

YOUR OWN SUN

A Manual on Solar Rooftop



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WHAT IS SOLAR ROOFTOP?

A solar photovoltaic (PV) system mounted on a rooftop of a building is a mini-power plant that converts solar energy into electricity to meet the property's power requirements or feed into the grid. Although anyone can install a solar rooftop system, the size of the installation varies significantly depending on availability of space, amount of electricity consumed by the property, and the ability or willingness of the owner to invest the capital required.

A 1 KW SYSTEM CAN GENERATE ABOUT 1,600 UNITS OF ELECTRICITY IN A YEAR

Load that would be met by
1KW
solar rooftop system with battery backup



Lighting | 4 LED lights (8 W)
12 HOURS



TV | 1 (100 W)
5 HOURS



Laptop | 1 (50 W)
2 HOURS



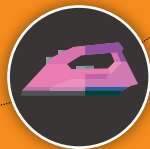
Ceiling fan | 2 (75 W)
8 HOURS



Refrigerator | 1 (150 W)
6 HOURS



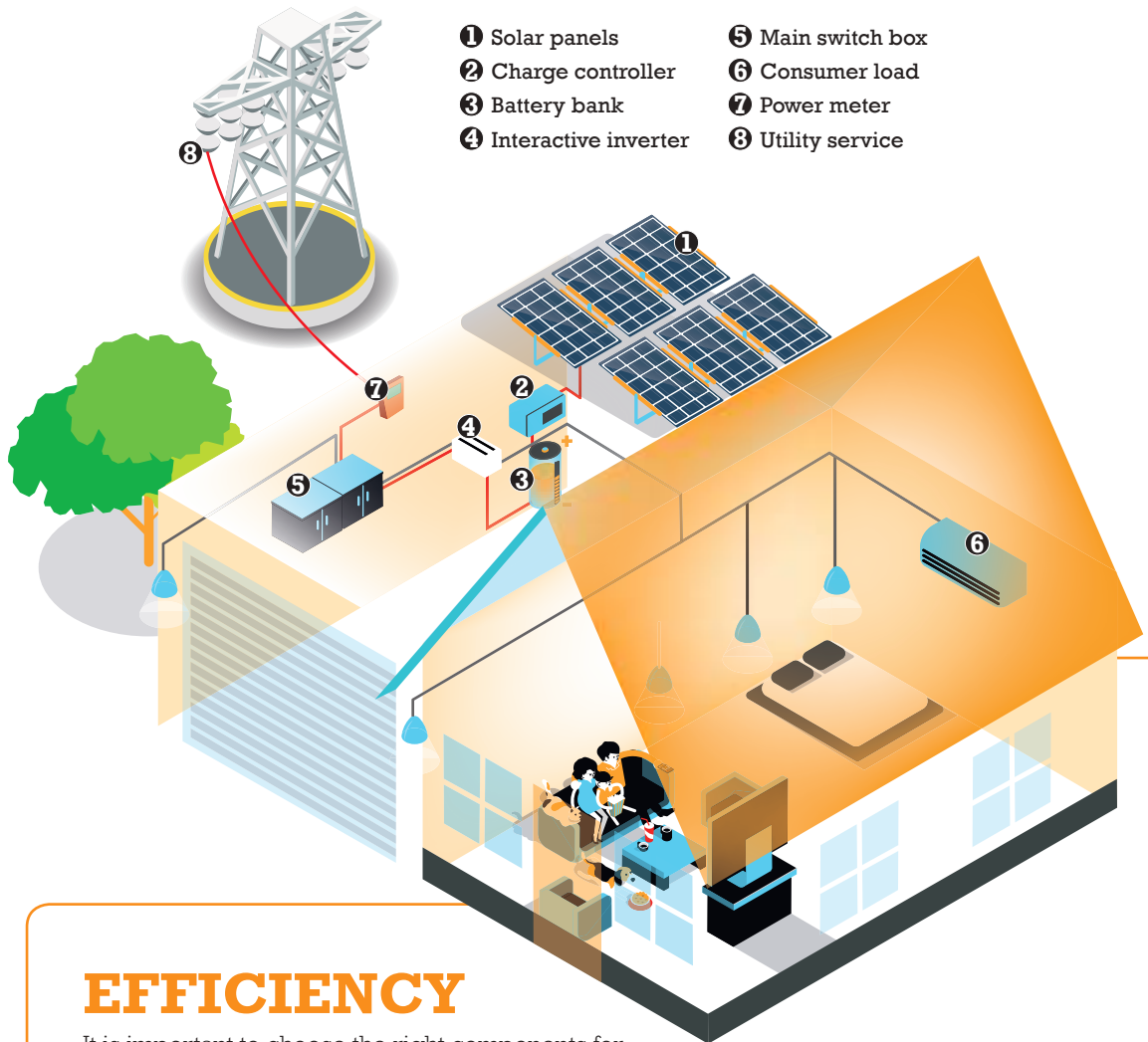
Kitchen mixer | 1 (750 W)
0.2 HOURS



Iron | 1 (1,000 W)
0.5 HOURS

TYPICAL LAYOUT OF A SOLAR ROOFTOP SYSTEM

The basic components of a solar rooftop PV system include PV modules, inverters and mounting structures. Other components like string boxes, transformers, meters, charge controllers, batteries and generators can also be incorporated into the system depending on its size.



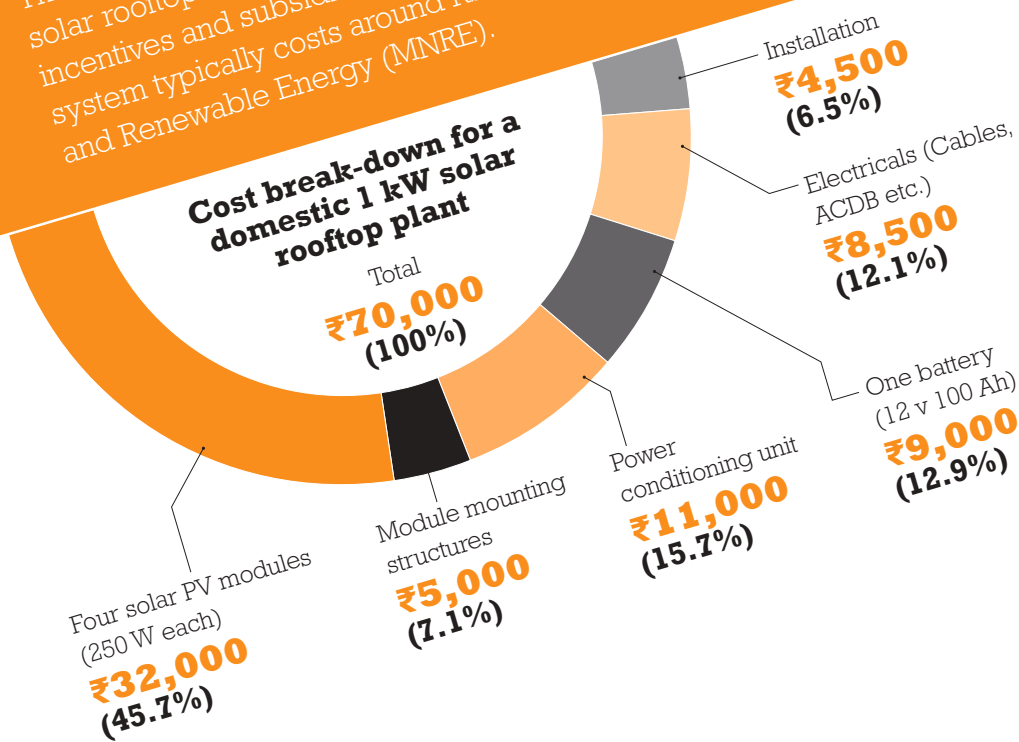
EFFICIENCY

It is important to choose the right components for the most effective use of solar PV systems. A PV module can generate 10–300 W output. The size of a solar PV module or panel required will depend not only on the output (requirement of the system) but also on the efficiency of the system. Expressed in percentage, the efficiency of the solar panel quantifies its ability to convert sunlight into electricity. Therefore, more the efficiency, more will be the electricity generated by a panel for a given area of exposure to sunlight. A majority of the panels available in the market today are around 14–16 per cent efficient, with a lifespan of 25 years. Solar modules do not require a lot of maintenance but it is good to clean the system of dust and bird droppings regularly to maintain the efficiency of the system.

SYSTEM COST

The cost of the system is considered the most important aspect in installing a solar rooftop. It broadly depends on the type of the system and the financial incentives and subsidies provided by the government. A 1 kW solar rooftop system typically costs around Rs 70,000, according to the Ministry of New and Renewable Energy (MNRE).

Source: CSE Analysis



TYPES OF BATTERIES

Two types of batteries are commonly used in solar systems—lead-acid batteries and lithium-ion batteries. Lead-acid batteries are cheaper and more reliable. Most household inverters rely on the dependable technology of lead-acid batteries. But these batteries are bulkier and have a lower lifespan of five–ten years. They are 80 per cent efficient (four-fifths of the energy stored in them can be reclaimed).

Lithium-ion batteries are used in phones and laptops. They possess a greater depth of discharge (reusable capacity) and, therefore, have a longer lifespan of 13–18 years. However, they are 50 per cent costlier than lead-acid batteries, and are less commonly used in rooftop systems.

LIFE OF A SOLAR MODULE

Generally, modules come with a warranty of 20–25 years. The output of a panel falls down every year (degradation) by around 0.8 per cent, which means a panel will produce around 80 per cent of its rated power after 25 years of use. Most solar panels used in India are made in China.

The longest operating PV plant in the world is in Spain. Installed in 1994, it supplies electricity to the national grid. Small-scale solar PV systems began to be installed in India in the 1980s. The longest operating large-scale PV plant in the country was established in 2009.

FINANCIAL ASSISTANCE

MNRE provides Central finance assistance (CFA) of 30 per cent of the benchmark cost for grid-connected rooftop projects. (The benchmark cost for 2017–18 for systems up to 10 kWp is ₹ 70,000 per kW; for >10–100 kWp it is ₹ 65,000 per kW; and for >100–500 kWp is ₹ 60,000 per kW.) CFA is only available for systems in the residential, institutional and social sector installed for personal consumption. For special category states, i.e., Northeastern states, Sikkim, Uttarakhand, Himachal Pradesh, J&K, Lakshadweep and Andaman & Nicobar Islands, CFA of 70 per cent of the benchmark cost is available.

In addition to CFA, some states also provide additional benefits to consumers who install solar rooftop systems. In Delhi, consumers receive a generation-based incentive of ₹ 2 per unit (kWh) on gross solar energy generated in a year. In Gujarat, a subsidy of ₹ 10,000 per kW is provided to household consumers (with a maximum limit of ₹ 20,000 per consumer) in addition to the 30 per cent subsidy scheme of MNRE.

Although there is no CFA for commercial and industrial sectors, these installations are eligible for accelerated depreciation benefits. The Centre also provides other benefits like custom duty concessions, excise duty exemptions, and soft loans from different banks. Several major banks of India have made solar rooftop PV a part of their home loan and home improvement loan schemes. State governments also provide a wide range of state-specific incentives, which is provided in their state net and gross metering, or solar policies.

PROCEDURE TO INSTALL SOLAR ROOFTOP

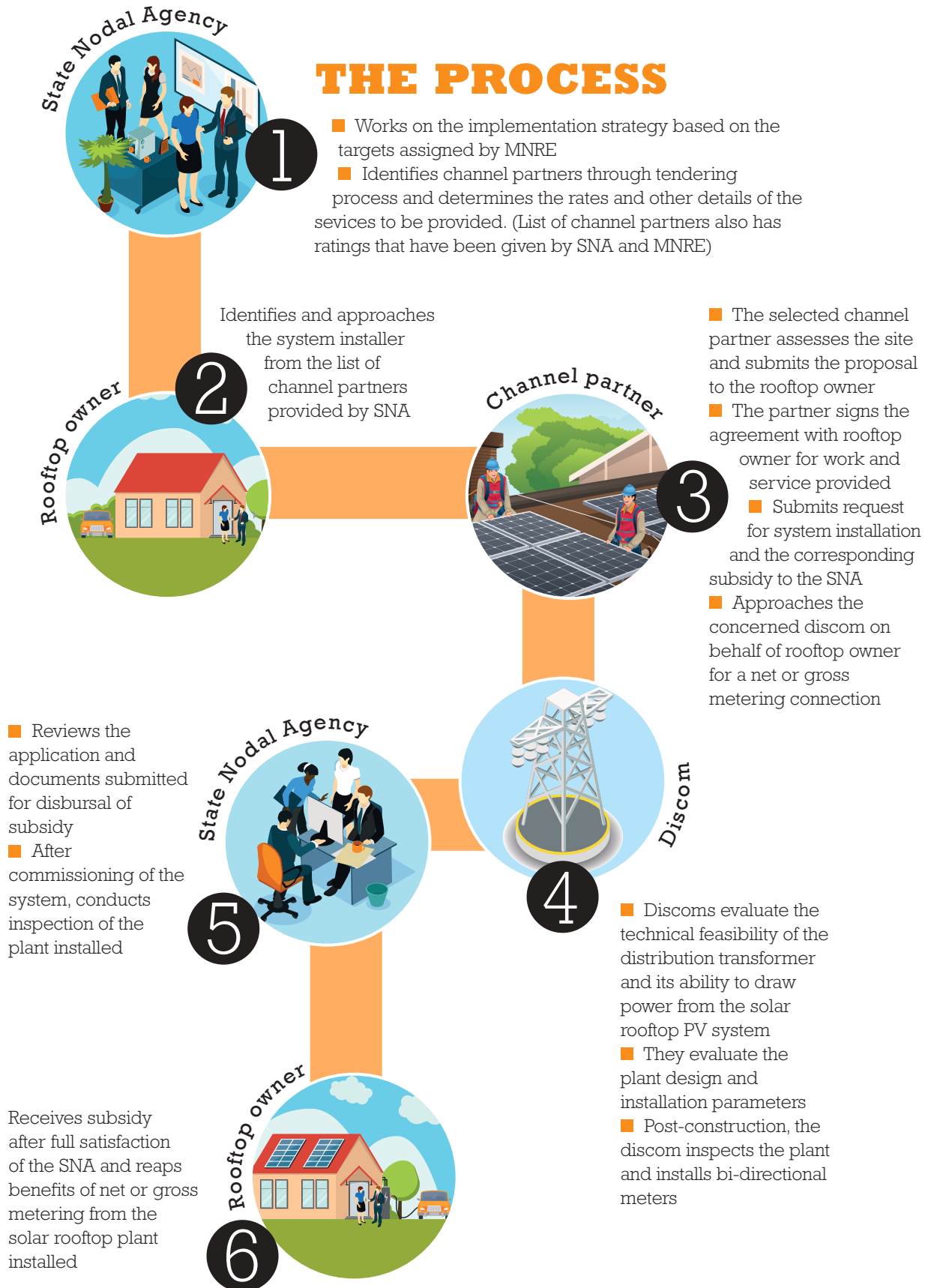
Before designing a solar rooftop system, it is important to understand the consumption load of the house. Typically, a house has various sources of electricity and many appliances that consume it. By feeding this information into a simple online tool—**solarmyroof.cseindia.org**—a consumer can determine the size of the rooftop system he needs, and the space and money required to install it.

To install the system, the consumer can approach one or more of the channel partners approved by MNRE. Channel partners are agencies empanelled by MNRE to install solar PV systems. Importantly, they facilitate individuals and small groups of clients to access the benefits available under the solar rooftop programme. State-wise channel partner list can be accessed at **http://solarrooftop.gov.in/Agencies_list.html**. Once selected, a channel partner submits a proposal to the rooftop owner as per site assessment and signs an agreement for the installation of the system, on basis of either capital expenditure or the RESCO model (see *section on types of solar rooftop PV*). The channel partner then applies for a net or gross metering connection (refer to *section on metering types*) from the concerned distribution company (DISCOM) on behalf of the roof owner. In general, it takes 45–60 days, depending on the state of the consumer, to get a net metering connection and installing a bi-directional meter.

To obtain the subsidy, the channel partner files an application for evaluation with the State Nodal Agency (SNA) or Energy Development Agency, set up by MNRE in every state to oversee the implementation of various schemes including solar rooftop, with all the relevant details, including the technical and financial aspects of the project. The details of all state nodal agencies are available at **<http://mnre.gov.in/mission-and-vision-2/contact-us/state-nodal-agencies/>**.

After evaluation, the project is forwarded to MNRE for final consideration and approval. Once approved, subsidy is disbursed. Many channel partners install the system at lower capital expenditure, assuming they would receive the subsidy, effectively shifting the burden of waiting for disbursement of subsidy from consumers to channel partners.

THE PROCESS



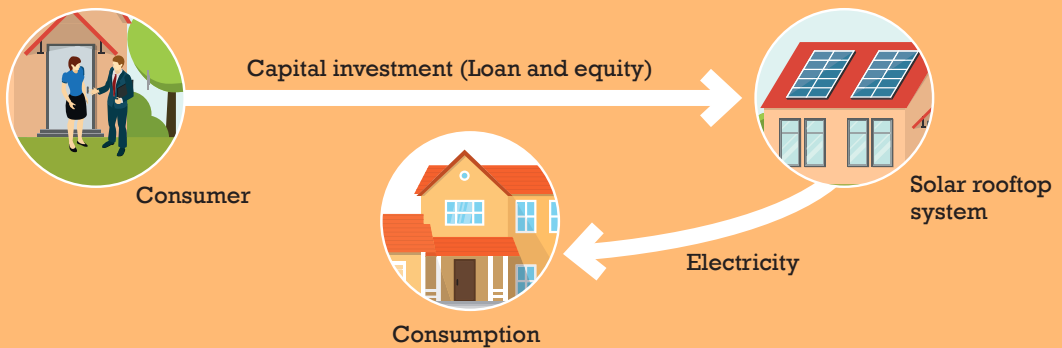
FINANCIAL MODEL-BASED CLASSIFICATION

There are two financial models under which a solar rooftop plant can be developed in India

1- Capital expenditure (CAPEX) model

Under the CAPEX model (pursued by developers like Sukam, Moserbaer and Tata Power Solar), a consumer purchases a solar rooftop plant like any other electronic gadget by investing in the entire system. The drawback of the model is that rooftop owners have to pay for the entire project at the time of installation.

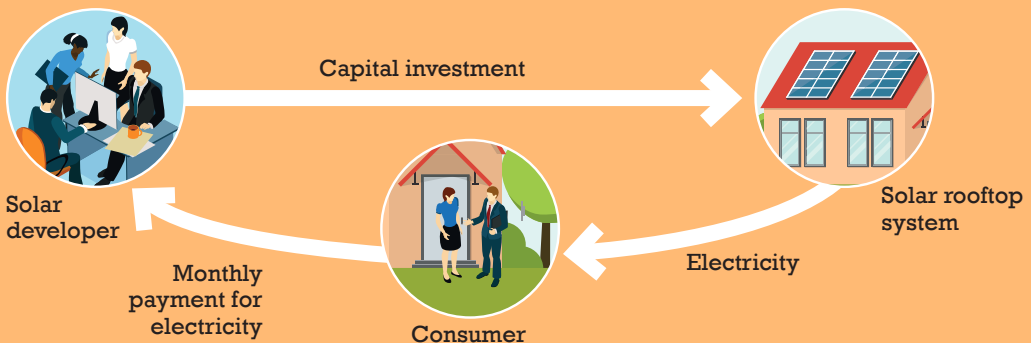
On the positive side of the CAPEX model, owners are eligible for capital subsidies from MNRE. In this model, the operations and maintenance (O&M) of the solar rooftop system is either with the rooftop owner or with the solar developer for the first few years, if stated in the contract. However, the subsidy is not available for commercial and industrial applications; instead, a tax benefit called accelerated depreciation (AD) is provided by the government. Under this scheme, the owner of the PV plant is allowed to depreciate most of the value of an asset in the first few years to reduce the tax liability of the company.



2- Renewable energy service company (RESCO) model

Under this model, a third party—a solar power developer installs the plant on the rooftop and sells the generated power to the consumer. The consumer does not have to make any investment. The tariff at which the consumer buys the solar power is mutually agreed upon through a power purchase agreement (PPA).

For consumers, in addition to the advantage of zero investment, they do not have to pay for the O&M costs as well, as these are usually the responsibility of the developer. This model is more feasible in case of institutional consumers, residential complexes etc., as developers are willing to offer long term PPAs as well as O&M contracts for such large-scale installations.

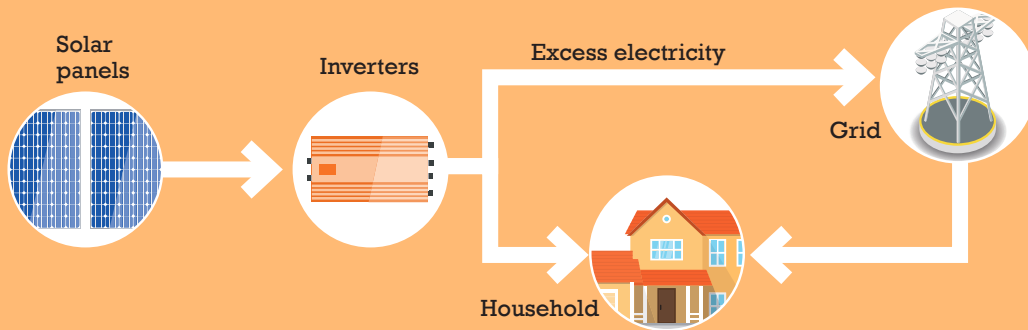


OPERATION-BASED CLASSIFICATION

Judging by operation, a solar rooftop PV can be classified into three types

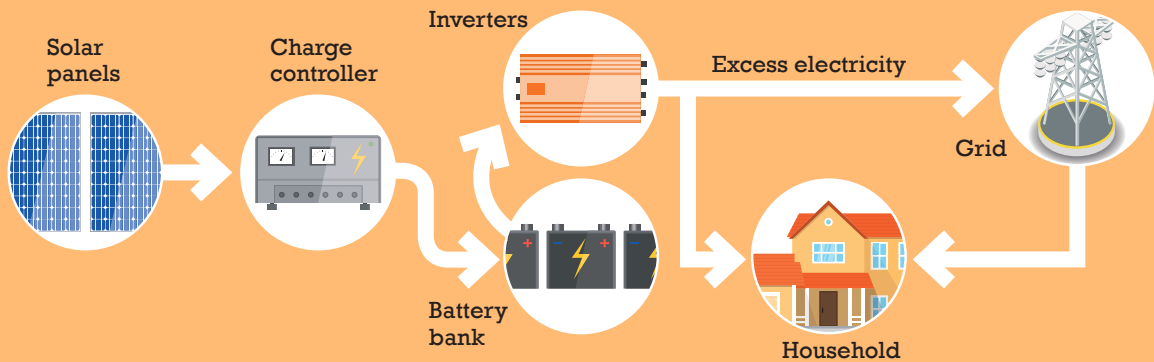
1- Grid-connected solar rooftop PV system

A grid-connected solar rooftop PV system is, as the name suggests, a plant connected to the grid through net or gross metering without any battery backup. Most of the state governments and the Central government are promoting this type of rooftop system.



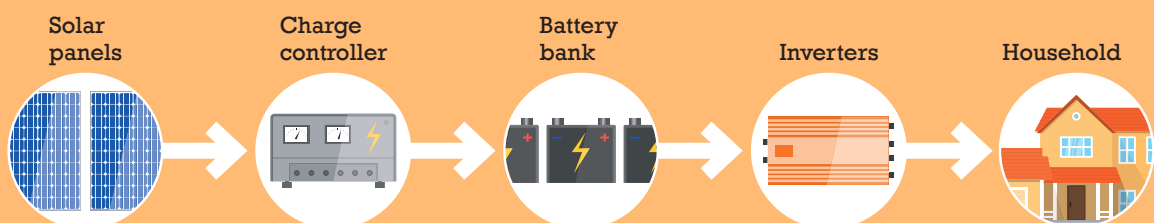
2- Hybrid plant

A hybrid rooftop system is similar to grid-connected solar rooftop PV, but it is installed with a battery backup. At times of power failure, the backup supplies power to the consumer, which a simple grid-connected solar rooftop system cannot do.



3- Off-grid plants

Off-grid plants are systems not connected to the grid. They are installed with a battery backup. They are considered to be expensive due to additional cost of battery bank. They are often installed in remote areas where the grid is yet to reach or will never reach.



POLICY FOR HOUSEHOLD SOLAR ROOFTOP

In 2016, Government of India released model building bye-laws and issued an amendment in the Environment Impact Assessment (EIA) Notification, 2006 in order to promote and encourage solar rooftop systems in the building sector.

The EIA Notification (which states are required to integrate with their building bye-laws) mandates all buildings spread in an area above 5,000 sq m to have at least 1 per cent of the connected applied load generated from renewable energy sources such as solar PV in order to obtain the necessary environmental clearance. If the state bye-laws integrate this clause, no separate environmental clearance from the Ministry of Environment, Forest and Climate Change is required. The model building bye-laws mandate all new buildings spread on more than 100 sq m to install solar PV.

Building bye-laws for solar rooftop PV

Category of buildings and area	Area standards	Generation requirement*
Plotted housing	For HIG plots and above	Minimum 5 per cent of the connected load or 20 W per sq ft for "available roof space"**, whichever is less
Group housing	All proposals, as per group housing norms	

Source: Model building bye-laws, 2016

*Area provisions on rooftop shall be @12 sq m per kWp, as suggested by Ministry of New and Renewable Energy.

** "Available roof area" = 70 per cent of the total roof size, considering 30 per cent area is reserved for residents' amenities.

In addition, some states have come up with their own provisions regarding the use of solar rooftop on residential and group housing buildings. For instance, Haryana has mandated the use of solar rooftop on all new residential and housing complexes. An HAREDA order issued on 21 March 2016 states that all new residential buildings on a plot size of 500 square yards or more have to install a solar rooftop system with a capacity of at least 1 kWp or 5 per cent of sanctioned load, whichever is higher.

For all new housing complexes, solar rooftop size is dependent on the area of the plot:

- (i) 0.5 acre to one acre—Minimum 10 kWp
- (ii) One–two acre—minimum 20 kWp
- (iii) Two–five acres—minimum 30 kWp
- (iv) More than five acres—minimum 40 kWp

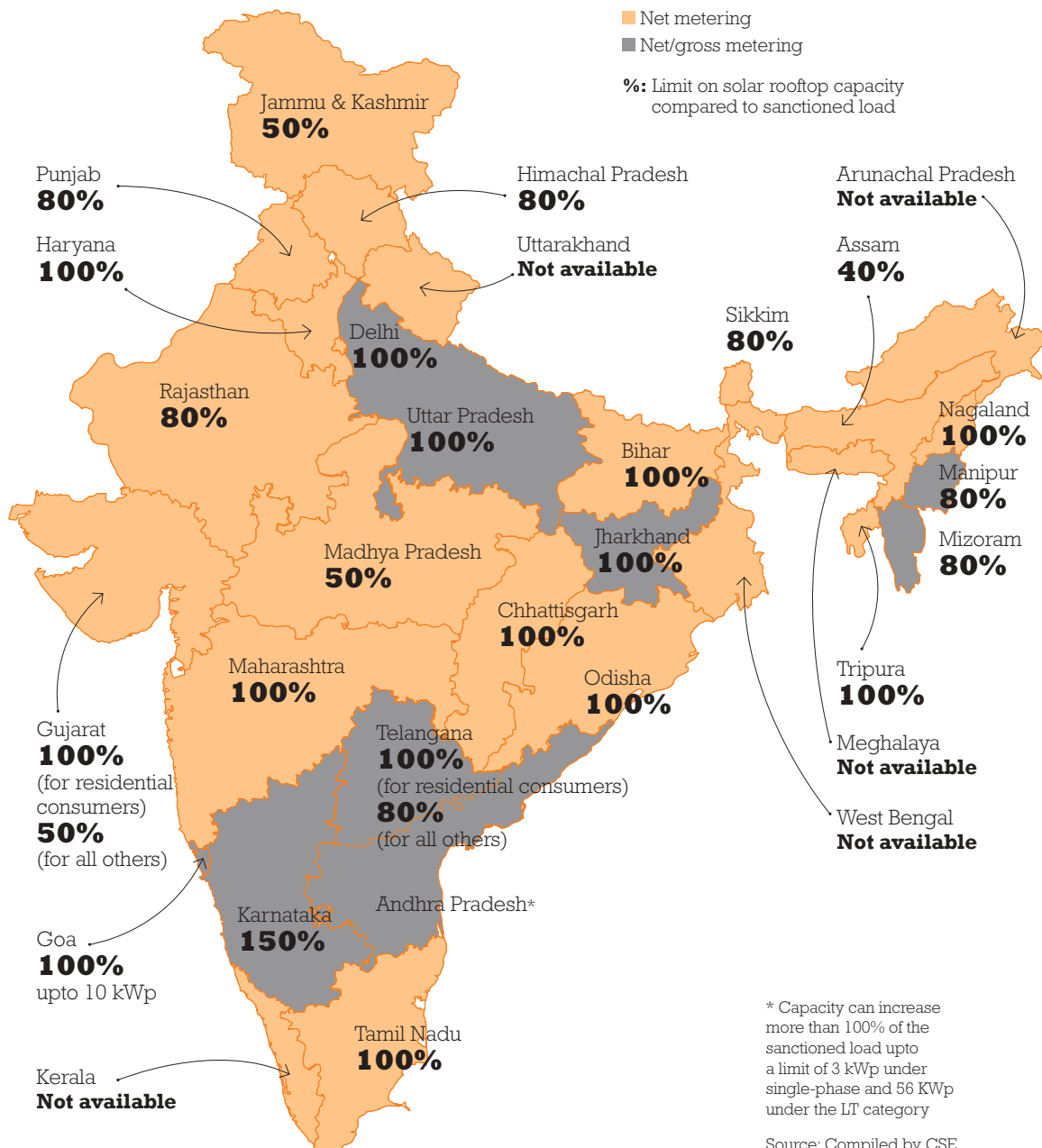
In an order issued on 31 May 2017, a provision was made in the Haryana Building Code, 2017 to grant benefit of additional floor area ratio if the applicant proposes to use a solar PV power plant.

Per cent of total connected load of the building generated by renewable energy	15–25	26–50	51–75	76–100
Additional FAR (per cent) for all building uses (except plotted residential)	3	6	9	12

The visible gap in these policy documents is that all clauses and changes are directed towards new buildings. For existing buildings that use huge diesel generator (DG) sets to partially meet their needs during power cuts, there are no provisions, even though their rooftops (or other spaces) can be utilized to generate electricity, thus partially replacing the DG sets and reducing the electricity bills of these societies.

ROOFTOP POLICY ACROSS STATES

The limit on the capacity of an individual solar rooftop system varies across states. A consumer in Delhi can install a system of a capacity matching his sanctioned load; in Madhya Pradesh, the maximum capacity of the system can only be 50 per cent of the load.



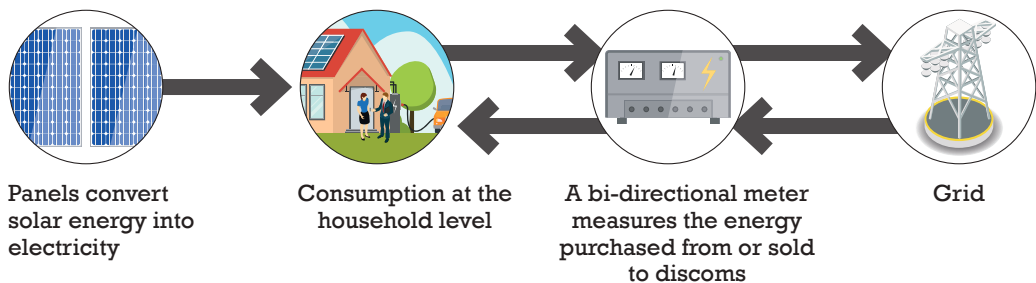
METERING TYPES

Type of metering affects the economics of a solar rooftop plant. Indian discoms offer two types of metering for solar rooftop plants, net and gross. The main difference between the two relates to accounting for energy consumed and billing involved.

1- Net metering

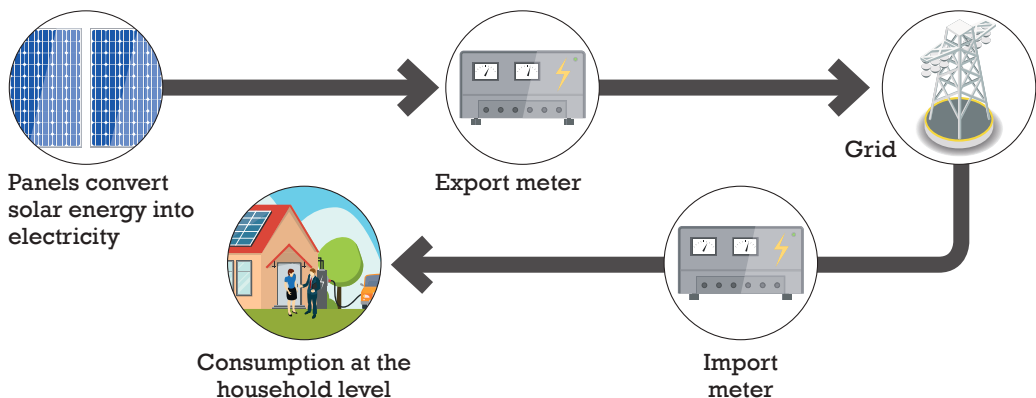
Under the net metering system, the electricity meter operates in both directions. The consumers make the first use of electricity produced by the solar rooftop plant and surplus, if any, is fed into the grid. If required, consumers can also import from the grid. The net meter will measure both electricity exported and imported by the system. At the end of the billing period, the net power consumed or sold is calculated.

If the net energy is positive (i.e. import is higher than the export), the consumer will pay the discom for the net units as per the tariff band. If it is negative, the discom may pay the customer or adjust during the next billing period.



2- Gross metering

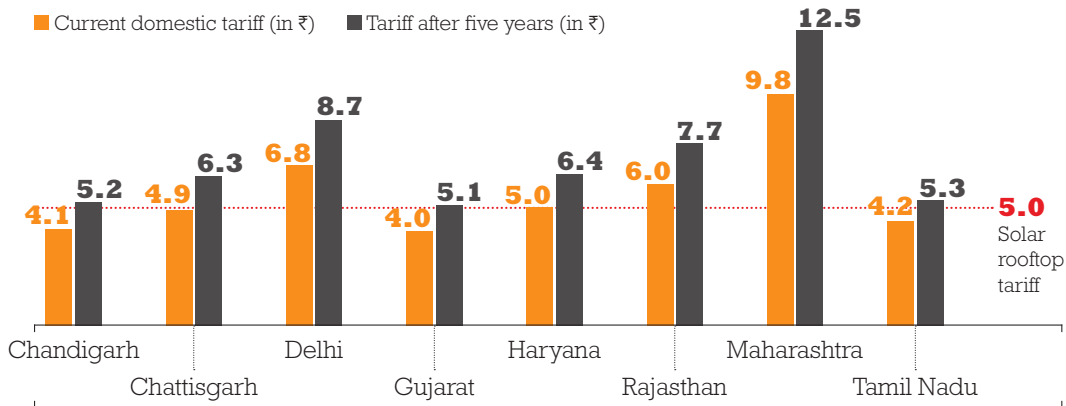
Under gross metering, generated power is not linked to consumption. Two separate meters are installed. The electricity generated by the rooftop system and the electricity imported from the grid are measured independently. Power generated by the solar rooftop plant is directly fed into the grid, which is measured through an export meter and power from the grid is imported through an import meter. By tracking the total units generated and the total units consumed separately, the discom has the flexibility to charge the two at different rates.



SOLAR VS GRID TARIFF

Electricity from solar rooftop is already cheaper than the average tariff for domestic consumers in Delhi, Haryana, Rajasthan and Maharashtra. Today, the tariff for solar from any rooftop system without battery is around ₹5–6 a unit. The electricity grid tariff ranges vary between ₹4–10 per unit between states. Considering an annual hike of 5 per cent, the average tariff for domestic consumers in almost all states will be higher than solar rooftop power in the next five years.

Solar rooftop tariff vs average state LT domestic consumer tariff



Source: CSE analysis

CASE STUDY

Individual home

The size of a solar plant for an individual home depends on the following:

- Total shadow free area available on roof
- Daily electricity consumption

Size of the solar PV: If the total shadow free area available on the roof is 40 sq m and the maximum daily electricity consumption of a household is 10 units (kWh), a 3 kW system would suffice (because 1 kW solar panel produce around 3.5–4.5 units/day and requires a shadow free space of 10–12 sq m. Therefore, in this case we need to install 3 KW of solar PV system on the roof, but since the user will depend on the grid at night, a 2 kW system will be enough for daytime needs.

Cost: MNRE benchmark cost for systems up to 10 kW is ₹ 70,000/kW.

Total system cost: $2 \times 70,000 = ₹ 140,000$. With 30 per cent MNRE subsidy, the total system cost will reduce to ₹ 98,000.

Savings: For a user who is not going for a loan and paying the whole system cost upfront, the monthly savings are calculated in the following manner:

- Number of units produced daily by 2 kW solar PV = $2 \times 3.5 = 7$ units
- Average grid domestic tariff (Haryana) = ₹ 5/unit (no increase assumed for 25 years)
- Monthly savings = $7 \times 5 \times 30(\text{days}) = ₹ 1,050$

For users taking loan, the monthly savings will remain the same, but they will have to pay an EMI of ₹ 1,211, considering debt–equity ratio of 70:30, rate of 12 per cent, and period of seven years.

SOLAR TRIUMPHS DGs

Most residential societies in urban India are equipped with DG sets to supply electricity during power outages and are essentially functioning as 'mini-grids', providing a mix of diesel-based and grid-based electricity to their residents.

Solar rooftop has many advantages over DG sets:

- Cost of the electricity generated through solar rooftop systems is significantly lower.
- Extra electricity generated through such systems can be exported to the grid.
- Solar panels used in these systems do not cause air or noise pollution.

Replacement of DG sets with solar rooftop

To assess the feasibility of solar rooftops in replacing DG sets in residential societies, CSE conducted a study of residential societies across Delhi, Haryana, Uttar Pradesh and Rajasthan.

The daily average power cuts in most societies are less than an hour. DG sets are hardly used for 200–300 hours a year, making them a redundant and expensive investment for the residents, besides being harmful for the environment.

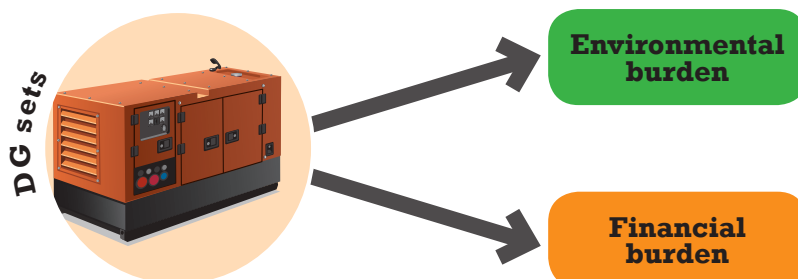
Environmental burden

DG sets are a major source of air and noise pollution in residential societies. In NCT of Delhi, DG sets contributes 6 per cent of PM_{2.5}, 4 per cent of PM₁₀ and SO₂, 25 per cent of NO_x and 7 per cent of CO levels.

Toxic fumes emitted by burning diesel in DG sets have serious health implications. In 2012, International Agency for Research on Cancer (IARC), a part of the World Health Organization (WHO), classified diesel engine exhaust as carcinogenic (causing cancer) for humans. DG sets are also a major source of noise pollution in residential areas. On account of the immense noise generated by DG sets, Delhi government has banned the use of DG sets of more than 4 kW capacities between 10 p.m. and 6 a.m. in residential areas.

Financial burden

In addition to the environmental cost, the power generated by DG sets is expensive. The approximate cost of generation from a DG set is ₹ 16–17 per unit (kWh), not including the capital cost of the DG set. If we also consider the capital cost of the DG set, which is included in the price of the flat, the cost of generation will rise to ₹ 27–33 per unit. This is around four times the cost of electricity supplied through the grid to residential societies.



CASE STUDY

ICON (Gurugram) and Rangoli Garden (Jaipur): Overview

Society	No. of flats	Connected load (kW)	Common area load(kW)	'Stated' backup	DG size (kW)	Annual grid electricity consumption (kWh)	Average outage (minutes/day)
ICON, Gurugram (Haryana)	344	1,998	550	Full backup for all loads	1,112	4,005,450	16
Rangoli Garden, Jaipur (Rajasthan)	1,300	10,635	555	Partial (common area load + 750 Watt for each apartment)	1,712	2,390,625	10

A hybrid system—in which power generated by panels is first used to charge the battery, and the surplus flows into households and the grid—is best suited for residential societies. To replace DG sets with these systems, we need to determine the capacity of solar PV, inverter and battery.

Size of the solar PV system

As a thumb rule, 10–12 sq m are needed to install a 1 kW solar PV system. The total shadow free roof available in ICON and Rangoli Garden is 864 and 4,104 sq m respectively. Hence, a maximum of 72 and 342 kW solar can be installed on the roof of ICON and Rangoli Garden respectively.

Size of the battery

The size of the battery is dependent on the connected load and the outage hours. To make the system efficient and responsible, we have allocated 0.3 kW load to every flat. The outage hours are taken as twice the average outage hours for both the societies. Therefore, for ICON the total outage hour becomes = $(2 \times 16) / 60 = 0.53$ and for Rangoli Garden = $(2 \times 10) / 60 = 0.33$

Number of units ICON's battery needs to store = 0.3×344 (no. of flats) $\times 0.53 = 56$ kWh

For Rangoli Garden's battery = $0.3 \times 1,300 \times 0.33 = 129$ kWh

The allowable percentage of discharge for a battery, without reducing its life, is called depth of discharge (DoD). Usually, manufacturers specify DoD for their batteries.

Taking 80 per cent DoD in calculation, ICON's battery capacity = $56 / 0.8$ kWh = 70 kWh

Rangoli Garden's required battery capacity = $129 / 0.8 = 162$ kWh

Time for which household appliances can be run with this battery capacity is listed below:

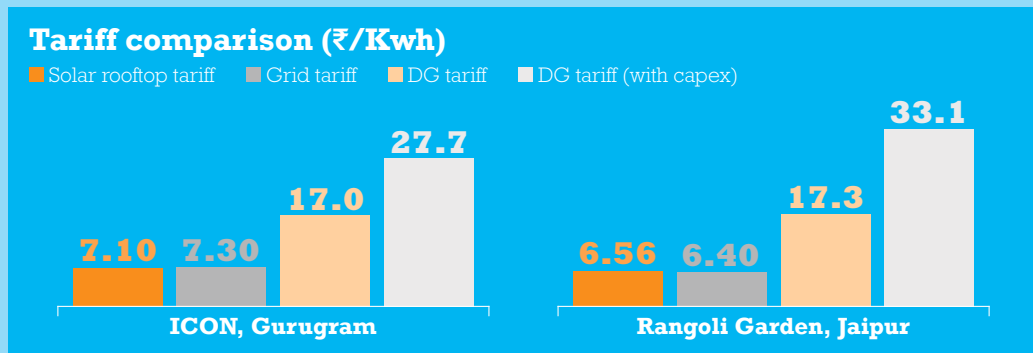
Appliances	Wattage	Quantity	Hours (ICON)	Hours (Rangoli Garden)
Lighting (LED)	8	2	0.53	0.33
32" LED TV	84	1	0.53	0.33
Laptop	50	1	0.53	0.33
Ceiling fan	75	2	0.53	0.33

Size of the inverter

Inverters convert DC into AC power, with a small loss. So, ideally, inverters are 1.1 times solar PV size. For ICON it comes out as $1.1 \times 72 = 80$ kW and for Rangoli Garden as $1.1 \times 342 = 377$ kW.

Financial viability

We have used the CAPEX model for cost comparison. Without considering the cost of a DG set, solar rooftop is 35–38 per cent cheaper, if we consider DG set cost, it is solar is one-fourth (ICON) and one-sixth (Rangoli Garden) the cost of DG set power. In fact, solar rooftop backup electricity cost is at par with grid tariff for the two residential societies.



Savings from solar rooftop

Annual savings for ICON and Rangoli Garden through solar roof are calculated as follows:

1- Units generated through solar rooftop in a year = Size of solar PV*Capacity utilization factor*24*365

(Capacity utilization factor is the ratio of the actual output from a solar plant to the theoretical maximum output from it, taking into account the length and intensity of sunlight in an area and efficiency of the panel. Generally, it ranges between 17–20 per cent.)

2- Units required to charge battery annually = Battery capacity*365

3- Extra units which can be used by residents annually = Step 1-Step 2

4- Annual savings = DG tariff*Units used to charge the batteries + Grid tariff*Extra units used by residents

Society	Units Generated through Solar (in KWh)	Units required to charge battery (in KWh)	Savings (in ₹ lakh)*
ICON	126,144	20,440	11.19
Rangoli Garden	599,184	47,085	44.36