signed between the developer of the rooftop solar power project and solar electricity consumer, under a third party business model. The developer of the project is referred to as Renewable Energy Service Company (RESCO).

The PPA is signed at an agreed tariff (Rs/kWh) and conditions, to which the RESCO will supply electricity to the consumer throughout an agreed period of time, which may vary from 10 year to 25 years.

Rooftop Lease/Rent Agreement
Under some circumstances, the consumer of the solar power project may or may not have the legal ownership of the rooftop. For example, a tenant may wish to purchase power from a rooftop solar project, but may not have rights to the roof, which can be owner's property.

Non-involvement of the rooftop owner as a party to PPA is a critical issue which needs to be addressed by reviewing the rooftop lease/rent agreement. It also needs to take into account the risk of tenant vacating the property within the contract period and costs associated with relocating of terminated the rooftop solar PV project.

Case Study - Agreements – Indian Railways, RESCO Model

The Indian Railways recently announced its intention to develop rooftop solar power plants on its properties across India. A program of this scale will involve projects which will be developed through the RESCO model, as explained earlier. Workings of the RESCO model are illustrated in Figure 77.

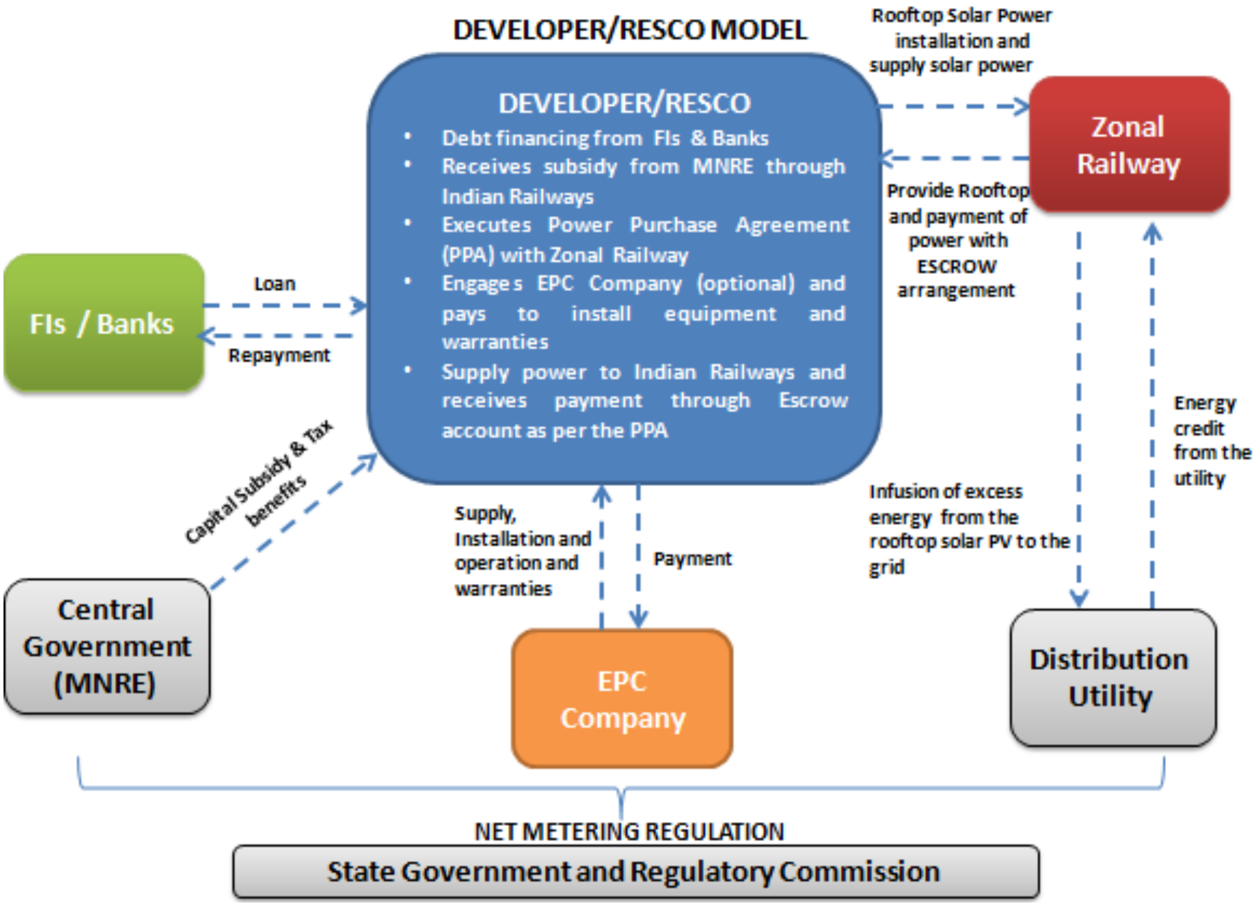


Figure 77: Case study – RESCO model

In this model, the RESCO takes responsibility for all aspects of the project management, including procurement of EPC services, transactions with financial institutions and central government, and also the grid interconnection process.

The end user involvement is limited to availing the solar power from the RESCO and getting credit from the utility for the surplus electricity which is exported to grid.

The RESCO makes revenue from the PPA tariff and service contracts.

Solar Lease/PPA – Contract Relationships

There are principally three set of stakeholders who interact within a PPA or solar/rooftop lease agreement:

1. Owner of the roof
2. Owner of the solar plant
3. Consumer of solar electricity

There are a number of contractual relationships that could be worked out among these stakeholders, which can help determine the level and nature of contract and agreements which need to be drafted. A summary of these relationships is provided in Table 37.

Owner of roof	Relation	Applicant (Owner of the solar plant)	Relation	Who consumes Solar energy	Metering scheme
Consumer		Consumer		Consumer	Self Consumption
Consumer		Consumer		Consumer	Net Metering
Consumer		Consumer		Utility	Gross Metering
Third Party	Lease Agreement	Consumer		Consumer	Self Consumption
Third Party	Lease Agreement	Consumer		Consumer	Net Metering
Third Party	Lease Agreement	Consumer		Utility	Gross Metering
Third Party		Third party	PPA	Consumer	Self Consumption
Third Party		Third party	PPA	Consumer	Net Metering
Third Party		Third party	PPA	Utility	Gross Metering
Consumer	PPA	RESCO	PPA	Consumer	Self Consumption
Consumer	PPA	RESCO	PPA	Consumer	Net Metering
Consumer	Lease Agreement	RESCO	PPA	Utility	Gross Metering
Third Party	Lease Agreement	RESCO	PPA	Consumer	Self Consumption
Third Party	Lease Agreement	RESCO	PPA	Consumer	Net Metering
Third Party	Lease Agreement	RESCO	PPA	Utility	Gross Metering

Table 37: Solar lease/PPA contract relationships

Rooftop Lease/Rent Agreement – Items to consider

Before embarking on a rooftop lease or rent agreement, a project developer should consider the following items before finalizing a contract.

- Does rooftop lease/rent agreement provide legal access to develop the solar project?
- What is the tenure of the agreement? If lesser than PPA, can it be extended? Extended up to what tenure?
- Does the agreement clearly mention the responsible party to repair the roof in case of damage and maintain it?
- Is the rooftop owner willing go for net metering and grid interconnection? If not, who will be doing it?
- What are the termination clause and the penalties in case of early terminations? Are they strong enough to safeguard the revenue losses from rooftop solar power project?

While the above list is not exhaustive, it gives a starting point to think about other factors which may not have been covered here.

PPA - Operation, Financing, Risks

Similar to the above, the following items should be considered before embarking on a PPA.

1. **Conditions Precedent**

Activities which need to be completed prior to the execution of PPA are termed as conditions precedent. Its presence in a contract ensures that the project does not commence without achieving certain minimum condition. For example, the PPA in the case study from Indian Railways has following conditions precedent:

- Performance security/guarantee to Railways by developer
- Execution of escrow and substitution agreement
- Drawings and project completion schedule (Approved by Railways)
- Execute financing agreements (Deliver copies to Zonal Railway)

2. Payment Security Mechanism

A payment security mechanism is used to avoid occurrence of default against performance of solar power from developer side, and payment for solar power from consumer side. It can either be a Letter of Credit or a Bank Guarantee. It gives both the parties an authority to retain the amount equivalent to the amount defaulted by another party.

For example, in the PPA case study of Indian Railways, the RESCO will be providing a payment security of Rs. 20 lakh per MW.

This will be retained by Indian Railways for a time period specified within the contract, and returned to the solar power developer later at the completion of the time period. This will protect Indian Railways against system's generation below the promised benchmark.

In other cases where developer and consumer both are private parties there may be a security mechanism for safeguarding developer's interest against consumer's default. In such cases, the security may be provided by the consumer to the developer in any form as mentioned above. The amount of which can be mutually agreed and can be 6 months to 12 months equivalent of estimated average monthly payments.

3. Right of Way

Some of the buildings, their premises and rooftops may not have a general access for works due to security reasons. The installation and operation of the rooftop solar power may require such access which shall be agreed in the PPA.

In the case of the PPA case study of Indian Railways, a Right of Way clause has been used in the contract, ensuring access to the site with the intention of using it for installation, operation and maintenance of Project.

This includes the way from the entry point to the rooftop through the shortest accessible way, easements and other rights of way, howsoever described, necessary for construction, operation and maintenance of the projects.

4. Deemed Generation

This clause addresses any loss of generation due to any reason beyond the control of the rooftop developer and not covered under Force Majeure.

Deemed generation protects the developer and the lender from delays in the repayment of the loan. It is crucial to assess whether the deemed generation clause has been included in the contract and appropriately worded to cover all eventualities.

The key eventualities have been highlighted below:

- In the event of consumer failing to off-take the electricity generated due to non-availability of reference voltage or lack of demand
- Non-availability of adequate space for solar rooftop installations or unplanned displacement of the system
- Any loss of generation due to shadow by new buildings or objects in the future

5. Performance Indicators

A project is structured based on estimated revenue earned, which in turn is based on certain estimated performance of the rooftop solar power system. A minimum performance level can be guaranteed as agreed under PPA.

This can be assured in terms of a benchmark CUF below which the developer has to bear a penalty in addition to the loss.

This ensures that the developers implement best available technology in the market to achieve the benchmark CUF. However the CUF of the project is also largely based on the location of the project and the local weather conditions and can be different for different projects.

Hence the benchmark CUF shall be estimated carefully so as to be in the interest of both the parties. Benchmark CUF/Performance Ratio in the existing PPA in the location or CUF calculated by SERC for solar could be a fair indicator to derive the benchmark CUF.

6. Tariff

The price agreed under PPA to be paid for a unit of electricity generated from rooftop solar power plant is called the tariff.

It is applicable for the complete tenure of the PPA; however the structure of the tariff can be combination or any of the following:

- **Constant Tariff –** Under this condition, a constant levelized tariff is agreed upon for the tenure of the agreement.
- **Constant Escalation** – A tariff structure which starts from a base tariff in year one and escalates based on a predefined rate can also be used. For example the period of escalation may vary in 5 years, 10 years, 15 years or for full tenure of PPA.
- **Variable Escalation** – A variable tariff with variable escalation can also be used. For example 5 percent from 1^{st} to 5^{th} year, 6 percent from 6^{th} to 10^{th} year, 7 percent from 11^{th} to 15^{th} years and so on.

7. Central Financial Assistance- CFA (if applicable)

CFA is the support from Central Government in form of subsidies. If applicable then following shall be included in the PPA:

Pre-conditions to avail the CFA shall be indicated e.g. MNRE requirements on:

- Domestic content ,technical specifications to be followed and vendor empanelment
- The modalities of channeling and disbursal of CFA shall be indicated

8. **Buyout Option for the Consumer**

In case the buyout condition is included in the contract, the contract will also clearly define:

- The circumstances situations where the Buyout Clause will be invoked; and,
- The price at which the buyout will be undertaken.

9. **Escrow Account**

It is a name for the bank account which the solar power developer shall open and maintain. The account handles all the transactions related to all inflows and outflows of capital, revenue receipts and expenditures, in accordance with the provisions of the PPA.

An example of typical deposit and withdrawal transactions through an escrow account includes:

Example of deposits:

- All funds constituting the Financial Package;
- All payments on account of tariff and any other revenues from or in respect of the solar power projects, including the proceeds of any rentals, deposits, capital receipts or insurance claims; and
- All payments by consumers, after deduction of any outstanding Agreement Fee.

Example of the preference of withdrawals:

- All taxes due and payable by the developer
- All payments relating to construction of the solar project system,
- O&M Expenses
- Debt Service due in an Accounting Year, etc.

10. **Termination due to default on PPA by Consumers**

The occurrence of default on consumer side will not be limited to but cover the following:

- How many months of delay after the credit period will be considered as default?

- For non-availability of synchronizing power, what percent of operating hours lost is considered as default?
- For non-availability of access to roof, what percent of days in a year is considered as default?
- In case of temporary non-availability of roof, what period of non-availability of roof is considered as default?
- In case of damage of major equipment caused by consumer, to what extent of damage leads to termination?

11. Termination due to default on PPA by Seller/RESCO

The occurrence of default on seller/RESCO side will not be limited to but cover the following:

- How many months of non-availability of solar plant will be considered default?
- How many years of not achieving minimum guaranteed (Benchmark) CUF leads to default?
- Are there any pre mature termination clauses?
- What will be the impact of pre-mature termination on project feasibility?
- What is the compensation for pre mature termination?
- Are there any other termination clauses?

12. Risk of Non-indemnity

Indemnity clauses are included to indemnify, hold harmless and defend the parties to the agreement from and against any and all loss and/or damages. The situation where the indemnity clause is applicable shall be clearly defined. For a fair agreement it is important to assess that the indemnity clauses adequately indemnify both the parties.

13. Dispute Resolution

The dispute resolution process shall be clearly laid out in the agreement with the appointment of authorities to resolve the dispute. The arbitration process shall also be clearly defined in case the dispute is not resolved in the given period.

14. Other conditions to be agreed in PPA

- Technical specifications and standards agreed to be provided by seller/ RESCO shall be clearly laid down in the agreement.
- Grid Inter connection if applicable shall be done complying with following the applicable regulations and codes.
- All approvals, permits safety requirements shall be clearly laid down for the project.

CHAPTER 13: PROJECT PERFORMANCE AND O&M PLANNING

System performance monitoring

Performance monitoring of solar photovoltaic (PV) power systems is very essential for initial system evaluation, and continuous output optimization. Monitoring is also essential for detection of operational issues, and to compare the performance of different systems across a range of technologies and climates. Performance and reliability data can therefore facilitate appropriate system design and technology choice, and in the long term, establish credible expectations about PV system performance.

The system performance data is usually made available monitoring software programs or data logging systems, available either as standard or an option with the majority of inverters. These loggers will provide data that can produce graphs showing:

- Daily energy yield for month/year
- Daily power generation
- Insolation/Irradiation
- Ambient temperature
- Module temperature
- Wind speed (Important for mounting systems with trackers)

The International Standard IEC 61724 'Photovoltaic system performance monitoring' provides guidelines for measurement, exchange and analysis of system performance data. As per the standard, performance measurements are done by using data for the following parameters:

- Irradiance
- Ambient air temperature
- Wind speed
- Module temperature
- Voltage and current
- Electrical power

The IEC 61724 also specifies standards for the data acquisition system, sampling and recording interval and data processing guidelines for the monitoring and evaluation process.

Performance indicators of PV power plant

According to There are two main indicators of performance according to the IEC 61724. These are:

- **Final Yield (Yf) –** This is the ratio between energy generated by the system to the rated PV array capacity, and is rated in kWh / kWp.
- **Performance Ratio (PR) -** This is the ratio between actual and theoretical possible energy output of the PV plant, and is rated in percentage (%).

Other indicators include the **Capacity utilization factor CUF (%)**, which is the total actual energy production from the system in comparison to theoretical maximum amount possible, if the plant was to be operating continuously at full capacity. In India, this lies somewhere in between 15 percent to 21 percent for solar PV projects.

Among the performance indicators, Performance Ratio (PR) are considered as the better one, as it is more comprehensive and is better reflection of a plant's performance. This is because of the following reasons:

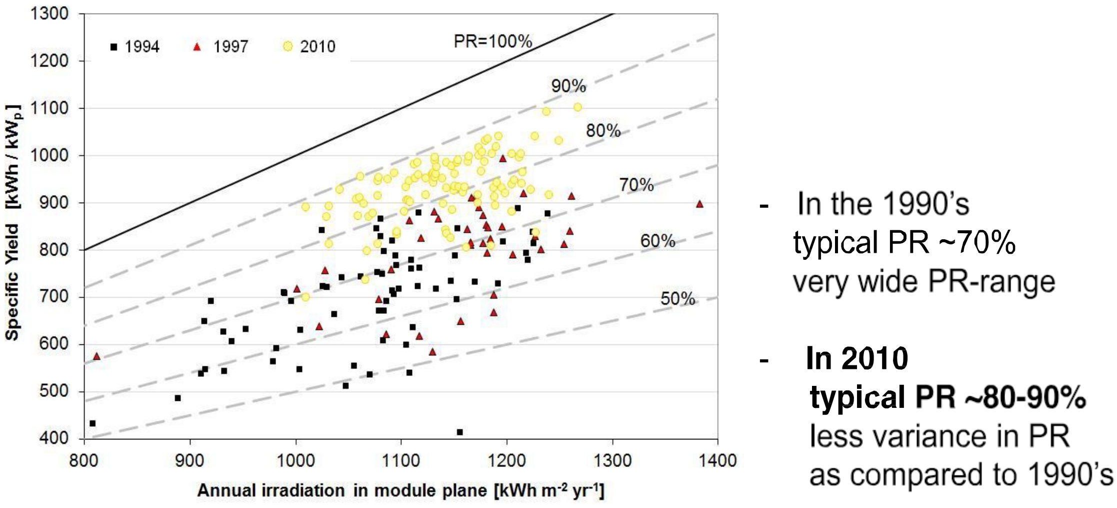
- Performance ratio is the indicator to compare the performance of PV power plants that may differ in design, technology and location.
- Performance ratio Indicates how well the plant is performing Independent of irradiation at PV plant location, unlike the Final Yeild (FY) and Capacity Utilization Factors (CUF). Typical figures for annual performance ratio (PR) lies between 75 – 85 percent.

Typical advantages of using PR as system performance indicator over CUF and FY are as follows:

- PR is independent from irradiation at the plant location.
- Underperforming plants can easily be detected by calculating PR.
- Measures can be taken to improve the energy production of plants showing low PR.

The PR of solar PV plants has continued to improve since early days of technology commercialization commenced in 1990s.

In the early 1990s, typical PR values hovered around 70 percent. With improvement in manufacturing process and cell efficiency, this value has improved to be around 80 – 90 percent in 2010. It indicates that overall, the solar PV technology is getting more efficient and reliable.



Source: Fraunhofer ISE

Figure 78: Solar PV Plant Performance Ratio through the years

Preventive maintenance plan

Performance monitoring of PV power systems must be backed with a rigorous preventative maintenance plan, to ensure longevity and reliability of the system. An example of a potential maintenance schedule and frequency is provided in Table 38.

Maintenance Work	Frequency
Ensure security of the power plant	Day-to-Day
Cleaning of solar PV panels to free from dust and bird droppings	Weekly
Monitoring power generation and export	Daily (Remotely)
Keep the inverters clean to minimise the possibility of dust ingress	Quarterly
Ensuring all electrical connections are kept clean and tight	Half-yearly
Check mechanical integrity of the array structure	Annually
Check all cabling for mechanical damage	Annually
Check output voltage and current of each string of the array and compare to the expected output under existing conditions	Annually
Check the operation of the PV array DC isolator	Annually

Table 38: Preventive maintenance plan

CHAPTER 14: PREPARATION OF TECHNO COMMERCIAL REPORT

Objective of preparing a techno commercial report

A techno-commercial report is an important piece of document in the overall solar PV project process. Its purpose is to serve as a pre-feasibility report for the decision makers, providing information on project site, available solar resource, system sizing, system yield, risks and mitigation strategies and financial indicators.

In effect, this document provides a go or no-go assessment for the decision makers, based on which the commission or abort funds to a project. In an entrepreneur's context, a techno-commercial report is a good communication and marketing tool to be presented to client to seek investment for a sale.

The overall objective of the report is to inform decision makers of the following project components:

- Techno-economic feasibility of the project
- Background and capacity of the promoter
- Site details
- Technical details of the project
- Energy yield projection and life cycle performance
- Economic and financial details – Project cost, Return on Investment
- Statutory requirement and compliances
- Environmental impact
- Project construction schedule and execution plan
- Operation & Maintenance Plan and manpower requirement
- Risk and ways of mitigation

The level of detail put in these reports is typically subject to the audience and scale of the project. As an example, a techno-commercial report may not even be required for installations of up to 5 kW for domestic clients, or, 3 to 5 pages of feasibility report may be provided for a system size of 5 kW to 20 kW to commercial clients. Industrial clients, of more than 20 kW, may be interested in doing a full scale techno commercial investigation before allocating funds to a project.

Content of a techno commercial report

A techno-commercial report may have the following contents.

- Financial and technical capacity of the Promoter to deliver a project
- About the site
- Solar resource assessment
- Selection of suitable PV technology
- Plant layout and technical specification
- Power system and grid interface
- Statutory requirements & compliances
- Project implementation schedule
- Operation and maintenance plan

- Economic assessment and financial analysis
- Environmental impact assessment
- Risk assessment and mitigation
- Sensitivity analysis
- Recommendations

Similar to above section, the level of detail put in these reports is also subject to the audience and scale of the project.

Methodologies to prepare a techno-commercial report

While there are no hard and fast rules for writing a techno commercial report, some typical methodologies may be applied to create a comprehensive report for the decision makers. A brief description of these methodologies, elaborating content for some of the points the points listed under the table of contents, is provided below.

About the promoter:
This section provides details on:

- Legal and financial status of the promoter, their objective of taking up a project and a resolution statement from the company Board indicating commitment for the project.
- A short CV of the core team, providing information on qualification and experience of core team should also be given.
- The financial and technical credential of the organization should also be provided. Some of the examples of these credentials include ISO ratings, credit score ratings, and membership certificates from industry organizations or relevant government panels.

About the site:
This section provides details on:

- Site coordinates, indicating location and availability of irradiation data for the project.
- Near and far (horizon) shading, indicating risks to system performance.
- Accessibility of the site by road/rail/air, important for organizing logistics associated with procurement of components.
- Water availability and quality of water for cleaning of solar PV systems once installed and commissioned.
- Socio economic issues involving habitation in vicinity, availability and security of labor availability. This will provide an idea of the availability of skilled labor in the area to deliver a work order, and provide O&M service to the installation. The labor can either be sourced from local contractors or organized by the promoter. Information on habitation is important in identifying vandalism risks from vandalism and future development of land or building, thus shading the system.
- Existing power infrastructure, grid interface and power evacuation facility for interconnecting to the grid and activating net metering.
- Natural environment, dust, pollution, salinity to account for losses due to system derating. These losses could amount to as high as 10 percent in some cases.

- Risks of Natural calamities – cyclone, flood, land slide, erosion, earthquake – based on available data should be provided. These pose risks to the investment put in the system.
- Climate data including temperature, wind, rainfall, and humidity, all important for forecasting system performance and accounting for losses.

Solar Resource Assessment

Sourcing of solar resource data is critical for reliable forecasting of energy yield from the system. Overestimations and disappointments can result from using only one source of data as there.

- Collect solar data from reliable multiple sources, including but not limited to NASA, Meteonom, MNRE and Solar GIS.
- Understand the appropriateness of the data as to whether the data collection centre is ground based or satellite based. The ground based (pyronanometer) data is most accurate, but may not be available for all places in the country.
- Compare and analyze data from multiple sources to draw an informed conclusion on level of estimation required for PSH data.
- Use conservative data; it is better not to promise too much rather than under deliver.
- Know the period of data. More recent data is likely to be more accurate.
- Understand risk of uncertainty and mention it in the report. Uncertainty is inherent in solar resource assessment process, acknowledge it and provide a window of accuracy for reference, for example, “all data is within the accuracy of +/- 20 percent”.
- Follow the user’s manual or instruction from data provider
- Derive p(90), p(70) and p(50) data whenever possible/ required.
- Indicate data accuracy in your report. This is generally available from the metadata of the data source.
- Study and understand coordinates of the site to arrive at decision on optimal system tilt and azimuth. Generally, a true south azimuth and a tilt angle equal to the latitude of the site results in best energy yield through the year. Software programs such as PVSyst, Heliscope and HOMER can be used to determine the optimal tilt and orientation based on site specific needs.

A screen grab of PVSyst software is illustrated in the following figure. The figure provides the best possible tilt at the site for yearly energy yield. It shows that at most optimal orientation, the loss is 1.8 percent.

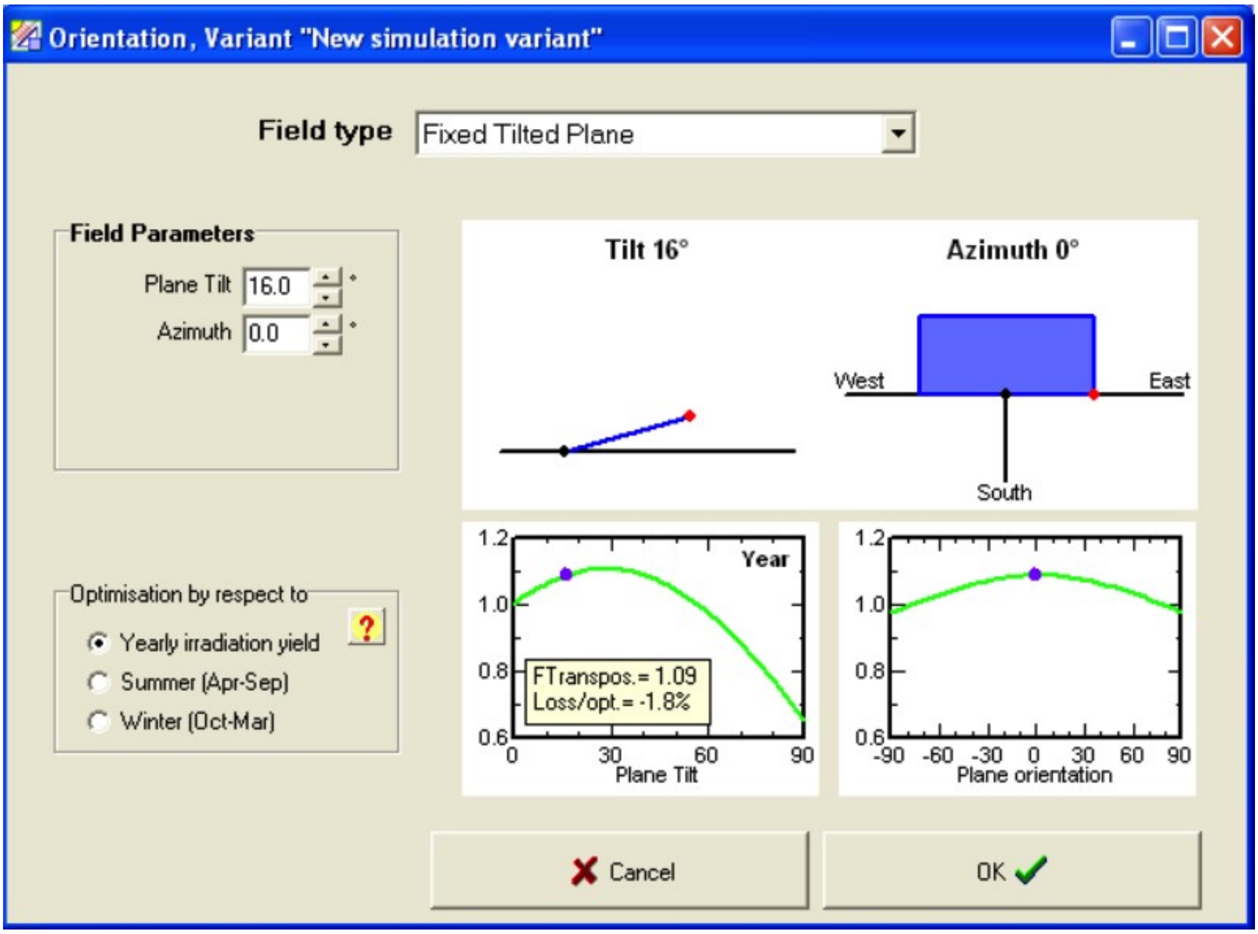


Figure 79: Solar resource assessment - tilt angle optimization

PV Technology Choice

Choice of PV technology is based on a range of factors, including budget, space constraints and local shading and climate variables. Choice of technology for the project should be explained in the report to client, and should include the following.

- Type of technologies including Crystalline and Thin Films
- Pros and cons of different technologies with respect to site climate, supply chain, availability, in-country policies and regulations etc. For example, thin film modules tend to be cheaper than crystalline modules, and perform better in shading situations, but require almost 50 percent more space to deliver same amount of electricity as they are less efficient.

PV Power Plant Performance Simulation

The PV power plant performance should be simulated to communicate the generation profile of the system to the customer. This plays an important role in establishing informed plant performance expectations and avoids disappointments in the later stages of a project. Several simulation programs are available in the marketplace; PVsyst and HOMER are two of the popular ones. The simulation should provide:

- Estimation of annual energy yield for different shortlisted technologies
- Generation loss estimation for site conditions. Typical losses occurring in a rooftop solar PV system is listed below. In cases poor system design and climatic conditions, these losses could compound to about 50 percent of the rated capacity of the system. In India, a loss factor of 20-30 percent is typically observed.

Cause	Average Expected Loss (%)	De-rating Factor
Temperature	10-15%	0.90 – 0.85
Dirt	5 – 15%	1.0 – 0.85
Manufacturer's Tolerance	0 – 5%	1.0 – 0.95
Shading	0 – 20%	1.0 – 0.80
Orientation	0 – 20%	1.0 – 0.80
Tilt Angle	0 – 10%	1.0 – 0.90
Voltage Drop	0 – 5%	1.0 – 0.95
Inverter	4 – 10%	0.96 – 0.90
Battery (standalone system)	10 – 20%	0.90 – 0.80
Charge Regulator (Standalone sys)	5 – 10%	0.96 – 0.90

Table 39: Summary of losses in a PV system

Life cycle energy generation of solar power plant is estimated after consideration of performance degradation of solar PV modules over the system life. Typically, this figure sits around 0.7 percent to 1 percent each year for crystalline modules. Actual degradation will depend upon quality of modules.

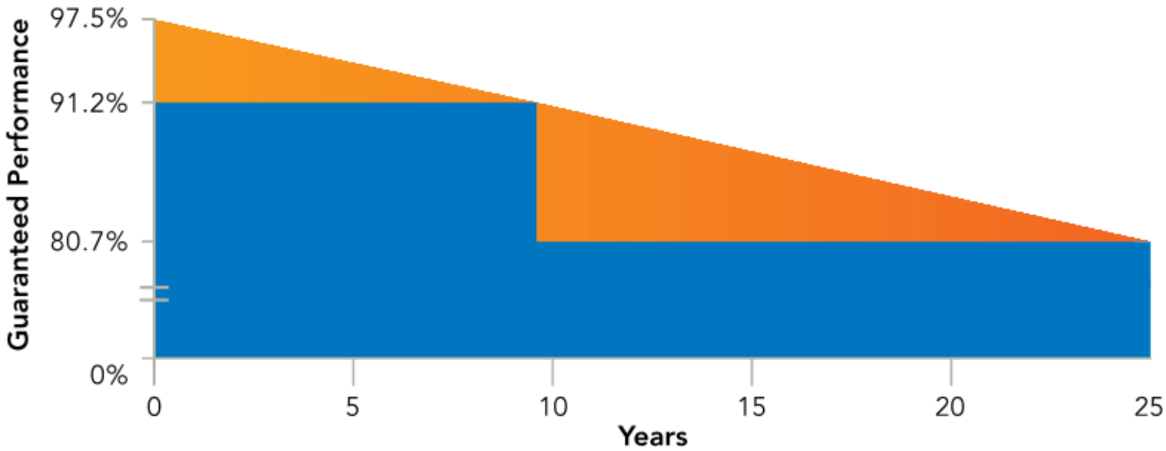


Figure 80: Example of module degradation

Fundamentally, the amount of energy delivered by the PV system depends primarily on size of the PV array, mount of irradiation (sunlight) it receives and the total efficiency of the system after considering all the losses and performance degradation over life cycle. It is expressed as the following algorithm.

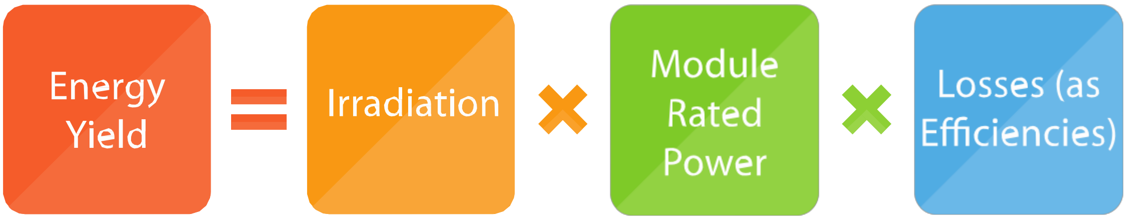


Figure 81: Energy Yield Estimation – How to estimate?

For selection of PV technology following steps may be followed:

1) Compare of projected energy yield for project life cycle for different technologies
2) Consider other cost factors
3) Select technology after trade-off on energy yield projection and levelized cost of energy (LCOE)

Power system and grid interface

This happens to be a most critical component of a grid connected rooftop solar PV project. A report should inform the customer on the process, cost, timelines and documentation requirements from customers to enable the utilities activating the grid connected system. The report should:

- Assess availability and characteristic of Distribution Transformer (DT) nearest to the site.
- Suggest grid interconnection facility requirements and component specifications.
- Estimate cost for interconnection.

Statutory Requirements & compliances

There may exist some statutory and compliance requirements in the area where an installation is scheduled. Some of the typical statutory and compliance requirements associated with large scale solar PV projects are listed below. The entrepreneur is advised to follow up with relevant state nodal agencies and electricity boards to understand which requirements and compliances are relevant to their project, and list them in the techno commercial report.

- Regulatory approvals,
- Land ownership and land use conversion
- Project registration/MOU with concerned agency
- No Objection Certificate from local authority
- Clearances from the State Transmission Unit (STU)
- Approval of the Electrical Inspectorate
- State Pollution Control Board Clearance
- Pollution Control Board Clearance
- Environmental and forest clearances

- No objection from local administration
- Technical feasibility report from local utility
- Clearance from airport authority if required
- Import export code if required
- PPA, if client wishes to have one.

Construction schedule

A construction schedule details the work program, milestones, deliverables and timelines of a project. While there are many ways and tools to present this information, a Gantt chart is highly used as it provides a good visual to the client about relevant details and completion timelines. An example of a Gantt chart is illustrated in Figure 82.

S.N	Activities	Sept 10	Oct 10	Nov 10	Dec 10	Jan 11	Feb 11	Mar 11	April 11	May 11	June 11	July 11
1	Mobilization											
2	Application/ clearance from NVVN											
3	PPA/ other permitting and clearances											
4	Engineering Design											
5	Internal roads and civil work											
6	Contouring of Land & leveling											
7	Construction of Fencing											
8	Construction of Control room											
9	Construction of internal Roads/paths											
10	Earth work for Structure foundations											
11	Foundation works											
12	Placement of order for solar system					PV/INV	BOS					
13	Placement of order for electrical system					X-mers	Others					
14	Erection of array mounting Structures											
15	Mounting of Modules to structure											
16	Module inter connections and cabling											
17	Installation of inverters											
18	Wiring and cabling for PV system											
19	33kV transmission line (3km)											
20	Power Evacuation Equipments											
21	Cabling											
22	Earthing Equipment installation											
23	Testing of PV array											
24	Testing of the Earthing system											
25	Testing of the Inverters											
26	Charging of Transformers											
27	Testing switch Gears & safety Relays											
28	Hooking of the complete system											
29	Hooking up with Grid											
30	Synchronization with the Grid											
31	Testing of the complete system											
32	Commissioning of system											

Figure 82: Project Schedule Gantt Chart

Operation and Maintenance Plan

An operation and maintenance plan is integral to the overall project process. This should be included in the report advising client on the process of ensuring that the system will be monitored and attended for reliable performance. The areas which will need covering include:

- Preventive Maintenance Schedule such as annual cleaning, checking of connections.
- Manpower and skill development plan for provision of maintenance services locally.
- Breakdown maintenance strategy advising how would the entrepreneur respond to maintenance callouts.
- Strategy to minimize downtime advising the process of getting system back up and running.

- Spare parts strategy to replace the damaged or non-functioning part both inside and outside warranty period.

An example of a potential maintenance schedule and frequency is provided in Table 40.

Maintenance Work	Frequency
Ensure security of the power plant	Day-to-Day
Cleaning of solar PV panels to free from dust and bird droppings	Weekly
Monitoring power generation and export	Daily (Remotely)
Keep the inverters clean to minimise the possibility of dust ingress	Quarterly
Ensuring all electrical connections are kept clean and tight	Half-yearly
Check mechanical integrity of the array structure	Annually
Check all cabling for mechanical damage	Annually
Check output voltage and current of each string of the array and compare to the expected output under existing conditions	Annually
Check the operation of the PV array DC isolator	Annually

Table 40: Example of operation and maintenance schedule

Economic Assessment

The economic assessment information will be used by the client to decide whether or not to invest in the project. This is typically applicable to large scale rooftop projects involving corporate or government clients. An economic assessment must be comprehensive and should include all possible financial costs and benefits from the project.

An example of few of these costs is listed below.

Costs:

- Equipment
- Erection, installation and commissioning
- Engineering design and project management
- Preliminary and pre-operative expenses
- Legal and statutory expenses
- Interest during construction
- Upfront financing fee
- Lender's engineer's fee
- Contingency
- Operation and maintenance Cost

Financial benefits:

- Accelerated Depreciation of system, 80 percent of the costs is allowed to be claimed from taxable profits in the 1st year.
- Revenue in form of offsetting electricity bills, income from feed-in-tariff, in case of gross metering schemes
- Revenue from the sale of REC and carbon credit.

These cost and benefits are further used with the following financial parameters to give a complete picture of the investment.

Financial Parameters

- Debt/equity ratio; usually 70:30
- Taxes on income from solar PV project
- Discounting Factor or hurdle rate marked by the customers

These parameters, cost and saving inputs are taken through the financial analysis process to give the following results.

- IRR Pre tax
- IRR Post tax
- Equity IRR Pre tax
- Equity IRR Post tax
- Project payback period (Capital Cost/Savings)
- Debt Service Coverage Ratio (DSCR)
- Average cost of electricity generation in Rs/kWh

Results of the above analysis lets client compare financial returns from solar project with other investment options, and make an informed decision on the project.

Economic Assessment – Project payback period

Example: A 5kWp PV system is installed at a cost of Rs.300,000 and the system is expected to displace 5,000 kWh of grid electricity and export 2,500kWh of electricity to the grid each year. The cost of electricity is Rs. 6/kWh and value of Feed-in Tariff (FiT) is Rs. 3/kWh. What is the project payback period?

Solution:
Income generated from the FiT: 2,500 kWh/year × 3/kWh = 7,500/year Money saved from self-consumption: 5000 kWh/year × 6/kWh = 30000/year Total system value: 7,500 + 30,000 = 37,500/year
Payback Period: 3,00,000 ÷ 37,500 = *8 years*

Environmental Impact Assessment

This may be applicable on case by case basis, typically for larger projects mandated by government. If required, the following factors must be considered and included in a techno commercial report. The process, in summary, is to collect project related information data from public sources and assess the major positive and negative environmental impacts which can be created from the proposed solar PV project.

- **PHYSICAL ENVIRONMENT data on** air emissions, water use, effluents, raw materials use, waste generation, energy consumption, noise and vibration and land contamination
- **BIOLOGICAL ENVIRONMENT** data on eco-sensitive land and water bodies
- **SOCIO-ECONOMIC ENVIRONMENT** data on local employment, health and safety

An assessment of significance of impacts on the three sectors mentioned above, a description of each of the mitigation measures and suggestions of an environmental monitoring program should be included in the environmental impact assessment report.

Risk Assessment and Mitigation

A risk assessment and mitigation planning should be inherent part of the decision making process of both the entrepreneur and the customer. While a risk assessment and mitigation process may not solve everything, it does provide an insight into the problems or hazards which may face a project in longer run. This would allow the project developer to come up with strategies to manage or reduce the risks, and avoid surprise. Some of the most commonly observed risks in relation to PV projects are listed below.

- Technology Risk
- Policy and regulation
- Financial Risk
- Grid Reliability
- Solar Data and energy generation forecast
- Performance warrantee
- Risk from Quality of design and Installation

Summary and recommendation

In summary, a techno commercial report is an important piece of document. It briefs the clients on the technical, commercial and environmental viability of the project and makes them aware of the potential risks and avoidance strategies. While it may not be relevant to all section of customers, especially to the ones who install small scale systems, it is hugely important for corporate and government clients, which will use it as a decision making tool. A techno-commercial report typically covers the following topics.

- Site details
- Grid interconnection facility
- Solar PV Technology used for the project
- Statutory requirement and clearances
- Design parameter
- Solar resource data

- Energy generation projection
- Project development cost
- Financial results

CHAPTER 15: INTERACTING WITH CLIENTS

Understand customer requirement/motivation

Understanding a potential customer's requirements and identifying the desire to put a solar rooftop system is the first step in a sales process. This will be of great value in identifying the customer segments one would like to pursue, and concentrate sales prospecting resources into the specific customer segments, thus increasing the likelihood of leads turning from potential customer into clients.

Similar to any other product or service, grid-connected solar PV will only be a sellable commodity if it solves a potential problem of a customer, or serves their needs. While it is challenging to identify all such motivations/requirements, few of the most cited ones are listed below:

- **Reducing their energy bill –** This is one of the most cited reasons for purchasing a rooftop solar PV business. In the Indian context, this typically applies to large scale consumers such as commercial and industrial buildings. Generally, energy bills for residential, commercial and industrial customers continue to be on the rise, and solar PV can be a good tool to reduce a client's energy bills.

- **Power during black/brown outs –** This typically applies to areas where the grid is weak, and black/brown outs are frequent. The grid connected solar PV system here will be designed with a battery backup, therefore increasing the cost of product. Care should be taken in communicating what is being sold to the client, as grid connected solar PV without battery back-up will not work when the grid is not present.

- **Environmental reasons –** This typically applies to customers with high level of environmental awareness. Budget may or may not be a constraint here, as this customer group is typically motivated to support clean energy technologies and engineering solutions such as rooftop solar PV, as an action to mitigate climate change.

- **Response to advertising –** A customer may approach a business as a result of advertising efforts.

- **Financial Benefits –** Many customers are interested in availing financial benefits that are announced by the government. These are helpful in reducing the cost of ownership of solar PV. They typically include MNRE and state subsidies, AD, and other excise duty exemptions.

- **Keeping up with the peers –** This customer group is motivated by their neighbors. Generally, it has been observed that uptake of solar PV is higher in localities where there was a competition between neighbors go get ahead of each other. While it is difficult to identify this customer segment, it is worth keeping in mind in delivering sales pitch.

- **RPO obligation –** The utilities and DISCOMs are typical customer segments here. These are obliged entities under RPO regulations and are required to purchase certain amount of renewable energy from project developers each year.

Determine PV system capacity

When approaching a customer, it is worth spending time to identify the site parameters which will influence and determine the proposed capacity of PV system. It is an important step of the sales process as it uncovers the opportunities and constraints available at the site, and sets out expectations from the project for both clients and developer.

A summary of factors which must be examined, documented and considered before developing design brief for a client are listed below.

- **Availability of shadow free area –** This will determine feasibility, technology choice as well as maximum possible capacity of the project.

- **Installation purpose and budget -** The client's requirements must be understood and a suitable solution must be designed. Avoiding this may lead to a perception of unsatisfactory system performance by the client, which may bring disrepute to the developer, and potentially loss of account.

- **Government program and incentive guidelines –** Many customers are interested in availing subsidies and incentives provided by the government. The project developer must be aware of the process and guidelines to bring these subsidies to the consumer.

- **State Electricity Regulation –** The State Electricity Commissions (SECs) have laid out regulations for interconnecting solar PV system to the grid in respective states. The project developer must be aware of these regulations for successful commissioning of the project.

- **Distribution Transformer (DT) capacity –** Most states, with an operational net metering scheme, require the installed capacity of solar PV system to be within a certain limit of the DT capacity in the area, for example, 15 percent of 1 MW DT. The project developer must be aware of these requirements before embarking on the design process.

- **Connected load –** Some net metering schemes require the connected load on the solar PV system to be limited to a certain percentage of the KVA or KW load sanctioned to the property. In many states, this limit is currently stated as 90 percent. A project developer must consult respective state's net metering policy and SECs. The project developer must be aware of these requirements before embarking on the design process.

More details on each of the aforementioned factors is provided in earlier chapters of this handbook.

Consult and determine a Design Brief

As previously discussed, understanding a client's motivation behind installing their PV system plays an important role in the design process. It is therefore important that a lot of conversations and questions should occur during a site visit; to uncover a customer's needs, and design an appropriate solution. It is also critical that the customers are given correct information on what the proposed system can and cannot do. This is important to set expectations outright to avoid disappointments and bad relationships with customers.

The goal of this communication is to ensure that the customer understands that:

- The 'income' from a system is often only manifest as a reduction in energy bills rather than a cheque or deposit in a bank account.
- A conventional grid-connected system does not provide power during blackouts.
- Government financial incentives are highly variable - what a household's neighbor received 6 months ago may no longer be available.

The above are only a few examples. The entrepreneur is encouraged to observe the general conversations which people have about solar energy, and prepare accordingly.

It is worth keeping in mind that the businesses that offer a 'one size fits all' standard system are not properly meeting their clients' needs. This is because clients differ in their energy consumption profiles, needs and expectations from a solar PV system. It is therefore recommended that the following three steps are undertaken to provide an 'individual' or 'tailored' solution for clients:

- The clients should be consulted to determine a design brief.
- Determine what the client wants from their PV system.
- Identify any design constraints. These design constraints should include budget, suitability of the site, aesthetics and requirement and size of battery backup.

In addition to client's requirement, the technical parameters which have been listed in the earlier chapters on system sizing, design and safety should also be considered when designing a system for safety and reliability. The process 'sizing' or 'matching' the PV array to the inverter is an important part of the design process. Inappropriately sized arrays may not only underperform, they may pose a serious safety hazard. An array must be sized because of the inverter's following parameters:

- Maximum input voltage
- Maximum Power Point Tracking (MPPT) range
- Maximum input current
- Maximum PV array rated power
- Maximum DC input power

Details on the above parameters is provided in chapters relating to system safety and design in Chapter 4, Design and Safety Overview of Rooftop Solar PV Systems.

Recommended information outcomes for the client

Few of the recommended communication outcomes from information provided to prospective clients are listed below. Please note that the list is indicative only and is aimed to provide starting thoughts to the entrepreneur.

- **Estimation of average daily electricity production from the solar PV system**, based on system size, peak sun hours (PSH) data and system derating variables. Details are provided in Chapter 4.
- **Estimation of Annual Yield (annual electricity production),** worked out from daily average electricity production, by multiplying the results with number of days in a year, i.e. 365.
- **Estimation of electricity production in the best and worst months of the year** based on the PSH data and load demand data. Generally, the best month has the highest solar resource to load ratio and the worst month has the least solar resource to load ratio.
- **Fraction of solar energy in their annual energy consumption.** The annual yield of the designed system should be compared with estimated annual energy consumption, and fraction of solar energy in annual energy consumption should be worked out.
- **The financial benefits derived from this reduction in annual energy consumption** in terms of avoided energy costs.
- **The greenhouse gas savings in tonnes or kg of CO_2 equivalent** as a result of using energy generated from a clean source.

System documentation

Upon installation and commissioning, system documentation of the project should be provided as per IEC 62446. This must include the following information.

- List of equipment supplied:
- System diagrams
- System performance estimate
- Operating instructions for the system and its components
- Shutdown and isolation procedures
- Maintenance procedure and timetable
- Installation checklist and commissioning records

This process is important for a safe handover of the system to the client and may even form as part of the requirement of the state electricity board for grid interconnection approval.

Warranty information

The following warranty applies to a typical rooftop solar PV project. This includes both product and workmanship and information on respective warranty elements should be provided to the customer.

- Product warranties covering defects in manufacture.
- Product warranties related to output performance over time.
- System integration (workmanship) warranties relating to proper operation of the installed system over time.
- Energy performance warranties relating to the guaranteed energy output of the grid-connected PV system over a period of time, typically a year.

Even as the entrepreneur may be purchasing components of solar PV system from manufacturers or distributors, a PV system is covered under consumer guarantees, whereby, the person selling and installing the PV system guarantees that:

- The goods being sold are not defective
- The service being provided is appropriate and the installation is of high quality

Provision and honoring of warranty is important to create long term goodwill and reputation in the market.

How to address troubleshooting

At times, the customer may send maintenance callouts to installer of the system when the system has stopped producing electricity. The installer will need to attend the callout, inspect and diagnose the system and provide a solution. Following is the example of decision making pathway which may assist in getting to the root cause of system under or non-performance. The questions one need to ask is:

- Is the system producing less power than usual (under-performing) or no power (non-performing)?
- Are any components obviously damaged?
- Is the inverter flashing lights or displaying error messages?
- How long has the problem been present?

For all of the above, check that you have a copy of the client's system documentation, if you don't you will need to ask the client for a copy. The technician will need to check this documentation and work backwards from inverter side to array side to look for the possible problems.

There could be a number of causes which may have caused to system to under-perform of stopped working. While a detailed description of each of these causes is beyond the scope of this handbook, a summary of some of the most commonly observed causes are listed below:

Most commonly, the following two causes are the first point of checks for a non-operating system.

- Grid supply is operating outside the range of the inverter's AC voltage/frequency window. Power will resume once the grid comes back within inverter's operating window.

- Shading objects such as cloud, tree, leaves, newly constructed buildings, dirt, snow, and antenna have obstructed path of light onto the system. While temporary soiling like tree, leave, snow and dirt can be removed annually, others may require either relocation of the system.

The Do's and Don'ts of selling solar

Running a rooftop solar PV business involves handling and communicating of a lot of technical information to largely non-technical customers. This creates a lot of space for miscommunication, creation and delivery of uninformed expectations from the system and poorly quoting for jobs without doing proper homework. While some may win clients based on these, in the longer run, wide spreading of these practices will hamper the sector's credibility, thus negatively affecting growth of the industry.

Here are a few tips for the Do's and the Don'ts for new entrepreneurs to enter this market and create long lasting enterprises:

The Do's:

- **Understand the market -** Find where the gaps are and what you can do well.
- **Explain the limitations of PV –** Yes, you cannot run your welder on PV system.
- **Streamline the sales process –** Efficiency and consistent communication is the key.
- **Conduct a Site Inspection –** Do not quote before this, the devil is in the detail.
- **Understand the Laws, Regulations and Standards –** Solar PV is a regulations driven market, spend time to know them all and achieve compliance.
- **Follow Standards and Industry Guidelines –** as above.
- **Explain the Quote –** Both inclusions and exclusions, the customer does not want surprises.
- **Build a Reputation as a Market Leader –** Quality work and word of mouth.
- **Discuss Comparative Offers –** Explain your point of difference or revise your offer.

The Don'ts

- **Use incorrect terminology and jargon -** If you get people confused, they will not buy
- **Size and quote a system without conducting an onsite assessment** – It will come back to bite in the end when the client's expectations are not met. You may end up bearing costs for things you did not scope, or you may lose the client, or there may be a conflict and subsequently litigation.
- **Make Unsupported Claims –** Solar PV systems are known to last for more than 20 years, long enough for your claims to be uncovered.
- **Advertise a system by its yield –** As it is different for different geographical regions in the country.
- **Advertise Financial Benefits without Context –** as above.
- **Relate Energy Production to Energy Use without Evidence –** Do not claim what you do not know.

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov