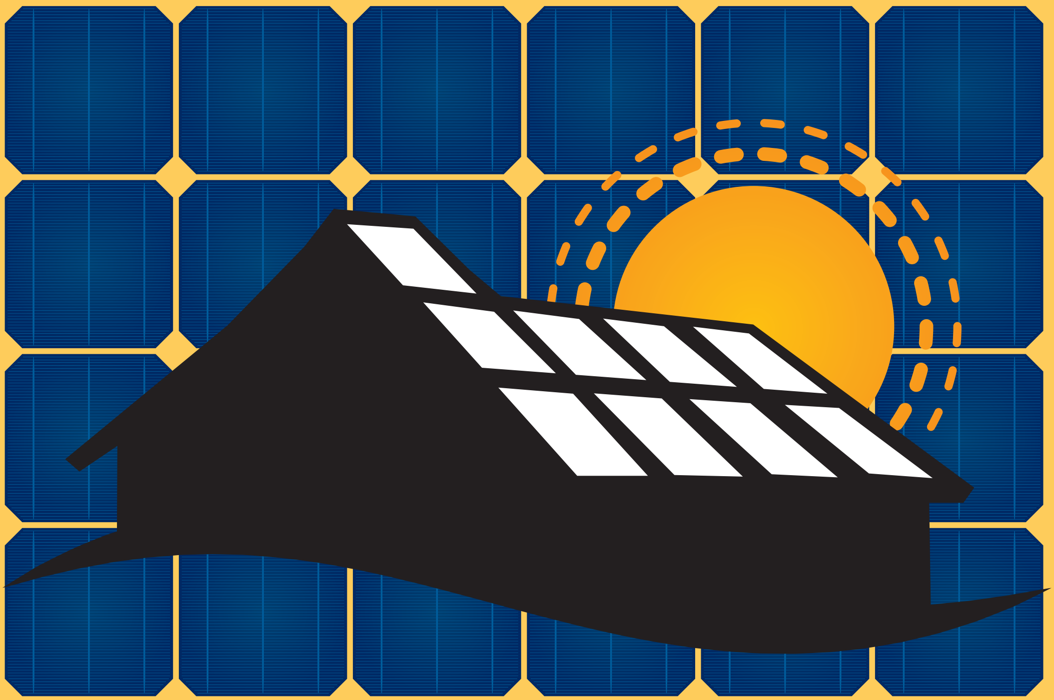
Reaching the sun with rooftop solar

Sudhakar Sundaray • Lovedeep Mann
Ujjwal Bhattacharjee • Shirish Garud
Arun K Tripathi



An initiative supported by

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

सत्यमेव जयते

**Ministry of New and Renewable Energy
Government of India**

teri
The Energy and Resources Institute

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The Energy and Resources Institute (TERI)
TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 4150 4900
Fax 2468 2144 or 2468 2145
India +91 • Delhi (0)11
E-mail teripress@teri.res.in
Website www.teriin.org

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Foreword

India's solar market, especially solar photovoltaic, has seen significant growth after the launch of the Jawaharlal Nehru National Solar Mission in 2010, with an installed capacity of over 3 GW in just four years. The Government of India is determined towards achieving 100 GW of grid interactive solar power capacity by 2020, of which 40 GW would be deployed through decentralized and rooftop-scale solar projects.

Rooftop solar PV would play a prominent role in meeting energy demands across segments. It has already achieved grid parity for commercial and industrial consumers, and fast becoming attractive for residential consumers as well. As a result, multiple state governments have taken necessary steps to kick-start implementation of rooftop solar PV projects.

However, it is challenging to scale-up such programmes until:

- Solar technology is easily available and accessible in markets as a complete package
- Well-established service networks exist just like those for other high-end commodities
- Consumers are fully aware of service levels and actual economic benefits that can accrue
- Market is prepared to take on deployment and services even after subsidies are taken off
- Consumers, policymakers and investors have decision tools that aid decision-making
- State governments have policies and state regulators have conducive regulations on net-metering/feed-in-tariffs.

This whitepaper, published by TERI with support from Shakti Sustainable Energy Foundation in consultation with Ministry of New and Renewable Energy (MNRE) and all stakeholders, assesses India's market potential for rooftop PV, surveys consumers to identify real and perceived barriers that prevent consumers to install such systems, identifies strategies to commoditize rooftop PV and proposes business, operating, financing and cost recovery models that may be appropriate to tap this huge customer-side market.

MNRE is keen to promote this sector and is planning to initiate series of consultations with state nodal agencies and state distribution utilities to accelerate deployment of rooftop PV systems.

I hope that this whitepaper feeds into the ongoing national and state-level action on accelerating deployment of rooftop PV and provides insights for implementing models that accrue benefits to all actors and stakeholders involved.

I congratulate TERI and Shakti for this excellent whitepaper and wish them success for their future efforts.

Tarun Kapoor
Joint Secretary
Ministry of New and Renewable Energy

Preface

Renewable energy is being seen as a transformative solution to meet energy as well as economic challenges, both globally and nationally. However, the large-scale deployment of renewable energy technology will involve a combination of interventions involving policy and regulatory mechanisms, technological solutions and institutional structures. In recent years, particularly with the adoption of the National Action Plan on Climate Change, the Jawaharlal Nehru National Solar Mission, and solar policies by several states, India has taken several steps towards increasing the share of renewables in its energy mix.

There is an increasing focus on the development of solar energy in India for a variety of reasons, including our limited conventional energy reserves, their local environmental and social impacts, energy security issues, energy access, and tackling the challenge of climate change. Solar photovoltaic (PV) technology, in particular, is emerging as an extremely attractive option, particularly with abundantly available solar resources, modular technology and zero fuel costs over 25-30 years of the project life. Considering this, the Government of India has recently expressed its intent to achieve 100 GW of solar capacity in the country by 2020, of which 40 GW is expected to be achieved through decentralized and rooftop-scale solar projects.

Stakeholders at the central and state levels are acknowledging the need for appropriate interventions to achieve this scale of customer-side solar generation. In this context, this study undertaken by The Energy and Resources Institute with support from the Shakti Sustainable Energy Foundation is particularly relevant. The study estimates the India-wide potential of solar rooftop PV, surveys consumers to understand barriers and perceptions at the consumer end, analyses existing policy frameworks and regulatory practices nationally and internationally and also scans the market to propose appropriate business models for large scale deployment of rooftop solar PV.

The study is based on primary and secondary research, and extensive interactions with senior officials from the Ministry of New and Renewable Energy, State Nodal Agencies, urban development authorities, financial institutions and solar developers.

We hope that this study will be of interest to policy makers, regulators, solar developers, educational institutions as well as different consumer groups in India and that its recommendations will be translated into action. The practical nature of this study makes this work highly relevant for policy-making.

Krishan Dhawan
Chief Executive Officer, Shakti Sustainable Energy Foundation

R K Pachauri
Director-General, TERI

Acknowledgements

The research team gratefully acknowledges the support and cooperation received from officials at the Ministry of New and Renewable Energy (MNRE), particularly from Mr Tarun Kapoor, Joint Secretary, MNRE. We are grateful to Shakti Sustainable Energy Foundation (SSEF) for supporting this initiative. In particular, we would like to thank Mr Deepak Gupta, Sr. Programme Manager (Power) and Ms Disha Agarwal, Programme Associate (Renewable Energy), for their inputs and suggestions during the course of this research.

The team is grateful for the support received from all stakeholders at the state-level, particularly from Chandigarh Renewable Energy Science & Technology Promotion Society, Delhi Electricity Regulatory Commission, Gujarat Energy Development Agency, Haryana Renewable Energy Development Agency, Karnataka Renewable Energy Development Ltd., Maharashtra Energy Development Agency, Tamil Nadu Energy Development Agency, Tamil Nadu Generation and Distribution Corporation Limited, Tamil Nadu Electricity Regulatory Commission, Department of Environment Delhi; and urban development authorities of Bangalore, Bhubaneswar, Chandigarh, Delhi-NCR, Gandhinagar, and Pune. We would also like to thank Indian Renewable Energy Development Agency, Canara Bank, and State Bank of India for providing crucial inputs. We gratefully acknowledge the support received from solar developers, particularly from Azure Power, Juwi, Luminous, Su-kam, Sun Edison, and Tata Power Solar. The team wishes to put on record their appreciation and thanks to IMRB International for their valuable support in conducting the primary surveys and market research during the course of the study.

The research team also acknowledges Mr Amit Kumar, Senior Fellow, TERI, Mr Gurudeo Sinha, Visiting Senior Fellow, TERI and Ms Parimita Mohanty, Ex-Fellow, TERI and Mr J N Barman, Director, Planning Wing, National Capital Region Planning Board for their guidance and support.

The team would also like to acknowledge Ms Rita Grover and Ms Nirmal Gupta for efficient secretarial assistance. The publication would not have been possible without the support of the dedicated team of professionals from TERI Press.

Preamble

Indian power sector is facing unprecedented challenges with the growing economy; a rapid increase in electricity demand on one hand and supply constraints and increasing costs of major fuels, such as coal and natural gas used for power production coupled with growing concerns about climate change and greenhouse gas emissions from the use of fossil fuels on other. Providing energy security and energy independence to billion plus population is also on the government agenda. It has been established that to meet power demand, India needs to have a basket of energy resources. Solar energy that is abundantly available across the country could be a logical choice. Solar photovoltaic technology, which has inherent advantages of being modular and solid state, is one of the best technological options for distributed generation close to the point of consumption. Hence, roof mounted solar PV systems can play an important role in augmenting the power generation capacity. This white paper, based on the study carried out by TERI, therefore, looks deeper into the various aspects of roof top solar PV segment with the objective of developing a strategic action plan to eventually develop the roof top solar PV systems as commodity and consumer product, free from government subsidies and policy driven market.

Towards the strategy formulation, the study looked in to key issues, such as

- Technology maturity
- Techno-commercial viability
- Grid interconnection challenges
- Impact on utilities and power sector operators
- Quality and standardization
- Financing
- Awareness and market development challenges

Methodology

Adopting a holistic approach, the study combined a) literature review, b) stakeholder consultation, c) market research and consumer survey, and d) development of financial models and implementation strategies for different consumer categories. While literature review covered the global status of roof top solar PV system deployment programmes, technology maturity, and availability and understanding of supporting policy frameworks; stakeholder consultation primarily focussed on understanding the perceptions and concerns of various stakeholders. Market survey covered the consumers' expectations, barriers, market evaluation of competing technologies including gen-set, and inverter and battery set to understand the market perceptions and barriers. This was followed by financial analysis and development of business models. The approach was based on classification of consumers in four segments, viz., a) Residential, b) Commercial, c) Industrial, and d) Institutional (based on the classifications of consumers for utilities and tax structure, and other benefits available for different categories).

Literature review

GLOBAL PV MARKET REVIEW

The global PV installed capacity has reached more than 100GWp in 2013 (Figure 1). The leading countries with large capacities in PV installations are Australia, China, Germany, Italy, Japan, Spain, and USA. The solar PV markets in these countries are driven by strong PV project pipelines, flexible and innovative financing mechanisms, and proactive government policies. **Major chunk of solar PV installations in the countries such as Germany, Japan, and USA are on building rooftops**.

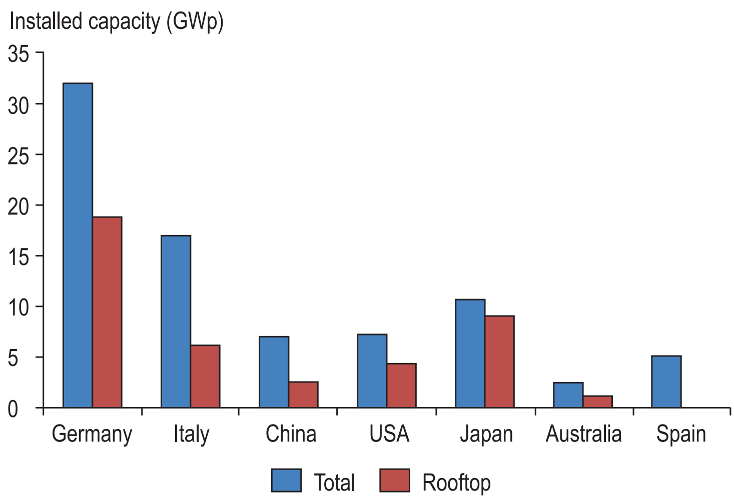


Figure 1: **Solar PV-installed capacity till March 2013**

*Rooftop Solar PV installed capacity data is not available for Spain

Support mechanisms

The development of PV in last decades has been powered by the deployment of supporting policies aimed at reducing the gap between electricity cost from PV and conventional electricity sources. These schemes took various forms depending on the local specificities.

Table 1 consolidates different support schemes to accelerate the deployment of rooftop Solar PV in different countries. A country wise explanation of different schemes currently practised is detailed out in Annexure I.

Table 1: **Overview of different support schemes for rooftop Solar PV in selected countries**

Schemes	Australia	Germany	India	Italy	Japan	USA
Direct capital subsidy		✓	✓	✓	✓	✓
Green electricity schemes	✓	✓		✓		✓
PV specific green electricity scheme						✓
Renewable Portfolio Standard (RPS)	✓	✓	✓		✓	✓
Solar set aside RPS target			✓			✓
Financing scheme	✓	✓	✓		✓	✓
Tax credits/tax benefits	✓	✓	✓	✓	✓	✓
Net metering/net-billing/self-consumption incentives	✓	✓	✓	✓	✓	✓
Sustainable building requirements					✓	✓

Direct capital subsidy: Direct capital subsidy aimed at tackling the up-front cost barrier, either for specific equipment (PV modules) or total installed PV system cost.

Green electricity scheme: Allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price.

PV-specific green electricity scheme: Allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price.

Renewable Portfolio Standard (RPS): A mandated requirement that the electricity utility source a portion of their electricity supplies from renewable energy.

Solar set aside RPS target: A mandated requirement that a portion of the RPS be met by solar electricity supplies.

Investment funds: Share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends.

Tax credits: Allows some or all expenses associated with PV installation to be deducted from taxable income streams.

Tax benefits: In India accelerated depreciation on investment in RE devices (excluding wind power plants) is allowed.

Net metering: The system owner consumes solar electricity and receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and obtained over the billing period.

Net billing: The electricity taken from the grid and the electricity fed into the grid are tracked separately. The electricity fed into the grid is valued at a different price.

Sustainable building requirements: Includes requirements on new building developments (residential and commercial) where PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development.

OVERVIEW OF INDIAN ROOFTOP SOLAR PV SECTOR

The Indian solar PV market has seen significant growth with the installed solar PV capacity, rising from 40 MW to more than 3,000 MW in the last four years.[1] It is also expected that the distributed generation (rooftop Solar PV) at the consumer end will drive solar power capacity additions given the acute power shortages in several states.

Institutional structure

Role of various stakeholders responsible for implementation of rooftop solar PV projects in India is shown in Figure 2.

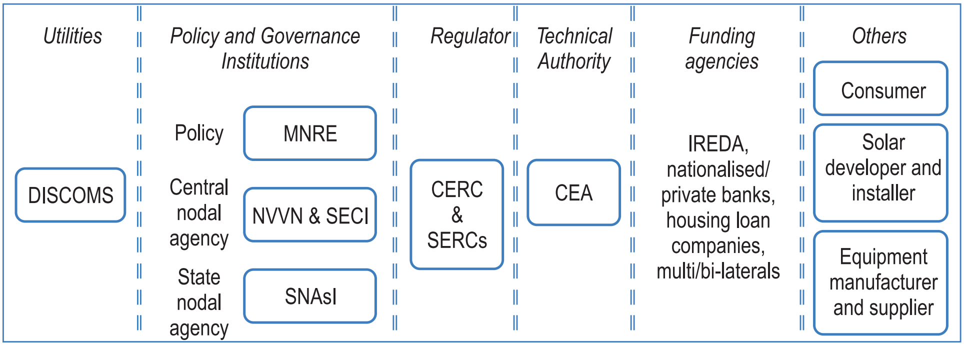


Figure 2: **Institutional structure of the solar energy sector in India**

Source: TERI compilation

Details of stakeholders and their roles and concerns are summarized in Table 2.

Table 2: **List of stakeholders, and their roles and concerns/ expectations**

Stakeholders	Roles	Concerns/ expectations
Consumer (residential, commercial, industrial, and institutional)	• System owner, power consumer	• Cost of solar power (equal or less than conventional power) • 24*7 power availability • System quality and durability • After sales service
Transmission and distribution utilities	• To provide and operate grid power and grid network	• Grid stability and safety for transmission and distribution utilities • Impact on revenue of distribution utility due to generation at the consumer end
Stakeholders	**Roles**	**Concerns/ expectations**
Investor/financier (loan provider)	• To provide finance (equity/ debt)	• Return on equity • Loan repayment/debt recovery

[1] Current trends/Status in Solar Power Market, A presentation by AF - Mercados EMI, 2013 Available at http://mnre.gov.in/file-manager/UserFiles/presentations-23052013/MERCADOS.pdf and MNRE website, Accessed on 1st January, 2014

Government/Policy maker	• Promote clean energy • Provide electricity access to all • Establish policy framework for market and industry development • Job creation	• Outlay on government support mechanisms • Providing affordable power to all citizen
Electricity regulator	• Regulate power tariff • Promote RE as per Electricity Act 2003 mandate • Provide regulatory support for clean energy market	• Determining power tariff • Maintaining grid code standards • Regulation of distributed generation
System developer	• Development of project • Provide EPC services • AMC services	• Stable market • Government permissions and regulations
Manufacturer	• Equipment supplier	• Quality • Access to technology • Competitive market • Stable market demand
Central and state nodal agencies/implementing agencies	• To implement government schemes	• Timely execution of project • Disbursement of subsidies • PPA with utility/developer/ roof owner

Notes: CEA – Central Electricity Authority, CERC – Central Electricity Regulatory Commission, DISCOMS – Distribution Companies, IREDA – Indian Renewable Energy Development Agency, MDBs– Multilateral Development Banks, MNRE – Ministry of New and Renewable Energy, NVVN – NTPC Vidyut Vyapar Nigam Limited, SECI – Solar Energy Corporation of India, SERCs – State Electricity Regulatory Commissions, SNA – State Nodal Agencies for Renewable Energy Development, T&D utilities– Transmission and Distribution utilities

Roof top solar PV potential

In this study, India's current potential for rooftop SPV has been estimated in terms of technical, economic, and market potentials (Figure 3). The technical potential is assessed from the rooftop space offered by its built area however GIS is the best technology available to get near accurate measurements of area through satellite mapping. In this study GIS technology is not used due to involvement of reasonably higher cost and time but in another study, TERI has undertaken a detail assessment of rooftop solar PV potential for Chandigarh city using GIS technology, which can be assessed in the website www.regisindia.com. In this study, the estimated realistic market potential for rooftop solar PV in urban settlements of India is about 124 GWp. It may be noted that the current total installed power generation capacity is 280 GWp. **Thus, rooftop solar PV can play an important role in providing energy security and in multiple utilization of land, a scarce resource**.

The detailed methodology and assumptions for estimation of rooftop SPV potential are given in Annexure II.

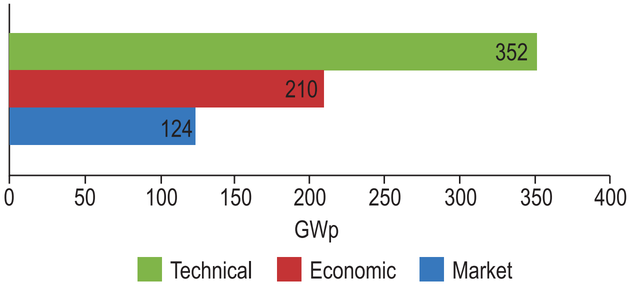


***Figure 3:* India's potential for rooftop solar PV**

Rooftop solar PV initiatives

The PV market in India is driven by a mix of national targets and support schemes at various legislative levels. India's solar energy initiatives fall under the larger purview of National Action Plan on Climate Change (NAPCC), which was unveiled by the Prime Minister of India on 30th June, 2008. Jawaharlal Nehru National Solar Mission (JNNSM), launched under NAPCC, aims to install 20 GWp of grid-connected PV systems and 2 GWp of off-grid systems including 20 million solar lights by the year 2022. Recently the government of India has expressed its intent to achieve 100 GW of solar capacity in the country by 2020, of which 40 GW is expected to be achieved through decentralized and rooftop-scale solar projects.

Central Government initiatives

Ministry of New and Renewable Energy (MNRE) announced the Rooftop PV and Small Solar-Power Generation Programme (RPSSGP) under Phase I of the Solar Mission to encourage grid connected projects. Under RPSSGP, grid connected small solar PV systems (ground and roof mounted systems of capacity not more than 2 MW each) of 90.8 MW capacity were commissioned as on 31st December, 2013. The local distribution utility in whose area the plant is located, would sign a Power Purchase Agreement (PPA) with the Project Proponent at a tariff determined by the respective State Electricity Regulatory Commission (SERC).

Currently, MNRE is providing a subsidy of 30 per cent for SPV rooftop systems, which is likely to be tappered down in future. The Solar Energy Corporation of India (SECI) is also promoting grid connected rooftop systems (100—500 kWp) under RESCO model, in which SECI will buy and sell electricity to utilities at INR 5.50/kWh.

MNRE is in the process of formulating a new rooftop policy based on net metering and capital subsidy. The scheme is under approval.MNRE has also requested to all public sector banks (PSBs) for providing loans to the loan seekers for installation of grid interactive rooftop solar PV systems as home loan/home improvement loan.

The technical guidelines for grid interconnection of small distributed generating systems, including rooftop solar PV, are recently approved and announced by CEA (Central Electricity Authority).

Table 3: **Details of different state and central policies for rooftop SPV**

Centre/state	Scheme	System size/ programme scale	Targeted segment	Incentive	Electricity sale/ utilization mechanism	Grid connectivity
Andhra Pradesh	Grid connected	Residential consumer: 1 - 3 kWp. Commercial, industrial, and institutional consumer: 5 - 100 kWp	3 phase service consumers	30 per cent capital subsidy from MNRE and 20 per cent capital subsidy from state government* (*only for projects up to 3 kW for residential consumers)	Self-consumption and sale to utility at pooled cost for exported power for 7 years. Energy banking for six months is allowed.	Net metering
Chhatisgarh	Grid connected	500 to 1,000 MWp by 2017	Rooftop and other installations. Under rooftop residential, commercial, and industrial buildings	30 per cent capital subsidy from MNRE	Sale to utility at feed-in tariff rate of INR 4.35 /kWh.	Both gross and net metering
Delhi	Grid connected	Minimum system size is 1 kWp and no information on program scale	Residential, commercial, industrial, and institutional buildings	30 per cent capital subsidy from MNRE	Self-consumption and energy banking for one year	Net metering
Gujarat	Grid connected	No limit, total 30 MWp in six cities	Government, institutional, residential, commercial, and industrial buildings	Roof owners get paid lease rent (minimum INR 3.00/kWh) and the project developer gets feed-in-tariff for 25 years	Sale to utility	Gross metering
Karnataka	Off grid and grid connected	400 MWp by 2018	All consumers	30 per cent capital subsidy from MNRE	Self-consumption and sale surplus power to utility	Net metering
Kerala	Off grid and grid connected	Off-grid: 1 kWp (10,000 systems) Grid-connected: 1 kWp to 1 MWp	Off grid: Household and small cottage industries Grid connected: All consumers	Off grid: 30 per cent capital subsidy from MNRE + INR 39,000 /kW capital subsidy from state government Grid connected: Only 30 per cent capital subsidy from MNRE	Off grid: Only self-consumption Grid connected: Net metering	Net metering

Centre/state	Scheme	System size/ programme scale	Targeted segment	Incentive	Electricity sale/ utilization mechanism	Grid connectivity
MNRE (RPSSGP)	Grid-connected	Up to 2MWp	Both rooftop and ground mounted	GBI (INR 5.50 /kWh for financial year 2010--11 and will escalate by 3 per cent/year.	Sale to utility	Gross metering
Rajasthan	Grid Connected	1 MW capacity each and total of 50 MWp	Not mentioned	FiT	Sale to utility	Gross metering
SECI	Grid connected	100–500 kWp (aggregation is allowed)	Any building in 4 cities – Phase I - 5.5 MW 6 cities – Phase II - 11.1 MW 9 cities – Phase III - 10 MW	30 per cent capital subsidy from MNRE through SECI	Self-consumption and sale to utility Maximum chargeable fixed tariff is up to INR 6.00/kWh for 25 years under RESCO model	Both gross and net metering
Tamil Nadu	Grid connected	(i) 350MW during 2012--15 in 3 phases (ii) 10MWp (10,000 1kW systems)	(i) 50MWp for domestic customers and 300MWp for government buildings and government schemes for rural and urban lighting (ii) 10,000 residential houses	(i) GBI of INR 2.00/ kWh for the first two years, INR 1.00/kWh for next two years and INR 0.50/kWh for the subsequent two years (ii) 30 per cent capital subsidy from MNRE and INR 20,000 per system capital subsidy from state government	Self-consumption and energy banking for one year	Net metering
Uttarakhand	Grid connected	0.3–500 kWp	All consumers	30 per cent capital subsidy from MNRE	Either self-consumption or sale to utility	Gross metering and net metering
West Bengal	Rooftop and small PV installations	16 MWp capacity installation by 2017	All consumers	30 per cent capital subsidy from MNRE	Self-consumption and sale of surplus electricity to the utility	Net metering

State Government initiatives

Apart from central policies, various states have also announced their state specific policies for rooftop SPV. Both off-grid and grid connected rooftop projects are being promoted by the state government. State Electricity Regulatory Commissions of 17 different states have issued the appropriate regulatory order for grid connencted rooftop solar PV projects. Key initiatives taken by few state governments are:

- Gujarat is the first state in the country to implement rooftop solar PV pilot scheme. This scheme allows direct sale of solar generated electricity to utility grid.
- Andhra Pradesh, Tamil Nadu, Uttarakhand, West Bengal and few other states (Table 3) have recently launched their policies promoting both, grid connected PV system and self-consumption of solar electricity.
- Kerala government proposed schemes for promoting both off-grid and grid connected rooftop solar PV systems.

Majority of the rooftop solar PV projects implemented in India are policy (central and state) driven. Companies are marketing solar PV systems that meet the requirements of different state policies. This clearly shows that the rooftop solar PV market is not yet self-driven in India.

The details of different state level policies are mentioned in Table 3.

Key observations

- Most states have net metering policies coupled with capital subsidy for roof top solar power plants.
- Policies encourage self-consumption, energy banking, and avoid direct sale of power to utilities.
- Excess generation is either not paid for or is paid at APPC (average power purchase cost) decided by the SERCs (as in case of Andhra Pradesh, Karnataka, and West Bengal), or can be banked for limited period.
- Energy storage and compensation for loss of power generation during grid unavailability is not supported by policies.

Commoditization
of rooftop solar PV

For large scale deployment of rooftop solar PV, even after having various central and state government schemes, many challenges still exist on the policy, technology, and consumer awareness fronts. These include regulations for metering arrangements, technical standards/rules for grid interconnection, tariff determination and accounting, monitoring, control and verification, and financing schemes, etc.

The deployment of rooftop SPV can be accelerated further if:

- Solar technology solutions are easily available and accessible as a complete product or as a package in the market.
- Easy finance schemes are available for procurement of SPV systems through banks.
- Consumers are fully aware of the service levels and actual economic benefits.
- Well established solar service networks exist just like those for other high-end commodities.

Thus, a need was felt to evaluate market preparedness and policy status in India for commoditizing solar energy based power solutions for various categories of consumers.

Given this context, The Energy and Resources Institute (TERI) carried out a detailed market research to identify drivers and barriers for commoditization of roof top SPV systems.

PRIMARY SURVEY AND MARKET RESEARCH

Six different cities (Bangalore, Bhubaneswar, Chandigarh, Delhi, Gandhinagar and Pune) were selected for primary survey and market research on the basis of city characteristics, state preparedness for solar implementation, regional representation, etc. Market research conducted to assess the characteristics for power supply, power outages, and propensity for adoption of rooftop SPV in the residential, commercial and industrial sectors revealed that:

- Power outage for about 1 to 2 hours and voltage fluctuation are experienced by all consumer categories in all cities except Gandhinagar
- Commercial and industrial consumers use generator set and residential consumers use inverter-battery set for power backup.
- Most consumers are willing to buy rooftop SPV.

- Power cut problem is predominant in residential and institutional segments. Inverters are used as back up. This results in wastage of grid electricity due to inefficient invertors and batteries, and losses in storage and conversion. It also reduces the available electricity for productive use.
- Consumers intuitively expect rooftop solar PV systems to reduce expenses on electricity and to assure reliable power supply even in case grid power outage. This however, is not being addressed in the current schemes.

The outcome of market survey can be summarized in the following four types:

I. Consumer's perception

a. Reduction in utility electricity bill

b. Minimal operation and maintenance cost

c. A reasonable independence from the grid

d. Economic value for unused roof space

e. Green electricity

f. Reliable electricity

II. Consumer's expectation

a. Government subsidy to bring down the upfront cost

b. Streamlined and user friendly processes for availing government subsidies

c. Easier loans and faster returns on investment (preferably 2–3 years)

d. Annual maintenance contract (AMC) from the supplier

III. Consumer's preference

a. Consumption of solar electricity and sale of surplus to utility is a common choice for all consumers

b. Low capital investment by roof owner

c. Commercial consumers are looking for rooftop SPV as an alternative to utility power

IV. Barriers for adoption

a. Lack of awareness among consumers

b. Lack of wide network of suppliers and service providers

c. Lack of financing schemes

Additional analysis is covered in the subsequent sections.

The details of findings from primary survey and market research are given in Annexure III.

The study also focussed on market evolution of competing technologies, such as generator set and inverter battery set. This study was done to understand the impact of policies on market dynamics, and the impact of consumer needs on market potential.

MARKET EVOLUTION OF COMPETING TECHNOLOGIES

Generator set

The demand for gen set grew largely from the huge demand-supply gap, which existed due to dismal electricity scenario in the country in the decades of 1950 to 1990. No alternate product existed at that time for household and small industrial/commercial uses (inverters came very late into Indian market). Hence, the market turned towards the only product available during that time–generator set. Of course, the capital cost and paying capacity of the consumers would have played a role. The evolution of gen-set market in India can be divided into five broad phases as mentioned in Figure 4.

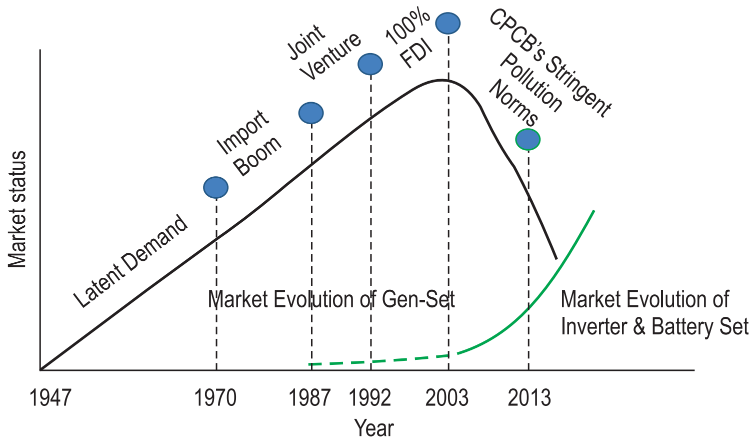


***Figure 4:* Market evolution of generator set and inverter & battery set**

Phase I: 1947–70: Latent demand

Focus was on increased state involvement in the rebuilding of the economy. Stress was laid on the development of agriculture and heavy industries.

Phase II: 1971–86: Import boom

Country faced huge power shortage. This led to an import boom of gen-sets.

Phase III: 1987–92: Joint venture

With 49 per cent FDI in gen-set segment, Honda and Yamaha moved in to the Indian market with their technologically superior products through joint venture with Shriram and Birla.

Phase IV: 1993–2003: 100 per cent FDI

- With the announcement of New Economic Policy (NEP) in 1992, 100 per cent FDI was allowed in many sectors including portable gen set. Honda acquired majority stake in Shriram-Honda group to form Honda Power Products India Limited.
- During this period, fuels were subsidized. Kerosene was heavily subsidized and was the cheapest fuel available. Indian manufacturers dominated the 2.5+ kVA gen-set markets, operated by kerosene, LPG, petrol and diesel.

Phase V: 2003 Onwards: Stringent pollution norms

- This phase saw stringent pollution norms. In 2003 the Central Pollution Control Board (CPCB) laid down norms for petrol, kerosene and diesel based gen-sets.
- This decision affected every player, except Honda, in an adverse manner. Many Indian companies who had to invest heavily in new pollution control technology had to exit the market. Also, the norms made it very difficult to manufacture diesel gen-set that were small/portable and met the noise and emission norms.

Inverter and battery set

- Post 2003, inverter and battery sets have started encroaching upon the gen-set market in a big way. Portable gen-set of less than 0.5 KVA categories have already been wiped out of the market and those of capacity 0.5-–1.6 KVA are facing extinction threats.

Inverter and battery set market

- Over the period inverter technology has improved and large ranged inverters which can handle heavy loads such as refrigerators, small capacity air conditioners, etc. are now available.
- Investment for inverter and battery set in a typical household varies between INR 5,000 to INR 20,000.

Electricity cost from inverter & battery system is about INR 20/kWh owing to battery charging and discharging, and inverter efficiency. Thus, it is clear that consumers are ready to pay both, the capital cost and running cost, (either knowingly or unknowingly) for reliable and assured power supply. If the rooftop solar PV systems can address this need then they are not only cleaner and greener solution, but also cheaper solution for consumers as there is no cost for electricity purchase.

It is further important from country perspective to avoid any wastage of grid power by the usage of inverter and battery set, simultaneously creating additional generation capacity at point of consumption.

DRIVERS FOR COMMODITIZATION OF ROOFTOP SOLAR PV

For a widespread acceptability of rooftop SPV across a larger group of consumers, there is a need for commoditization of the product. A product is commoditized if it essentially meets following three criteria;

- Availability
  - The product is available in a range of standardized packages.
- Accessibility
  - The product is backed by a wide network of suppliers and service providers.
- Affordability
  - The product is available through easy financing.

Figure 5: **Elements for commoditization of rooftop SPV**

Our assessment shows that there are five elements, which need to be focussed for commoditization of rooftop solar PV, as shown in Figure 5. These are (a) consumer awareness, (b) product attributes, (c) cost and procurement parameters, (d) after sales service, and (e) policy and regulatory support.

Each of the above mentioned elements are critical for commoditization. The parameters under each element for commoditization are listed below:

I. Consumer awareness

a. Awareness about rooftop SPV like any other commodity

II. Product attributes

a. Ability to power all end-use loads
b. Ability to supply electricity 24*7
c. Ability to provide backup power during outage
d. Ability to reduce grid electricity consumption
e. Ability to last for longer period (25 years)
f. Safety

III. Cost and procurement

a. Availability of financing
b. Ease of getting finance
c. Options for buying through EMI scheme
d. Availability of third party insurance
e. Availability of government incentives
f. Ease of getting government incentives

g. Competitiveness of unit cost of solar electricity from solar with grid electricity

h. Ease of installation (network of suppliers and service providers)

IV. After sales service

a. Availability of annual maintenance contract from system suppliers

b. Ease of getting after sales service

c. Availability of system recycle after end of life

V. Policy and regulatory

a. Existence of regulations for metering arrangement and connectivity standards

b. Regulations for energy accounting

There could be a possibility of large scale deployment of rooftop SPV system when all these above mentioned parameters are addressed. The barriers to these parameters are also identified through consumer's survey, market research, and stakeholder's interactions.

BARRIERS FOR COMMODITIZATION

The key barriers to large scale adoption of rooftop SPV across various consumer categories are:

- High upfront cost
- Limited financing schemes by banks
- Lack of awareness among consumers
- Limited standardized rooftop solar PV systems
- Inadequate supply chain for rooftop solar PV systems
- Inadequate experience of grid connectivity at low voltage
- Limitations of solar systems to function during power outage.
- Higher cost of dual function inverter (which allows consumption of solar electricity during power outage) in India

Apart from above mentioned barriers, few challenges specific to market are:

- Cost reduction for small capacity SPV systems
- Few companies in the market deal with small capacity solar PV systems; utility scale system integrators (EPC providers) are reluctant to enter into the small SPV domain

Strategies
for commoditization of rooftop solar PV system

The steps followed for the proposed implementation of models to address the aforementioned barriers include:

- Standardized packages of rooftop solar PV systems,
- Grid interconnection configurations, and
- Business models

STANDARDIZATION OF ROOFTOP SPV SYSTEMS

a) Commercial/industrial/institutional consumers

It is difficult to have a standard size of PV system for commercial, industrial, and institutional consumers due to higher variation of electricity demand and roof area availability among consumers. However, some standard configurations could evolve over the period especially in institutional sector (educational institutes, hospitals, government offices, etc.).

b) Residential consumers

From market research it was observed that lack of availability of standardized rooftop SPV system is one of the key barriers for uptake of rooftop PV market in residential sector. SPV system is rarely available in Indian market as a standard product. As rooftop SPV system is offered by companies as a project not as a product, it usually creates confusion among consumers while purchasing the system. Financial institutions are also not certain of the standard PV products to be easy financed.

Standardized packages need to be developed for large scale deployment of rooftop SPV. In order to develop standardized packages, residential sector, which represents most of the urban population, is considered. The appropriate size of a rooftop solar PV system to meet a residential consumer's electricity demand is estimated. This is done based on two basic approaches (i) considering end-use loads of a middle class residential consumer staying in an urban settlement and (ii) assuming potential rooftop area available for PV installation on a typical residential building.

Approach I

Table 4 depicts the end-use loads, and their rated capacity and duration of usage in a day considered for system sizing. The standard rated capacity of the appliances available in the market is considered for this study. Ratings of few appliances, such as refrigerator and ceiling fan are considered as per ratings of Bureau of Energy Efficiency, Government of India.

Table 4: **End-use loads, and their rated capacity and duration of usage in a day**

Appliances	Rated capacity (W)	Quantity	Hours of operation/day	Daily energy consumption (Wh)
Fan	80	4	8.0	2,560
Refrigerator (250 L, 4 star rated)	120	1	24.0	1,373
Cooler	120	1	8.0	960
TV (edge led Sony Bravia 32")	70	1	5.0	350
Washing machine	130	1	0.5	65
CD player	35	1	3.5	123
Computer	80	1	3.0	240
Tube light	36	5	6.0	1,080
CFL	18	5	6.0	540
Laptop charging	50	1	2.0	100
Total				**7,390**

Energy intensive appliances, such as clothe iron, geyser, microwave oven, toaster, and air conditioner are not considered in this study. Maximum energy demand is in Summer, therefore considering above mentioned loads, PV system sizing is done for peak demand.

A PV system capacity of 1.6 kWp is estimated to meet the maximum daily energy energy need of a residential consumer.

Approach II

A residential house built on a standard 260 sq. yard plot is considered as a standard plot size. The assumptions for ground coverage, roof area as percentage of building occupied area, and percentage of total roof area suitable for PV installation are taken from building by laws, view of architects/town planners, and available literatures. The detailed assumptions are described in Annexure II.

Based on above assumptions, a 2 kWp solar PV system can be installed on the rooftop of a building constructed on a 260 sq. yard plot.

From above two approaches, it is observed that a residential consumer needs a PV system of 1.5 to 2kWp capacity. However, based on the electricity demand and roof area availability the system size will differ.

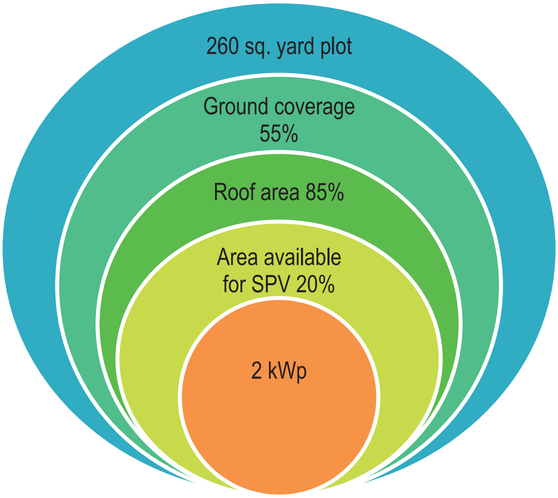


Figure 6: **Rooftop solar PV system on a 260 sq. yard plot**

Observations

- For residential consumers, individual owned rooftop SPV system with 1kWp–-3kWp standard combinations could be preferred.
- For commercial/industrial/institutional consumers, capacity of PV system should be project specific instead of a standard size.

GRID INTERCONNECTION CONFIGURATIONS

The rooftop SPV system can be installed in two configurations, namely (a) as a standalone system or (b) as a grid interactive system. In urban areas the grid interactive systems are more feasible than the standalone systems as almost all locations are connected by grid. These grids act as storage for an intermittent source of generation. In this study we are focussing on grid interactive rooftop SPV systems. In the grid interactive systems, there are different grid interconnection configurations depending on the reliability of electricity supply to the loads and the consumer needs.

Figure 7 illustrates the flow of energy in a grid interactive rooftop SPV system under different operating conditions.

Wherever battery is not envisaged, the solar system can be directly connected to consumer AC bus and the total energy of the solar system will be supplied to consumer/grid depending upon the requirement of the consumer.

Based on above mentioned configurations, following schemes of grid interactive roof top SPV system have been considered:

1. Grid interactive SPV system without battery backup (Figure 8)
2. Grid interactive SPV system with full load battery backup (Figure 9)
3. Grid interactive SPV system with partial load battery backup (Figure 10)

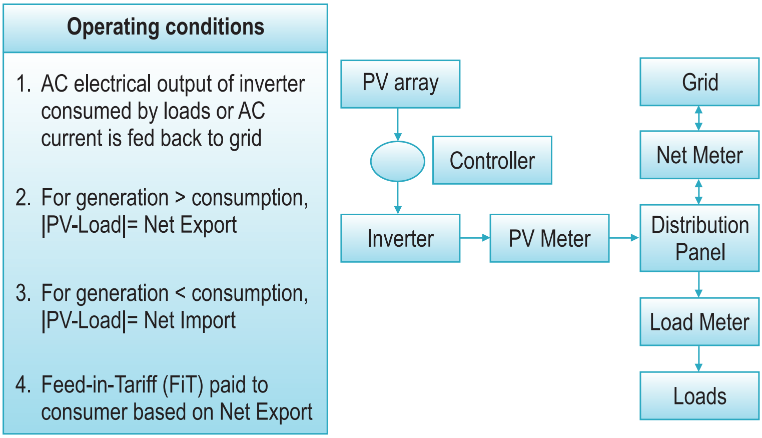


Figure 7: **Flow of energy in a grid interactive rooftop SPV system**

The above mentioned grid connectivity configurations are described in the subsequent paragraphs:

Grid interactive rooftop SPV system without battery backup

This is a simplest configuration of the grid interactive rooftop SPV system. In this arrangement inverter, which is heart of the entire SPV system, continuously supervises the grid condition and in the event of grid failure or under voltage or over voltage, the solar system is disconnected by the circuit breaker/auto switch provided in the inverter. Since there is no power back up in the system, it cannot supply the consumer load in the event of grid failure. Block diagram of the derived scheme is shown in Figure 8.

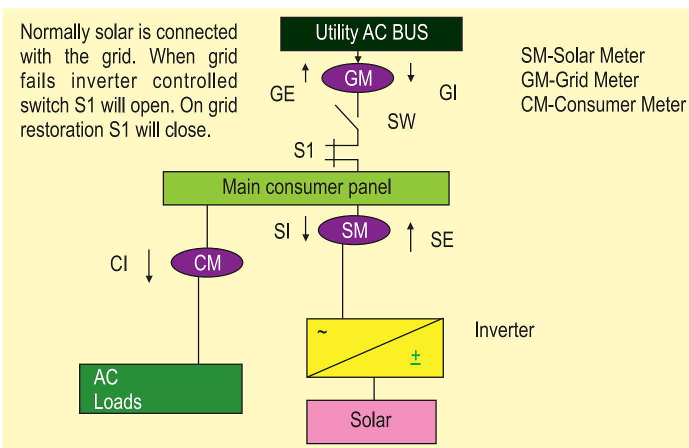


Figure 8: **Grid interactive rooftop SPV system without battery backup**

CI-Consumer energy import

GI-Import of energy from grid

GE-Export of energy to the grid

SE-Export of energy from solar system

SI-Import of energy by solar system

SW-Manual lockable switch for distribution feeder maintenance by the distribution company

Grid interactive rooftop SPV system with full and partial load battery back up

In this configuration when the grid is available, consumer loads are fed from grid as well as from solar system with a priority to solar PV system. SPV also feeds to the grid in case of surplus generation. Battery and inverter cum charger are also present in the arrangement. The DC generated from solar is first converted to AC and then it is supplied to other equipment/grid. When grid fails, automatic disconnection from the grid side takes place and solar gets connected to battery system and AC consumer load. Block diagram of the scheme is shown in Figure 9.

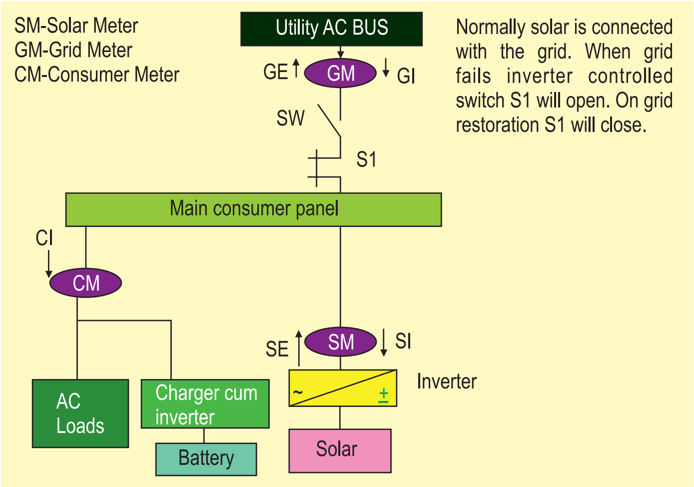


Figure 9: **Grid interactive rooftop SPV with full load battery backup**

(based on Configuration-I in Figure 11)

In case of grid interactive rooftop SPV system with partial load battery backup configuration, the basic operation is same as in full load battery backup scheme but bus splitting is necessary in this scheme in the event of grid failure, so as to supply critical loads as battery backup is not sufficient to feed the entire consumer load. In the event of grid failure, or under voltage or over voltage, inverter disconnects the grid supply and the non-emergency loads. Solar and battery system only gets the emergency loads. Battery system gets charged if battery is not fully charged. Block diagram of the scheme is shown in Figure 10.

In case where battery is also envisaged, the scheme of connection for solar PV system will depend upon the way the battery is charged. There are two possible ways of charging battery. First one is through AC coupling, i.e., the DC produced by solar is first converted into AC and then this AC is converted to DC by a charger. This arrangement is shown in Figure 11. In this arrangement as long as grid is available, the solar system, consumer, and battery system will be interactive up with the grid. In case of grid failure, rest of the system (solar PV system, battery system and consumer load) would be disconnected from grid and solar will be connected to battery and AC loads through another route.

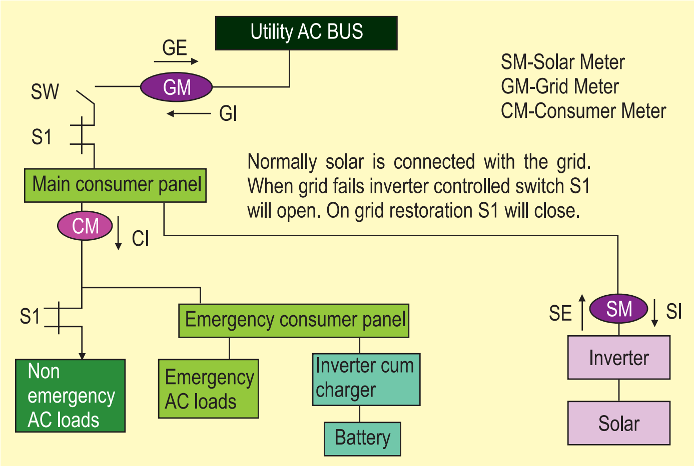


Figure 10: **Grid interactive rooftop SPV with partial load battery backup**
(based on Configuration-I in Figure 11)

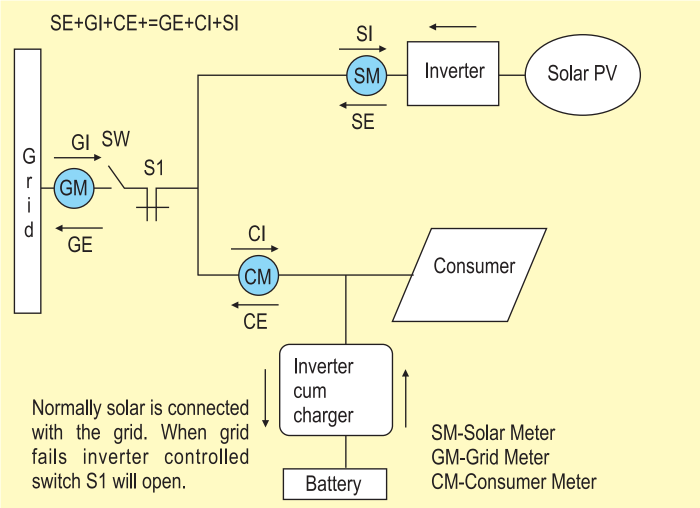


Figure 11: **Configuration-I for grid interactive SPV system with battery backup**[2]

This configuration is envisaged in Europe where feed-in tariff is employed. However the only difference proposed here is regarding the positioning of the solar meter (SM). In the scheme, the SM is towards the grid side and does not record the energy drawn by the consumer /battery during grid failure. In the Configuration-I, during grid failure also it measures the solar generation including the energy drawn by battery and the consumer load.

In the second configuration, solar system directly charges the battery through charge controller, i.e., DC coupling (Figure 12). In this arrangement, the AC system is not involved

[2] Report of subgroup-I on Grid Interactive Rooftop Solar PV System, 2009, Central Electricity Authority, New Delhi

to charge the battery and battery will always be connected to solar system. In case battery is discharged due to any reason, solar system will first charge the battery and the excess generation from the solar will be fed into the grid. This scheme would not reflect the true gross generation produced by the solar PV system.

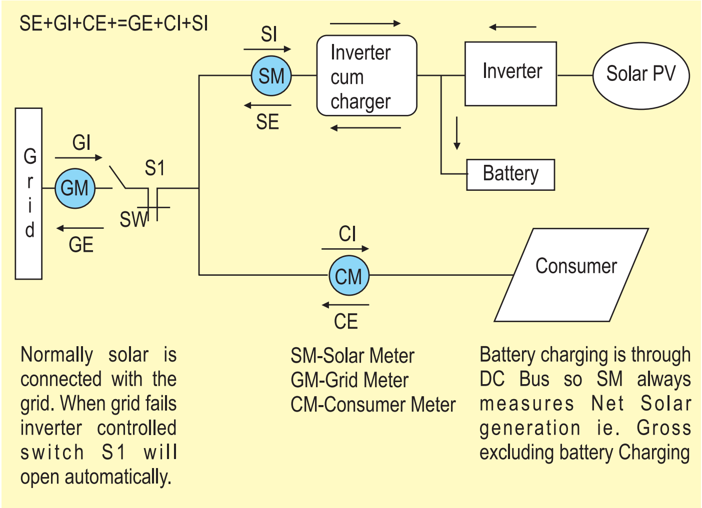


Figure 12: **Configuration-II for grid interactive SPV system with battery backup**

Observations

Grid interactive SPV system with battery backup (Figure 9 & 10) work during power outage but comparatively higher capital cost of these systems due to additional cost of battery and dual function inverter stands as a barrier. Grid interactive system without storage backup is a cost effective solution and applicable to consumers who are not affected by fragile grid conditions.

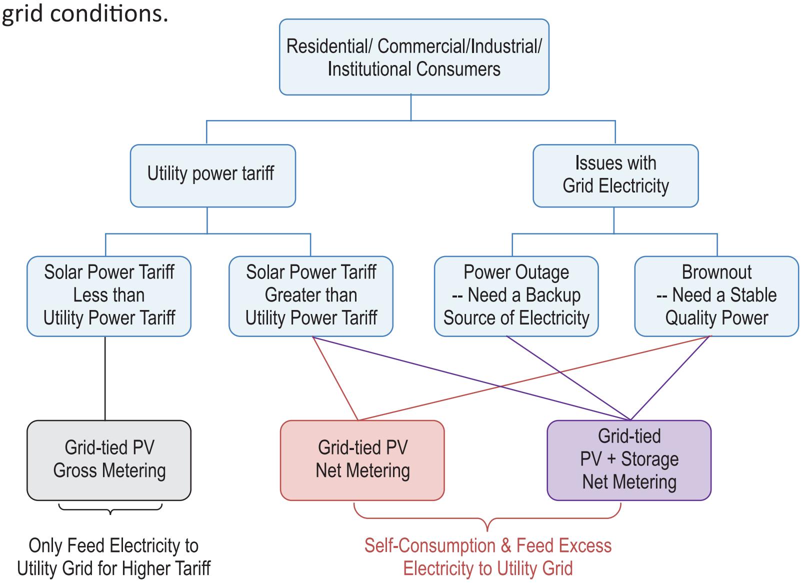


Figure 13: **Rooftop SPV decision tree**

Proposed
rooftop SPV business models

Basically there are two business models prevailing in the market based on the ownership of the rooftop solar PV system, which includes self-owned solar PV system and third party owned solar PV system.

In self-owned system, the roof owner owns, operates, and maintains the roof top SPV system. The generated electricity is either consumed by the end-use loads or supplied to the utility grid or combination of both.

In third party owned system, the third party (solar developer/system integrator or any other company) owns the roof top solar PV system and sale electricity either to the roof owner or consumer or both. Third party owned model does not allow roof owner to avail certain financial benefits, such as tax benefits, capital subsidy, etc., (Figure 14).

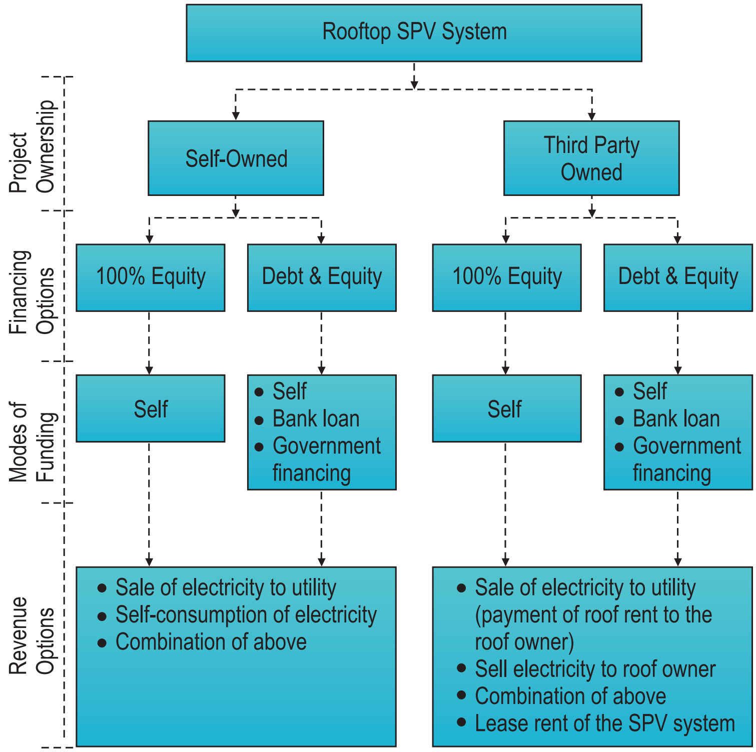


Figure 14: **Different modes of financing based on system ownership**

Note: Government finance includes financing from central/state governments, in terms of either capital subsidy or low interest loan or their combination.

For residential consumers, Accelerated Depreciation (AD) benefit will not be applicable; for third party owned model, AD benefit may be applicable. In third party owned model, there would also be additional benefits, such as economy of scale, and centralized O&M network.

The four primary business models are explained below:

GROSS METERING
(Only Sale of Electricity to Utility) And Self-Owned Model

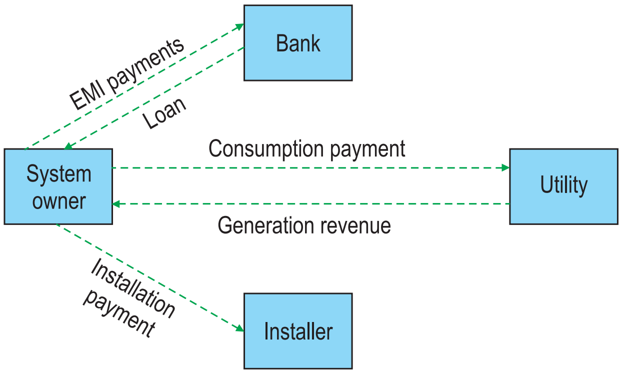


Figure 15: **Revenue flow in gross metering and self-owned model**

In this mechanism (Figure 15), the rooftop PV system is owned by the roof owner. The entire electricity generated by the rooftop SPV system is supplied to the grid and in return, the system owner gets compensated at a predetermined regulated tariff.

GROSS METERING
(Only Sale of Electricity to Utility) and Third Party Owned Model

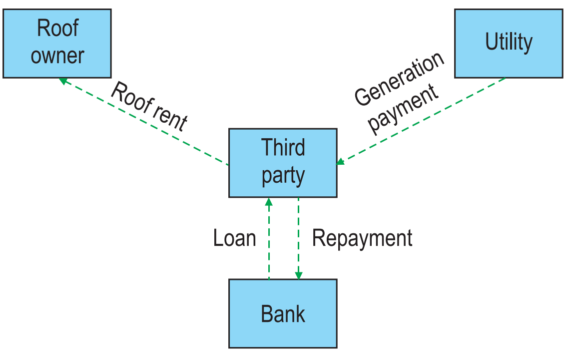


Figure 16: **Revenue flow in gross metering and third party owned model**

Under this mechanism, as depicted in Figure 16, the rooftop SPV system is owned by the system integrator/a third party. SPV systems are installed on rooftops (government, residential, public, commercial, industrial, and institutional buildings). In this model, the system owner signs a long term lease agreement with roof owner, invests in equipment, sets up the projects, and sells the generated energy to the grid. Gandhinagar Rooftop Solar Programme is an example of this model.

NET METERING
(Self-Consumption and Supply to Utility Grid) and Self-Owned Model

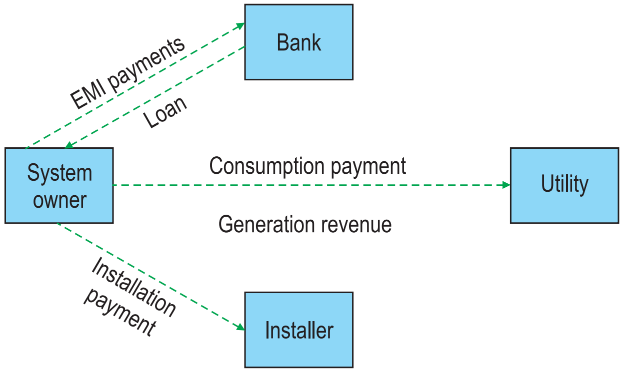


Figure 17: **Revenue flow in net metering and self-owned model**

In this model, as shown in Figure 17, the rooftop SPV system is owned by the roof owner. The generated electricity is supplied to roof owner's end-use loads and the surplus power is fed into the grid. The utility can purchase the surplus power or provide banking facility for a particular period of time.

NET METERING
(Self-Consumption and Supply to Utility Grid) and Third Party Owned Model

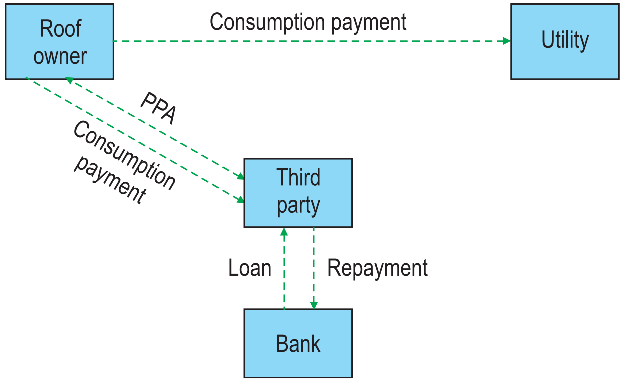


Figure 18: **Revenue flow in net metering and third party owned model**

In this model, the third party owns the system. The generated electricity is supplied to the roof owner's end-use loads and the surplus power is fed into the grid. The utility can purchase the surplus power or provide banking facility for a particular period of time (Figure 18).

Other possible option could be that the developers/third parties lease out solar PV systems to interested roof owners. The rooftop owners in turn pay developers/third parties a monthly lease rent. The electricity generated from such a system is used to meet the households'/rooftop owner's energy needs with excess being fed into the grid on net metering basis. The leasing company generates revenues by lease rentals and by claiming depreciation on the capital cost of the PV systems, with associated direct tax benefits.

Financial Analysis

Financial and cost analysis of the proposed business models for residential, commercial/ industrial, and institutional sectors will provide inputs to consumers and decision-makers to assess the financial merit in adopting an appropriate business model for deployment of rooftop SPV. In this section, a framework has been developed to estimate the financial performance indicators, such as the net present value, the internal rate of return, and payback period.

FINANCIAL FRAMEWORK FOR ANALYSIS OF BUSINESS MODELS

For financial analysis, two types of rooftop solar PV systems are considered, viz.

- a 2 kWp SPV system for residential sector, and
- a 100 kWp SPV system for commercial/industrial sectors

Residential and commercial/industrial/institutional sectors have different capital cost structures for PV systems. It is assumed that the commercial/industrial/institutional sectors have potential for higher capacity (more than 100kWp) PV system and hence, likely to have certain cost advantage over the residential SPV systems. There can also be cost advantages of bulk purchase of systems for residential sector.

The financial accounting procedure to capture cost components differ for residential consumer owned system and commercial/industrial/any other third party owned system. The self-owned systems account for capital cost, O&M cost, and for replacement costs. A commercial/industrial/any other third party owned system adopts a project finance based accounting route and considers the cost components for asset depreciation, interest on loan, interest on working capital, O&M charges as percentage of capital cost, and return on equity.

On the revenue side, the net solar energy is multiplied with electricity tariff rate. The electricity tariff is annually increased with an escalation factor. Note that due to grid outage some solar generation will be lost. This has been taken into account in estimating the available net solar power. Average power outage hours in the cities have been considered. However, for cities without any power outage, such as in Gandhinagar, maximum generated solar energy can be utilized. The financial performance indicators, such as Levelized Cost of Electricity (LCOE), payback period, Net Present Value (NPV), and Internal Rate of Return (IRR) are estimated from the cost and revenue parameters.

ASSUMPTIONS FOR FINANCIAL ANALYSIS FRAMEWORK

a. **Electricity generation:** The SPV systems used for residential and commercial sectors are 2 kWp and 100 kWp, respectively. The effective sunshine hours (ESH) at latitude tilt angle are estimated using PV Watt software tool. The overall system loss is assumed to be 25 per cent. There is 20 per cent degradation in PV module efficiency in over 20 years. The SPV system has a life of 25 years, while, the inverter service has a life of 12 years.

b. **SPV system cost:** The costs for two categories of SPV systems – residential owned and commercial/industrial/any other third party owned— are considered. The cost of a residential rooftop individual SPV system is assumed to be INR 100/Wp. For residential systems deployed through bulk procurement, a cost advantage of 10 per cent over the single procurement is assumed due to procurement of SPV system components in large quantities. The SPV system prices considered in the study have been validated from various system integrators and CERC guideline.

   For commercial applications, the cost of a SPV system is INR 90/Wp and that deployed through a third party installer is INR 81/Wp. We assume that the cost of self-owned commercial SPV system is lower than that of residential system, as larger sized systems for commercial sector are more cost-effective than smaller systems.

c. **Financial assumptions:** Equity and debt split for all sectors is 30 per cent and 70 per cent, respectively. For residential customers the estimated monthly instalment (EMI) is calculated on the basis of 70 per cent of the capital cost, which is available through loan paid back in 10 years. Discount rate of 10.95 per cent is assumed (as per CERC SO 243).[3]

d. It is assumed that the annual O&M expense, as part of capital cost, is 1 per cent and the annual O&M escalation rate is 5.72 per cent (as per CERC SO 243). Annual depreciation rate is 5.83 per cent during first 12 years and thereafter it is 1.54 per cent per annum. Interest on term loan on debt is 13 per cent and the loan tenure is 12 years. The working capital assumes O&M charges for one month, maintenance spares at 15 per cent of O&M charges, and receivables for debtors for two months. The interest on working capital is 13 per cent. The return on equity is 20 per cent per annum for first 10 years and 22.4 per cent thereafter.

e. **Operation and maintenance:** The O&M charge for self-owned residential systems is assumed to be 1 per cent of the capital cost of the system. The inverter replacement is 25 per cent of the system cost.

f. **Electricity cost:** Electricity tariff data for six cities from 2007–08 to 2013–14 has been used. For projecting the increase in electricity tariff over 25 years, we calculated the compound annual growth rate in tariff for each city and have been averaged for six cities.

g. **Power outage:** The duration of daily power outage for residential, industrial, and commercial sectors was obtained during the market survey conducted for six cities.

[3] Petition No. 243/SM/2012 (Suo-Motu), Central Electricity Regulatory Commission, New Delhi

The power outage hours differ from summer and non-summer months. Therefore, the power outage duration has averaged for summer and non-summer months. It is assumed that 50 per cent of the power outage occurs during the day and rest in the night.

h. **REC:** The current REC mechanism envisages minimum plant capacity of 250 kWp. The REC prices (floor and forbearance) are declined during 2011. Being very high compared to cost of generation at current capital cost of SPV systems, the REC plants are unable to sell RECs. Hence, we have not considered the impact of REC in financial calculation for rooftop SPV systems, which are predominantly less than 250 kWp.

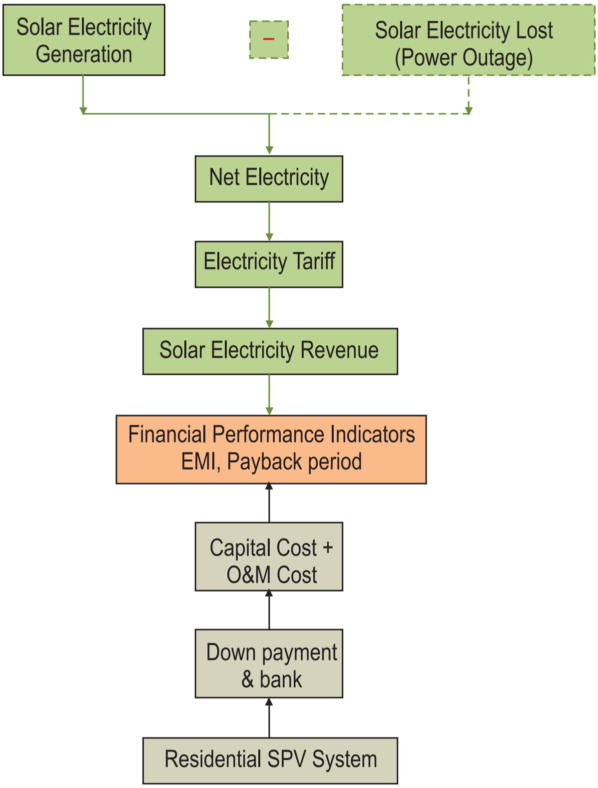


Figure 19: **Methodology adopted for financial analysis for residential consumers**

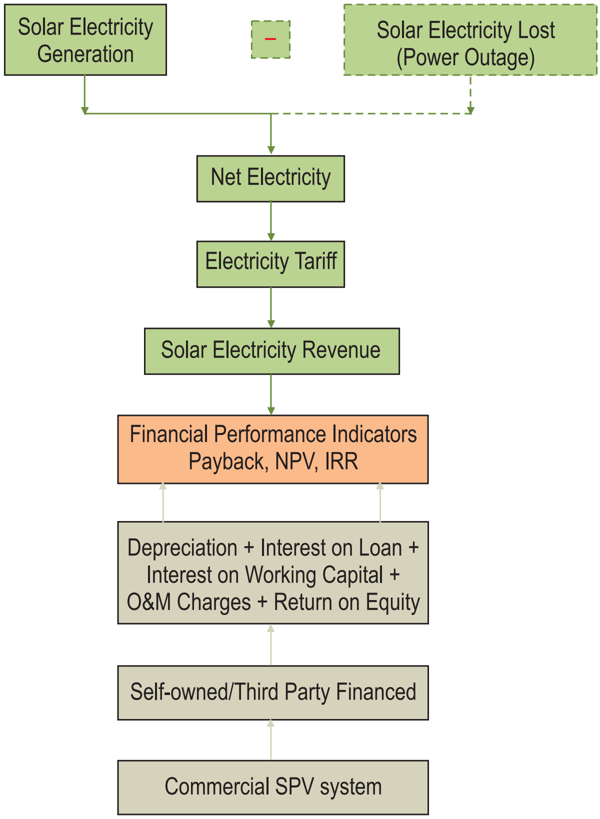
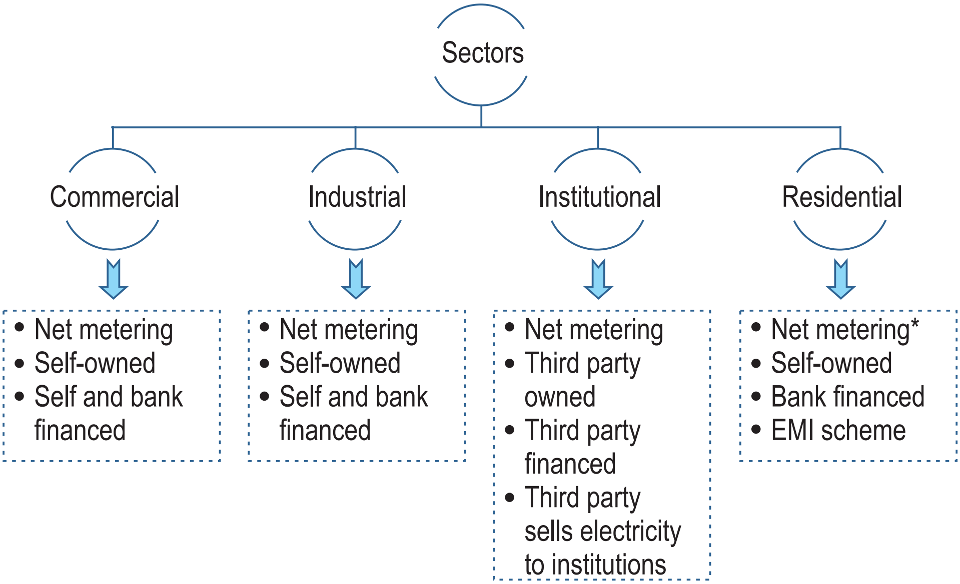


Figure 20: **Methodology adopted for financial analysis for commercial/ industrial/institutional consumers**

Pictorial representation of implementation models appropriate to each consumer category is given below.



* Net metering configuration combined with storage system is an option for consumers, who use additional power backup system

A PV system for residential sector without any incentive

System capacity = 2 kWp

Monthly generation in Delhi = 241 units

Energy loss due to grid outage in Delhi = 9.6 units

Net generation = 231 units/month

Grid electricity rate = INR 5.4 /unit

Waived off electricity bill = INR 1,238 /month

Total benefit per year = INR 14,851

Payback period for the investment = 10 years

Grant/subsidy/bulk purchasing will help in reducing the capital cost of the system and then reduce the payback period.

In another model, some part of the project cost can be financed through a bank, for which the residential consumer has to pay EMI's for 10 years. In this case, interest rate for the financed amount is assumed to be 13 per cent. The graph in Figure 21 shows variation in monthly EMI's at varied capital costs. It also depicts a variation in the EMI's at 70 per cent and 50 per cent financing by the banks.

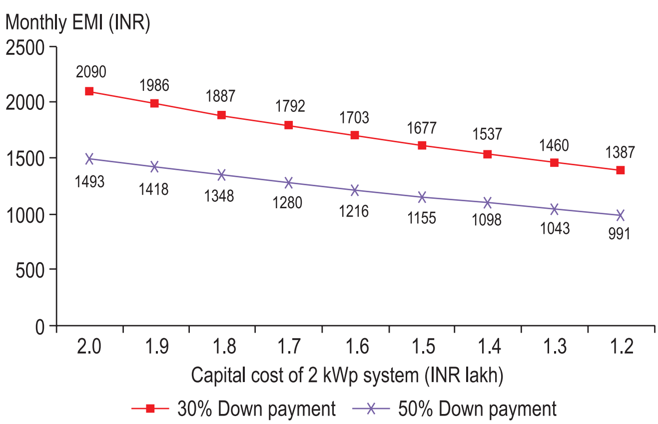


Figure 21: **Monthly EMI vs. capital cost at different percentage of down payment**

The effect of interest rate on the monthly EMI is calculated and it is observed that, at 5 per cent interest rate, the monthly EMI amount will reduce to INR 1,485 from INR 2,090 at capital cost of INR 2 Lakh for a 2 kWp system and at 30 per cent down payment.

Different system capacities would be required by the consumers in residential sector, depending on their monthly electricity consumption (Table 5).

***Table: 5:* Financial analysis for different size rooftop SPV systems in residential sector**

Parameters	Monthly electricity consumption (kWh or units)							
	100–150		150–250		250–350		350–550	
PV system capacity (kWp)	1		2		3		4	
Electricity generation from solar (kWh)	116		231		347		463	
Monthly electricity bill (INR)	621		1,191		1,947		2,773	
Payment option (Down payment: Bank finance)	30:70	50:50	30:70	50:50	30:70	50:50	30:70	50:50
LCOE (INR/kWh)	4.78	4.67	4.78	4.67	4.78	4.67	4.78	4.67
EMI (INR/month) for 10 years	1,045	747	2,090	1,493	3,136	2,240	4,181	2,986
Payback period (years)	10	10	10	10	10	10	10	10

A PV system for commercial/industrial/institutional sector without any incentive

We assume a 100 kWp and a 500 kWp PV system for a commercial/industrial/institutional building. The system capacity could vary depending on roof space available in a particular building. In all these sectors, it is likely that a medium or large sized system integrator will be engaged for installing the system. In case of institutional sector, a third party, preferably system integrator (also called solar developer) can also own the system as well as installation. In this case they can sell electricity to the institution because it is beneficial to the institution and also to third party due to their day time working hours and solar generation in the day time. Therefore, the financial analysis would include additional element, such as debt financing, return on equity, working capital, etc. However, cost advantages due to larger system size (as compared to small residential rooftop systems) are assumed in this analysis.

Here the tariff considered for selling electricity is INR 7.5/ kWh. In case of gross metering mode of implementation, system integrator will pay lease rent to the roof owner and extract the additional cost by selling electricity at preferential tariff (Table 6).

***Table 6:* Financial analysis for different size rooftop SPV systems in commercial/ industrial/ institutional sector**

System capacity	100kWp	500kWp
Solar generation	11,880	59,400
Monthly electricity bill	1,14,158	5,70,789
Capital cost (INR/Wp)	90	81
LCOE without AD benefit and tax (INR/kWh)	5.11	4.61
LCOE considering tax after 10 years (INR/kWh)	5.79	4.61
AD benefit (INR/kWh)	0.48	0.43
Payback period (years)	7	6.5

The system cost will be paid soon if the system can be procured at low cost due to grant/capital subsidy or economy of scale.

The change in IRR with capital cost and unit cost of grid electricity is shown in Figure 22.

From the graph it is clear that one of the best possible options that IRR could be 22 per cent, if the system price is INR 7.33 Crore /MW, and electricity sale price in first year is INR 8.00/kWh and escalates by 7 per cent each year.

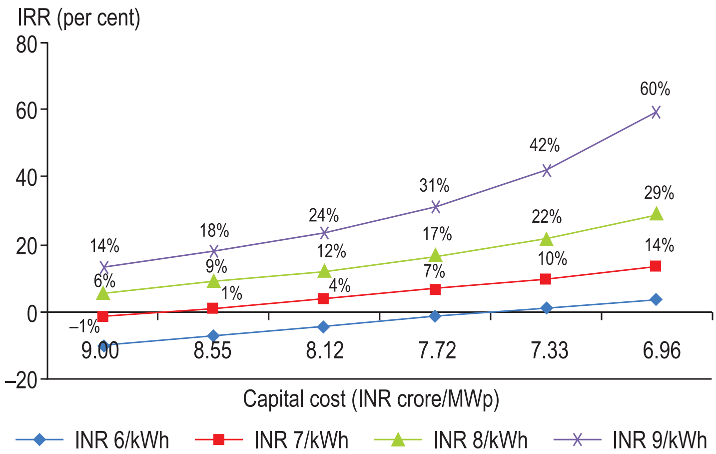


Figure 22: **PV system owned by a commercial/industrial consumer or a third party with net-metering configuration**

In gross metering mode the electricity generated from solar is fed to the grid, but in case of net-metering, during power outage generated electricity get wasted. Gross metering mode brings little more revenue than the other due to generating electricity during power outage and due to similar reason; IRR is better compared to net-metering mode of implementation (Figure 23).

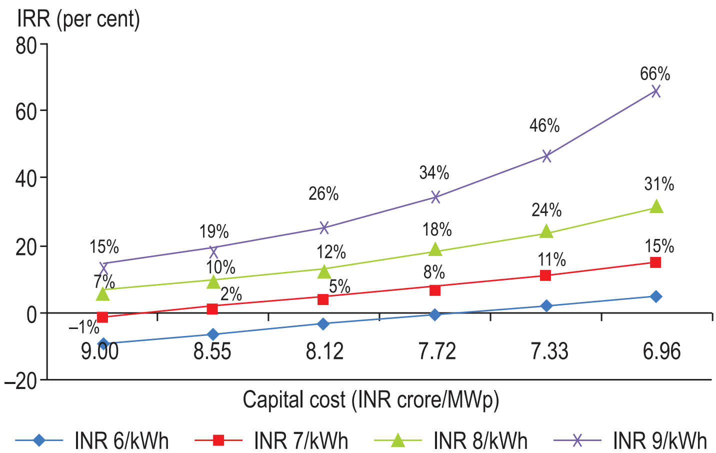


Figure 23: **PV system owned by a commercial/industrial consumer or a third party with gross-metering configuration**

Risk Analysis

Risk analysis for different stakeholders involved in different business models for implementation of rooftop SPV systems is presented in Table 7.

Table 7: **Risk analysis for investors/financers**

Consumer type	Risk perception	Risk level (High(H) / Medium (M) /Low (L))	Likelihood of occurrence (H/M/L)	Risk mitigation strategy
Residential	Loan default	H	L	Linking solar loan with property loan
	Electricity generation revenue lower than expected	M	L	Quality control and design standardization
	Sale of property	H	M	Linking solar system with the property. The owner of the property also owns the system
Commercial/ industrial	Loan default	H	L	Linking solar loan with the existing loan of commercial/ industrial entity
	Electricity generation revenue lower than expected	M	L	Quality control and design standardization
	Sale of commercial/ industrial establishments	H	M	Linking solar system with the commercial/industrial establishment. The owner of the commercial/ industrial establishment also owns the system

Table 8: **Risk analysis for utility**

Client type	Risk perception	Risk Level (H/M/L)	Likelihood of occurrence (H/M/L)	Risk mitigation strategy
Residential/ commercial/ industrial	Revenue loss due to generation by consumer	M	M	Utility may enter into the business in third party ownership mode
	Loss for power surplus utilities	M	L	Sale of electricity to power deficit regions and industries
	Payment for surplus electricity fed to the grid	L	L	Cap on system size for individuals Choose energy settlement mode instead of paying for surplus

Table 9: **Risk analysis for consumers**

Client type	Risk perception	Risk Level (H/M/L)	Likelihood of occurrence (H/M/L)	Risk mitigation strategy
Residential/ commercial/ industrial/ institutional	Lower generation from solar than expected	M	L	Quality control and design standardization
	Grid unavailability	M to H	M	Consumers can opt for PV system with storage and dual function inverter, which will allow consumption of electricity during grid outage

Conclusion

The study concludes that

a) Roof top solar PV systems have great potential.

b) There is a need for awareness creation both about rooftop solar PV systems/ technology packages as well as about the financing avenues available.

c) There is need for standardization.

d) The policy support is essential in terms of regulations for net metering, grid-interconnection, and energy accounting.

e) There is a need for promoting large scale, local manufacturing of dual function inverters (functionality of both grid-tied and hybrid inverters) to reduce cost.

f) There is need for technical innovations in storage technologies - mainly to reduce costs and improve efficiency.

g) Roof tops solar PV systems can play an important role in providing reliable and assured power for buildings and establishments.

The market can broadly be categorized into two major segments – a) residential systems and b) commercial/ industrial and institutional systems.

Recommendations

RESIDENTIAL SECTOR

This sector needs

- Standard configurations
- Initial support from the government in terms of soft loan to stabilize the market.
  - Soft loans could be implemented through banks and home finance companies which have established business processes for client assessment, loan security, disbursal and recovery. This can be done in line with MNRE's solar water heating programme in which, MNRE is providing soft loan at 5 per cent interest rate.
  - Bulk purchasing of individual systems could help in reducing the upfront capital cost. Soft loan coupled with standardized system configurations would create right market conditions for larger off-take of roof top solar PV systems.
- Certification of installer and developers along with specialized training and certification of technicians for installation of roof top solar systems would infuse confidence in clients and would also enhance the quality of installations.

COMMERCIAL AND INDUSTRIAL SECTORS

Major challenge for this segment is meeting the expectation of reliable and cheap power. While reliable power solution could be expensive and may not be practical considering the limitations on availability of area for installation, intermittent nature of solar energy and so on, the solar power generation could be cheaper than the grid power in most cases.

One major concern is revenue from excess power during holidays or non-working days when consumption is low. The study shows that state policies have different stands on this. While some state policies allow banking for up to one year others just ignore it. MNRE, CERC, SERCs, and utilities can come to a common understanding, which can help in creating uniform or reasonable duration for banking.

INNOVATIONS IN UTILITY POWER BUSINESS MODEL

One of the major challenges for market development of roof top solar PV systems is the reluctance of DISCOMS to encourage the roof top systems as they see it as a threat to their revenue. This issue need to be studied in detail as there are many facets to this. It can be argued that by promoting roof top solar PV systems, the utilities can meet their service obligation of providing power to the consumer. There is an urgent need for developing new tariff models, which can incorporate the possible impacts of large scale implementation of roof top solar systems.

System sizing would be critical especially if the grid outage is severe and solar PV system is designed to provide adequate back-up power. This capacity may become redundant once power supply situation improves.

Second major concern of utilities/grid operators is the technical issue of grid balancing. This can be handled with appropriate interventions, such as smart controllers, forecasting and grid interactive short term storage at feeder level to handle sudden short term dips in solar generation.

Technology development for innovative solutions for grid interactive inverters, including load management during grid outage or power cut would be essential.

Further, areas of intervention, and roles and responsibilities of different stake holders are summarized in the Table 10.

***Table 10:* Interventions and actions required by responsible organizations**

Areas of intervention	Actions required	Roles and responsibilities
Creating awareness	• "Solar Shop" at commercial establishments • Spread information through advertisements • A dedicated website for rooftop SPV • Design competitions	• Private developers to open solar shops • MNRE and SNAs to support private entities
Promoting standard PV systems	• 1–10kWp for residential • 10–100kWp for commercial • >100kWp for industrial	• Solar developers to manufacture and promote SPV systems • MNRE and SNAs help to achieve economy of scale
Technical standards for LT connectivity	• Need to follow, CEA guidelines, Net-metering guidelines, G83-1/1 (EN 50438), IEC 61727 and IEC 62116	• CEA to strengthen technical standards • Distribution company to specify upper limit for capacity addition
Self-consumption during power outage	• Grid interactive system with storage should be promoted. • Promote indigenous manufacturing to reduce overall system cost	• Developers to manufacture SPV system • MNRE and SNAs to support developers and consumers
Quality assurance for rooftop SPV	• Introducing star rated programme for rooftop SPV system	• MNRE and BIS/CEA to take initiatives
Creating infrastructure for after sales service	• National and regional level skill development and training centres • Service centres by solar companies • Certification of technicians	• MNRE, SNAs, technical training institutes, and solar companies to take initiatives

Areas of intervention	Actions required	Roles and responsibilities
Strengthen supply chain for rooftop SPV	• Availability of standard PV system packages at electrical shops/company outlets	• Solar companies and retail Outlets to take initiatives
Cost	• Different capital subsidy for different types of consumers • More than one project can be bundled and procured together for cost reduction	• MNRE and SNAs design the subsidy mechanism • Consumers to bundle projects
Financing schemes	• Easy financing and EMI payment options • MNRE subsidy for establishing distributorship/retailer ship	• MNRE and SNAs to take initiative • Rural, and other nationalized and private banks to finance
Generating funds	• Government or municipality can raise funds through green bonds	• MNRE, SNAs, and municipality to take initiatives
Simple approval procedures	• Single window clearance • Online processing of application • Removal of unnecessary clearances	• MNRE and SNAs
RPO and REC	• Electricity from rooftop SPV should be used by DISCOMS to claim REC	• DISCOMS, CERC, and SERCs
Monitoring, control, and verification	• Energy accounting at regular intervals should be done • SPV system as a product should be certified for enhancing confidence on the product by the consumers as well as banks • SNAs should check product quality and its implementation.	• DISCOMS, SNAs, MNRE, and certifying agencies
Lack of roof space	• People living in high rise buildings (> 3 storeys) should invest in green bonds • Rooftop SPV should be compulsory for new government buildings, educational institutes, and hospitals	• Consumers, development authorities, real estate developers, SNAs, and MNRE should follow coordinated approach
Replication of web GIS tool for other cities	• Phase wise targeting of several more cities	• SNAs, SECI, and NRSC

Way forward

Roof top solar PV systems can play an important role in augmenting the generation capacity and using solar energy effectively and efficiently by generating power at the consumption point.

A long term strategy for promoting this market is essential. MNRE and MoP can decide strategies for a) residential sector (smaller systems up to 5 kWp) capacity and b) for larger systems (> 5 kWp).

Furthermore, detailed implementation model development including action plan for capacity building, standardization, and certification could be taken up on priority basis by concerned departments.

Annexure I:
Global experience of rooftop SPV

Figure 24a shows various market incentive schemes for rooftop solar PV implementation adopted globally since 1992 to 2011. It clearly shows the dominance of feed-in tariff and direct capital subsidy. But in the year 2012 it was observed that self-consumption mode of implementation increased from 3.4 per cent to 12 per cent[4]; however, feed-in tariffs schemes (approx. 61 per cent) and direct capital subsidies (21 per cent) aiming at reducing the upfront investment cost still dominated a large part of the market (Figure 24b).

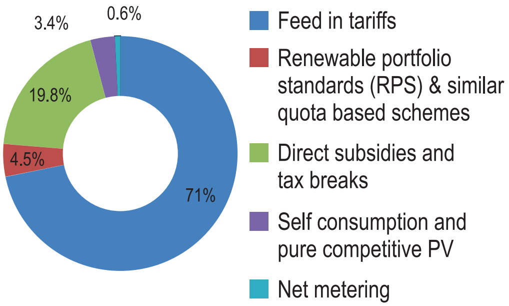


***Figure 24a:* Historical market incentives for rooftop SPV in the world (1992-2011)**

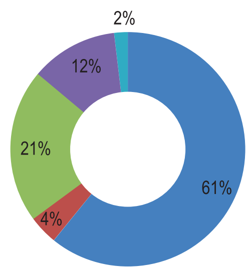


***Figure 24b:* Market incentives for rooftop SPV in the world in 2012**

AUSTRALIA

The total installed PV capacity in Australia is approximately 2.4 GW by the end of 2012. Till 2008, off-grid solar applications were the predominant format in Australia, after which on-grid solar applications have almost become the norm. Major reasons for a strong evolution of the market can be seen in terms of feed-in tariff/net-metering schemes, incentives and rebates, mandatory renewable energy targets, community projects, etc. Currently, the federal government of Australia has not enacted any national tariff scheme for solar PV project, hence different states follow different schemes, for e.g., while Australian Capital Territory (ACT) and New South Wales follow feed-in tariff schemes, other state government have enacted net-metering schemes.

[4] As per IEA Energy Agency Trends 2013

At the federal level, Solar Homes and Communities Plan (SHCP) provides rebates of up to AU$ 8,000 for 1 kW of PV installed on residential buildings and up to 50 per cent of the cost of PV systems installed on community buildings (e.g., schools). In addition, National Solar Schools Programme (NSSP) allows schools to compete for grants up to AU$ 50,000 to install solar and other renewable power systems[5].

Under the Renewable Remote Power Generation Programme (RRPGP), rebates up to 50 per cent of the capital cost of renewable energy and of related components is provided for displacement of diesel generated electricity. Some typical applications include use in off-grid households, indigenous communities, community organizations, retail/roadhouses, tourism sites, pastoral stations, and other off-grid business and government facilities.

Utilities are losing market share, especially during the daytime peak load period where electricity prices are quite high. However, two utilities have stepped into the PV business, capturing significant market share.

GERMANY

Germany has installed around 32 GW of PV systems by end of 2013. Feed-in tariff was introduced for PV electricity that is adjusted in the electricity bill of the consumers. With the decrease of PV price, Germany introduced the "Corridor" concept in 2011. It is a method, which allows feed-in tariff levels to decline according to the market evolution. The more the market was growing during a defined period of time, the more the feed-in tariff levels were lowered. Self-consumption premium was paid above the retail electricity price. The premium was higher for self-consumption, i.e., above 30 per cent. In 2012, the premium was cancelled when feed-in tariff levels went below the retail electricity prices.

Market Integration Model: Opposite to self-consumption incentives, Germany pushed PV producers to sell electricity in the electricity market through a "market premium". The producer can decide to sell its electricity in the market any period of time, instead of getting the fixed tariff. The producer receives an additional premium on top of the market price. As the penetration of PV is more than 5 per cent of the electricity demand, the behaviour of utilities can be seen as a mix of an opposition towards PV development and attempts to take part to the development of this new business. Companies such as E.ON have established subsidiaries to target the PV on rooftop customers.

JAPAN

The total cumulative installed capacity of PV in Japan has reached 10.5 GW by the end of 2013. The cumulative annual growth rate during the 11 year period of 2002 to 2013 has been phenomenal (about 27 per cent). The major reason for the consistent and sustainable growth has been the new feed-in-tariff policy of the government of Japan, which was introduced in 2009 and strengthened in 2011 (Figure 25).

With the start of the Feed-in Tariff (FiT) programme, the market for public, industrial application, and utility-scale PV systems grew fast.

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[5] Source: Trends in Photovoltaic Applications – Survey Report of Selected IEA Countries Between 1992 and 2010 (2011) published by International Energy Agency, Wikipedia (http://en.wikipedia.org/wiki/Feed-in_tariffs_in_Australia, date accessed 10th Sep 2013)

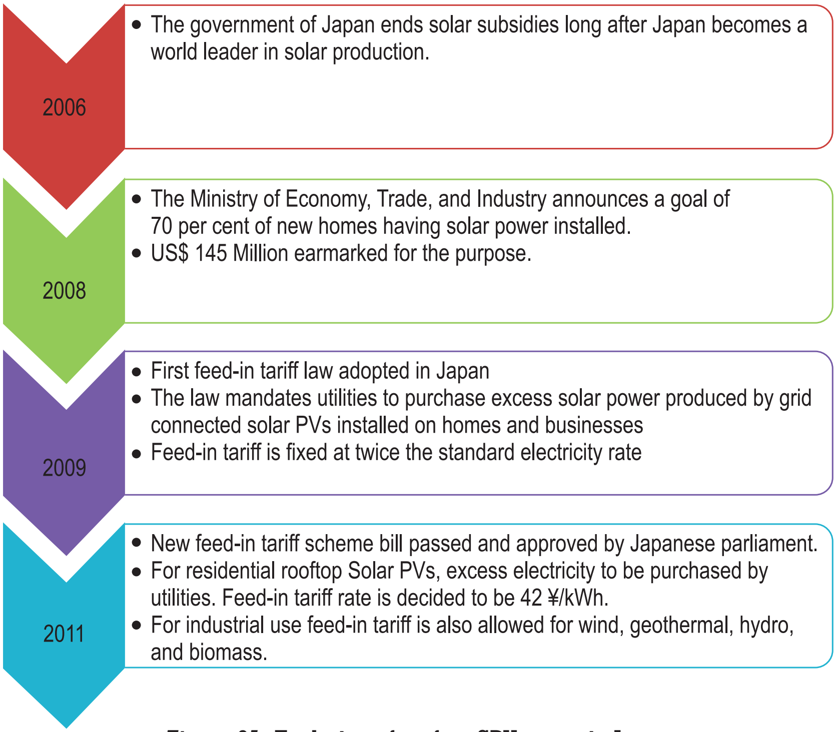

***Figure 25:* Evolution of rooftop SPV sector in Japan**

SPAIN

In 2007 and 2008, Spain's FiT programme triggered a rapid expansion of the PV market. Large PV installations developed fast and drove Spain to the very first place in the world PV market in 2008. In October 2008, a moratorium was put in place in order to control the growth. FiT was granted only after a registration process capping the installations at 500 MW/ year. After a low 2009, due to the time required to put the new regulation in place, the market went down to between 200 MW and 450 MW a year. In 2012, a 223 MW SPV was installed in Spain. Some measures taken have affected retroactively the PV electricity producers, due to difficult economic conditions. The most visible one is the cap on hours during which PV installations received the FiT. As a result FiT's are granted for a part of yearly production only. This was done in a context of overcapacity of conventional electricity plants in the country, combined with limited interconnections. This situation lead to opposition of conventional stakeholders and grid operators in such a way that it forced the government to decide a moratorium for all new renewable and co-generation projects benefiting from FiTs ("Special regime") from January 2012. Finally, at the end of September 2012, Spain imposed a new tax on all the generation technologies to cover the electricity prices deficit, reducing the profitability of the existing PV plants. Discussions on a possible net-metering system were not conclusive in 2012 and even self-consumption became difficult to implement.

USA

USA has a total installed solar PV capacity of approximately 7,272 MW by March, 2013. The main driver for accelerating the US PV market are the tax credits and rebates granted by the federal US government for initial years. Apart from the federal push, some states as a complementary measure also offered net-metering to promote self-consumption of solar electricity. Renting rooftop SPV system is also popular among residential consumers in USA.

Currently, SPV installation in USA is slowing down, as utilities have reached and exceeded renewable energy obligations. Some utilities have started opposing PV development, especially the net-metering systems, due to two reasons. The first reason is that the RPS targets of the utility have already been met and the other reason is that the self-consumption from solar generation is a revenue loss for utility.

In recent years, rooftop and other distributed solar energy generation has become an established global market, and is rapidly becoming a significant contributor to a number of regional energy markets. Stakeholders involved in solar energy business are utilities, commercial and residential consumers, developers, manufacturers, banks and regulators. Stakeholders make daily choices that create different business options.

The initial cost of solar PV system acts as a major barrier for its deployment. To overcome this barrier various types of government subsidies, tax incentives/rebates, and financing options have emerged across different countries. Some of these financing mechanisms practiced in USA are:

1. *Financing through government/ municipalities*

Government and municipalities can play a significant role in accelerating the adoption of rooftop SPV. Several municipalities in USA have initiated programmes to increase the affordability of rooftop SPV projects either through the provision of financial incentives such as low-interest loans, rebates, subsidies, or creating alternative ownership structures, such as shareholding structure in solar farms. In order to make such programmes possible, government or municipalities may need to initially raise capital through the issuing of bonds or other sources.

a. Property-Assessed Clean Energy Programmes (PACE)

Property Assessed Clean Energy (PACE) is a municipal financing mechanism in which property owners receive 100 per cent financing (loan) for renewable energy projects from the municipalities. They repay the loan through their property tax bills. Municipalities collect this fund from local people by issuing of green bonds.

In PACE financing mechanism, the payment is tied to the property tax bills of the property owners. If the property is sold before the end of the repayment period for the rooftop SPV system, the new owner will inherit the repayment obligation and can enjoy the benefits of the rooftop SPV system, including power generation and increased property value.

b. Municipal bond-PPA model (The Morris Model)

In this model, the government raises fund through issuing a bond at a low interest rate. Government then passes on the proceeds raised by the bond to the solar developer in exchange for an attractive lease-purchase agreement. The solar developer designs, builds, owns, and operates the system. The solar developer can sell the electricity produced through a power purchase agreement (PPA) to the DISCOMS. This model has first been implemented in Morris County, New Jersey, USA in 2010.

2. Third-party ownership model: Solar leasing and Solar PPAs

The third-party ownership model has been a driving force for rooftop solar market expansion in different countries. In this model, a commercial company owns and operates the SPV system on the building owner's rooftop. The electricity generated from the SPV system is either used by the building owner ("solar leasing" model) or sold to the utility ("solar PPA" model). The owner of the SPV system enjoys the subsidies, tax benefits etc.

a. Solar leasing

In this model, the customer or building owner ("solar lessee") does not pay the upfront cost of the SPV system but instead leases the system by paying fixed monthly instalments over a specified period of time and consumes the electricity generated by the leased system at a price that is sometimes cheaper than utilities price. The building owner ("solar lessee") would sign a long-term contract with a "solar lessor." The solar lessor is a company that owns, operates, installs, and maintains the PV system. These "solar lessors" install the system on the customer's property for free or at minimal cost and collect monthly payments from the customers. The companies also guarantee system performance with a promise to compensate the customer in case the system does not perform according to specifications. The solar leasing model is now pre-dominant in the residential rooftop market in the U.S.

b. Solar Power Purchase Agreements (Solar PPAs)

Solar PPAs is an arrangement in which customers buy electricity from a third-party developer at a price specified during the contract term, typically for 10–20 years. The third-party developer installs, owns, and operates the solar system on the customers' properties or other types of properties. This model helps in reduction or elimination of the upfront cost, allowing those with less income to afford SPV systems.

3. Utility-sponsored model

In addition to local administration, power utilities have begun to offer their customers the options of owning solar power systems. In this model, utilities find a source of finance on behalf of its customers.

a. On-bill financing

On-bill financing is a mechanism by which renewable energy projects are paid for by electric utility customers on their monthly electricity bills. Utilities have access to low-interest capital, compared to individuals and small businesses. On-bill financing programmes work in three stages. 1) Utilities obtain low-interest loan. 2) This money is made available to qualified small scale commercial, residential, or community renewable energy or energy efficiency projects in the form of a loan. 3) This loan is repaid to the utility as on-bill financing, i.e., as a line-item in the customer's electricity bill.

This programme helps address financing issues in several ways:

- Loan collection is bundled with electricity bill, thereby reducing transaction costs associated with collecting payments.
- Loan payments are offset by feed-in payments. This arrangement lowers the risk of non-payment.
- Collection risk is also lowered as failure to pay loan payment would lead to power cut.
- Reduction of risks described above, combined with utility access to low-interest financing translates to lower interest rates for borrowers.

b. Utility-owned distributed solar

The utility will install, own, and operate the systems. Utility-owned rooftop systems can be installed on leased commercial and public properties in the utility's service territory. This model lowers the transaction costs associated with the customers' payments for the systems through utilities' bills.

4. Volume purchasing

The high upfront cost of distributed solar power can be overcome by combining the purchasing power of the individual rooftop owners through bulk purchasing of solar panels. This model decreases the cost when combined with government incentives. Homeowners interested in solar power get together in educational workshops where they together decide as a group on the size of solar installations and the contractor. The system integrators can offer high discounts because they can save on marketing and permitting costs.

Annexure II:
India's rooftop solar PV potential

This section presents the findings on calculation of India's rooftop solar PV potential in terms of technical, economic, and market potentials.

VARIOUS POTENTIAL DEFINITIONS

India's potential to generate electricity from rooftop solar PV can be measured at three different levels. These are explained below:

Technical potential: This describes the fraction of resource potential that can be used under the existing technical, structural, ecological, legal, and regulatory restrictions.

Economic potential: This is the fraction of technical potential that can be economically realized. There can be multiple ways to further define economic potential as it depends on the aspect of economic situation considered. In the present case, paying capacity of a household/establishment for rooftop solar PV is considered as defining economic potential.

Market potential: It is defined as the final rooftop solar PV potential under the market dynamics (demand and supply, acceptability, etc.)

APPLIED METHODOLOGY AND ASSUMPTIONS

This section discusses the methodology and assumptions to calculate technical, economic and market potentials. The fundamental requirement for calculation of potentials at various levels is deriving the total rooftop area on which solar PV can be installed. Also, the basic assumption is that in order to install a 1kWp (kilo Watt peak) solar PV system, an area of 10 m^2 is needed.

Calculation of potential for whole country is a complex task, as calculation of technical potential for rural settlements would require a different methodology given the diversity and variety of rural areas in India. Therefore, potential estimation is limited to areas under urban settlement. Total area in India under urban settlements is 77,370 km^2.

TECHNICAL POTENTIAL

Technical potential of rooftop solar PV would require calculation and derivation of total eligible rooftop. The eligible rooftop area is defined as the total usable rooftop area of residential, commercial/institutional, and industrial buildings after deducting area which may be used for alternate uses.

Various primary and secondary sources have been used to determine the following:

- Total urban area in India(77,370 km^2),[6]
- Total area earmarked for residential, commercial/institutional, and industrial uses,[7]
- Total area which can be used for actual construction of buildings as a percentage of earmarked area[8], and,
- Total rooftop area as percentage of actual constructed area[9].

Table 11 shows the land use classification of four cities in India.

Table 11: **Land use classification of some of the major cities of India**

Type of land-use	Bhubaneswar	Chandigarh	Delhi/NCR	Pune	Average
Data Year	1999	2011	2001	2001	--
Residential	75.40	42.69	603.39	103.74	38%
Commercial/ Institutional	4.94	5.36	42.10	3.93	3%
Industrial	5.86	5.31	56.13	9.88	4%
Other Areas	147.10	59.32	781.38	126.29	55%
Total Area (km2)	**233.30**	**112.68**	**1,483.00**	**243.84**	**100%**

The above information is for four cities of India. There are thousands of towns and cities in India and it is a cumbersome task to collate similar information for all. However, it is understood that on an average, the residential areas in most Indian cities would have larger share of the city while commercial/institutional and industrial areas would occupy lesser areas. This would be due to flat structure of cities (leading to lesser high rise buildings which occupy less area) with lesser economic activity (which accounts for commercial and industrial areas). In absence of any comprehensive figure and with respect to average number of four different kinds of cities, the following norms are assumed for India.

Residential area : 40 per cent of the city

Commercial area : 2 per cent of the city

Industrial area : 3 per cent of the city

Also, study of building construction norms which define ground coverage (percentage of area on which a particular building can actually be constructed; also called covered area) has led to following norms.

Average ground coverage of residential buildings : 55 per cent

Average ground coverage of commercial buildings : 40 per cent

Average ground coverage of industrial buildings : 60 per cent

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6 Utilization of Land Resources for Urban Sector in India – Present Practices and Policy Requirement published by Town & Country Planning Organization under the Ministry of Urban Development of the Government of India

7 Town planning documents of various cities as examples

8 Building construction norms for various cities defining ground coverage , discussions with experts such as architects

9 Discussions with experts such as architects and town planners

Based on discussions with town planners and architects, it is understood that at least 85 per cent of the covered area accounts for roof and the rest being balconies, external stairs, porch, etc.

Therefore, to summarize, total area in India under urban settlements is 77,370 km^2. The land use classification and building norms under this area are depicted in Table 12.

Table 12: **Calculation of total eligible area for calculation of technical potential**

Typical land use configuration in Indian cities			Typical ground coverage (%)	Rooftop area (% of GC)	Rooftop area (Sq. Km.)
Land use type	Area (%)	Area (km^2)			
Residential	40%	30,948	55%	85%	14,468
Commercial/ Institutional	2%	1,547	40%	85%	526
Industrial	3%	2,321	60%	85%	1,184
Other areas	55%	42,554	-	-	-
Total area	100%	77,370	-	-	16,178

However, not all area as calculated above can be utilized for installation of rooftop solar PV. To calculate usable area, following assumption has been taken (Travel 13):

Table 13: **Assumptions to calculate usable rooftop area for solar PV implementation**

Segment	Rooftop area (Km^2)	Pessimistic	Realistic[11]	Optimistic
Residential	Optimistic	10%	20%	30%
Commercial	526	20%	30%	40%
Industrial	1,184	30%	40%	50%

From experiences it is assumed that in order to install a 1kWp solar PV system, 10 m^2 area is required.

Applying the assumptions, **the total *realistic* technical potential for rooftop solar PV in urban settlements is around 352 GWp**.

ECONOMIC POTENTIAL

The proxy for economic situation of a household/establishment has been taken as the condition of roof for the purpose of this study.

Thus, as per NSS report for 63rd round (for 2006–07), 85 per cent of the households were living in pucca structures in urban areas, 4 per cent were estimated to be living in katcha structures, and 11 per cent in semi-pucca structures. Except the few cities, where high rise buildings are in vogue, in most of the cities row house is prevalent. Therefore, in absence of any definitive data, the percentage of pucca structures can be assumed to be around 60 per cent (all katcha and semi-pucca structures will be largely single storey) when considering the built-up area.

[10] Rooftop Revolution: Unleashing Delhi's Solar Potential, 2013. A study done by Bridge-to-India with the help of Greenpeace International

For commercial and industrial structures, no data exists on the type of roof. While it may be assumed that all the commercial structures will be pucca structures, a conservative figure of 80 per cent may be taken for the same. In case of industrial structure, it may be assumed that many factories and warehouses may have roofs made up of sheets. Even if they are of concrete, they may be used for some industrial purpose. Therefore, the report assumes that only around 50 per cent of industrial roofs can have solar PV installed.

Based on the above assumptions, **the total realistic economic potential for rooftop solar PV in urban settlements of India is around 210 GWp**.

MARKET POTENTIAL

Market potential of a product/service is defined as its acceptance among the target segment, given the technical and economic requirements are met. This acceptance has been derived using the comprehensive sample survey conducted among the consumers (residential, commercial and industrial). A question to measure the acceptance of rooftop solar PV was posed to the respondents with answer to be given on a 5-point Likert scale. The scale and percentage of respondents who selected a particular response is given in the Table 14.

Table 14: **Acceptance levels for rooftop solar PV**

Score	Reaction	Residential (177)	Commercial (88)	Industrial (89)
1	Product and the associated idea are quite bad and there is nothing which can ever make it good.	0.00%	3.40%	2.20%
2	Don't think this product and the associated idea is good. At this stage, it requires much improvement to become acceptable.	0.60%	3.40%	2.20%
3	Unable to decide whether this product and the associated idea are good or not. The pros and cons almost match each other.	20.50%	34.10%	30.30%
4	Product and associated idea are quite good but may be improved further to increase its acceptance	38.60%	38.60%	40.40%
5	Product and idea are excellent and there is nothing in it which I can call as a drawback.	40.30%	20.50%	24.70%

However, not all who like the product usually buy it. Therefore, three scenarios have been taken which assume percentage of respondents, among those who liked/disliked rooftop solar PV concept to a degree, who would actually buy it. These scenarios are presented in Table 15.

Table 15: **Conversion of like ability to actual purchase**

Score	Pessimistic	Realistic	Optimistic
Score 1	0%	0%	0%
Score 2	0%	0%	0%
Score 3	0%	25%	50%
Score 4	25%	50%	75%
Score 5	50%	75%	100%

Based on the above assumptions and applying these to results of economic potential, the **total realistic market potential for rooftop solar PV in urban settlements of India is found to be around 124 GWp**.

Annexure III:
Primary survey and market research

CURRENT ELECTRICITY SUPPLY SCENARIO

Power outage and voltage fluctuation are faced in various cities. The results from primary survey done in six cities in this regard are shown in Figure 26 and 27.

Maximum power outage happens during summer. However, average power outage is lesser for commercial segment as compared to residential and industrial segments. The power outage duration reduces towards monsoon and winter seasons.

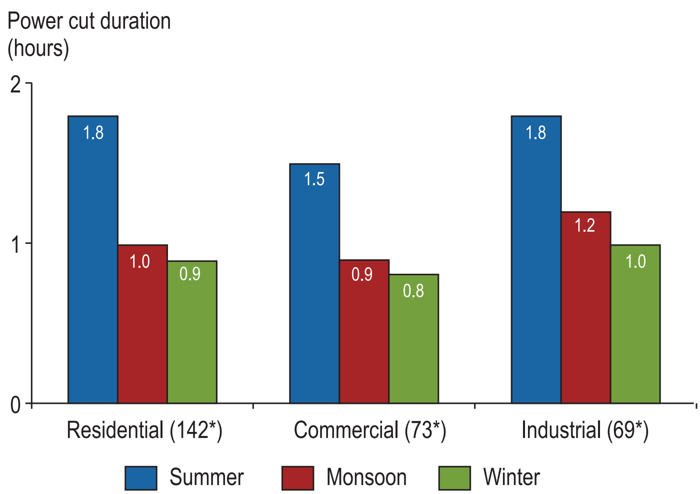

Figure 26: **Average power outage duration in various seasons (segment wise)**

* Number of respondents

Voltage fluctuation is usually much more in residential segment. Around 75 per cent respondents in this segment reported voltage fluctuation and more than 60 per cent of these respondents were found to be using voltage stabilizers to mitigate it. Around 50 per cent of the respondents in commercial and industrial segments were found to be facing voltage fluctuations and half of these were found to be using voltage stabilizers.

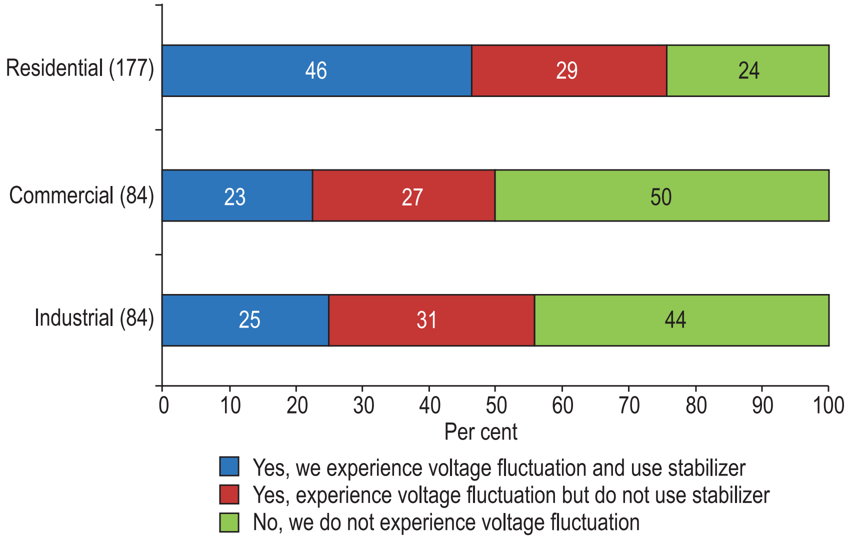

Figure 27: **Experiencing voltage fluctuation and usage of stabilizer**

CURRENT ELECTRICITY BACK-UP PRACTICES

Inverter-battery system

Usage

Around 33 per cent of respondents in residential segment, 30 per cent in commercial segment, and 23 per cent in industrial segment were found to be using inverter-battery system as their electricity back-up option. On an average, respondents were found to be using inverter for 1–2 hours. This back-up was for around 75 per cent of the duration of power cut faced by them.

Operation and maintenance

Only a handful of respondents (~3 per cent; all segments combined) had replaced inverter after its installation. However, a larger number of respondents had changed the battery of the system. It was found that around 34 per cent of the residential users, 22 per cent of commercial users, and 19 per cent of industrial users had changed the battery. This battery was roughly replaced after 3–4 years.

Generator set

Usage

Generator was used more for commercial and industrial segments than for residential segment. Thus, while only 10 per cent of the respondents in residential segment were found to be using generator, the proportion was as high as 60 per cent and 43 per cent in case of commercial and industrial segments respectively. Over 95 per cent of the respondents were found to be using diesel as a fuel for running the generator set while petrol and kerosene were used sparingly. On an average, respondents were found to be using generator set for 1–2 hours. However, in case of industrial segment, both its usage and average power cut duration is higher (for those who use generator; perhaps this is the reason why they keep generator).

Operation and maintenance

Looking at average fuel consumption, it is found that fuel consumption in summer is much more than monsoon or winter (for all the three segments). On an average, a residential respondent uses 12.5 litres, 10 litres, and 5.5 litres of fuel in summer, monsoon and winter seasons, respectively. While for a commercial segment respondent, the values are 15 litres, 11 litres, and 9.5 litres, respectively for different seasons, and for industrial segment respondent they are 10 litres, 8 litres, and 6 litres, respectively for different seasons.

On an average, while annual maintenance charges for generator are in the range of INR 5,000–6,000 for residential segment they can range anywhere between INR 10,000–20,000 for commercial and industrial segments depending upon their capacity.

Back-up electricity cost and cost-sharing mechanism

When the back-up option is common for a group of houses, like in a high rise housing society, the cost is usually shared among the residents. On an average, cost of back-up electricity may range from INR 10–16 per unit. In around two-third of the societies, the cost is included in the fixed monthly maintenance charge, while for a quarter of the housing societies separate meters are installed in each household to measure the usage of back-up electricity.

Issues with back-up systems

Most of the respondents were not facing any problem while using inverter-battery system except the lesser duration of back-up available after charging. However, some of the key issues identified by the users of electricity generator included high cost of operation due to high (and rising) fuel costs leading to higher per unit back-up electricity costs, costly maintenance, loud noise, and air pollution caused by its operation. One of the respondents also identified the vibrations caused in the building by operation of generator as one of the problems.

CURRENT USAGE OF ROOFTOP SPV SYSTEM

Figure 28 shows the proportion of respondents who are in various stages of solar PV system adoption. Thus, it was found that a majority of respondents, in all the three segments, had heard about the solar PV systems but had never used it. The proportion is as high as 83—88 per cent. Only around 6—8 per cent of the respondents were found to be using solar PV system.

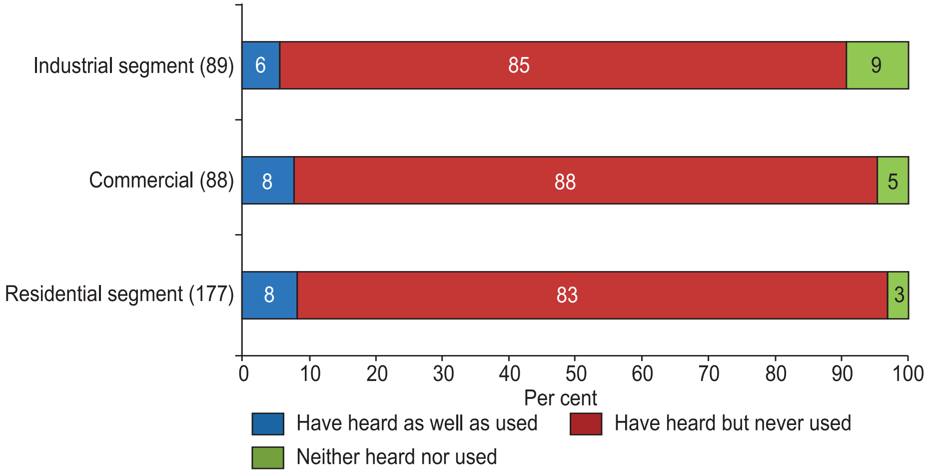

Figure 28: **Awareness and usage of solar PV systems**

BARRIERS TO ADOPTION OF ROOFTOP SPV

Rooftop solar PV is a nascent phenomenon and it is difficult to directly enquire about the barriers to its purchase. However, one of the indirect ways to understand the barriers is through enquiring about the information areas which potential / current users of rooftop solar PV may have collected about the product. The hypothesis here is that query raised by customers during purchase enquiry, if not addressed, may turn into potential barriers to purchase. In case of rooftop solar PV, there can be three broad aspects on which customers collect information. They are purchase and usage, finance, and policy related.

It was found that, on an overall level, a larger percentage of respondents had sought information on purchase and usage related aspects of the rooftop solar PV. Finance related aspects came second while policy related aspects fell in third place of importance. It was observed that respondents in Bangalore, of all segments, and residential respondents in Gandhinagar were in the forefront of collection of information.

Figure 29 shows the purchase and usage related information collection for the major segments enquired as above.

While "product technology" remains the major purchase and usage related information sought for, Gandhinagar respondents are much more concerned with available policy support. On the other hand, safety during usage and high product quality are the major information areas sought by the respondents in Bangalore.

During finances related information collection it was found that the respondents in all the six cities are concerned about capital costs and return on investment. No significant difference was seen in various cities. As per the manufacturers of PV system, high cost of installation is one of the major reasons for dissuading the adoption of solar PV system.

During policy related information collection it was found that, presence of a policy structure (in terms of subsidies and incentives) is a must for most of the respondents. Bangalore residential segment respondents emphasized on streamlined and user friendly processes for availing these subsidies.

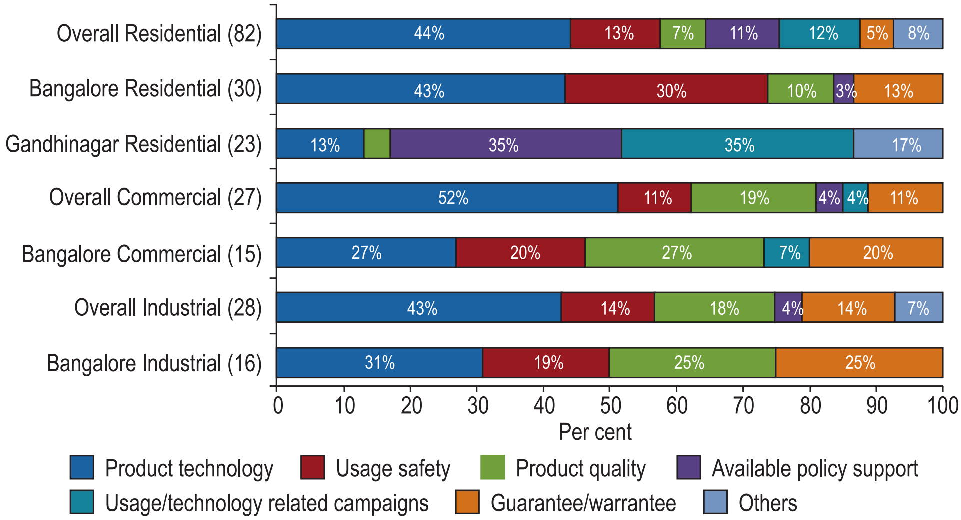

Figure 29: **Information sought by potential buyers of rooftop SPV**

As per PV manufacturer experiences, there are a few more barriers to adoption of rooftop solar PV with regards to policy. These are:

- Lowering of consumer confidence due to delays in release of subsidy. This delay largely happens because of the following:
  - Probable paucity of funds with the Ministry/Government, or,
  - Low activity of state nodal agencies in creating awareness for rooftop solar system
- Excise duty exemptions are provided only on those rooftop installations that fall under JNNSM Scheme.

Friends/family, internet, and newspaper are found to be the most important sources of information regarding solar PV (purchase and usage, finance, and policy related). However, case is slightly different for residential segment when it comes to finances and policy related information. Newspaper acts as a very important source of information for this segment in the given scenario.

THE ROOFTOP SOLAR PV CONCEPT TEST

The following procedure was followed to capture the response of this section:

- A detailed concept card was shown to the respondent with technical, operational, and financial aspects of the rooftop solar PV.
- Respondents were allowed going through the concept card and confusions were cleared by well-trained interviewers.

Based on the understanding achieved after the exposure to the concept card, pointed questions were asked to the respondent (Figure 30).

Perception of the product idea

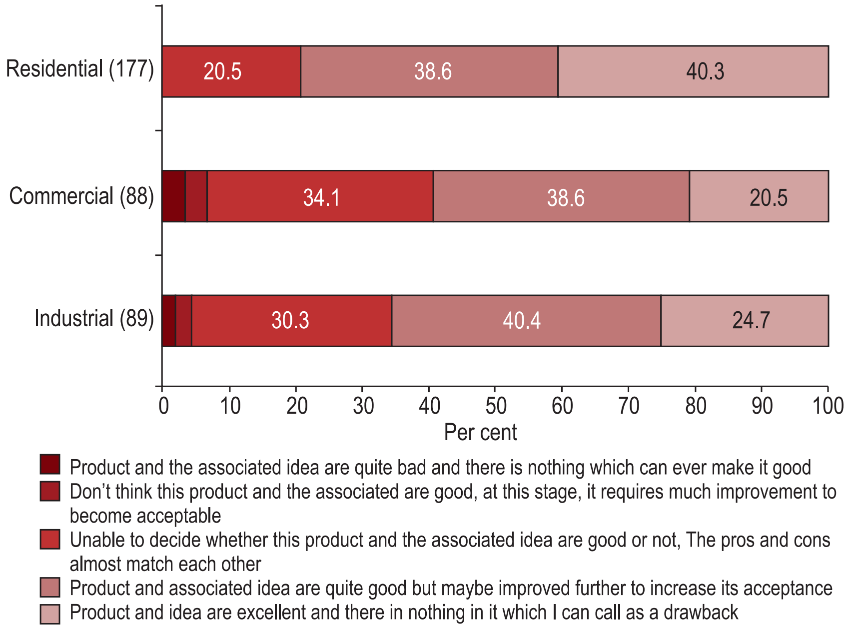

Figure 30: **State of mind after going through solar PV concept**

An overwhelming majority of respondents (~80 per cent in residential segment, ~ 60 per cent in commercial segment, and 65 per cent in industrial segment) felt that the rooftop solar PV concept and product are quite good, even excellent. Around a quarter of respondents, from various segments, were unable to decide whether the product/ concept is good or not. A miniscule minority (from residential segment) felt that they were not impressed with the idea citing the low power generation by the equipment which would prohibit them use most of the appliances, such as TV, washing machine etc.

Table 16 shows the acceptability score (on a scale of 1—5). The score definitions are as follows:

Table16: **Definition of concept likeability scores**

Score	Interpretation
0—1	Product and the associated idea are quite bad and there is nothing which can ever make it good.
1—2	Product and the associated idea are good. At this stage, it requires much improvement to become acceptable.
2—3	Unable to decide whether this product and the associated idea are good or not as pros & cons almost match each other.
3—4	Product and associated idea are quite good but may be improved further to increase its acceptance.
4—5	Product and idea are excellent and there is nothing in it which I can call as a drawback.

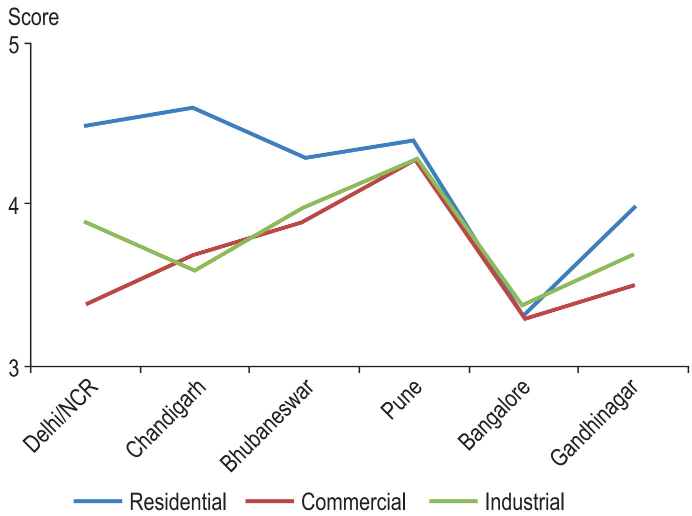

Figure 31: **Likeability of rooftop solar PV concept in various study centres**

Respondents from commercial and industrial segments said that they would like to have more knowledge in terms of awareness campaigns and advertisements before they shift to a positive opinion, at the same time pointing out that the capital cost involved with installation of a rooftop solar PV were currently high and were an expensive investment. They also have other expectations for example, with regards to finances, these respondents expect lower capital costs, higher government subsidies to finance the purchase, easier loans, and faster returns on investment (preferably 2—3 years). They also demand higher tariffs on sold electricity to achieve this. Operationally, respondents (especially industrial segment) demand high voltage generation to suit their needs. They also want some annual maintenance contract (AMC) from the supplier.

Advantages, disadvantages, and perceptions

Various advantages of the rooftop solar PV, as understood by the respondents can be summed up as follows.

- Rooftop solar PV would reduce consumption of grid electricity, thereby bringing down electricity bill. It may also help earn revenues by selling electricity to the grid.
- Solar electricity is a renewable energy, green in nature, i.e. doesn't cause any harm to the environment (being non-polluting), and can help reduce carbon footprint.
- The technology involves one time capital cost with minimal operation and maintenance cost.
- A reasonable independence from the grid electricity would be achieved.
- Unused portions of the rooftop can be used.

One respondent even highlighted reduction of fuel import bill and consequent saving of foreign exchange reserves as one of the advantages! Some of the respondents, however, pointed out the long term accrual nature of the advantages of rooftop solar PV while enumerating its advantages. A few others also pointed out the need for better advertising, distribution system, and government support for this product to become a success.

Two major disadvantages are perceived by the respondents with regards to rooftop solar PV. The high investment required for the installation of the system is a clear turn-down for most of the respondents. This factor along with the fact that productive days are lost during cloudy weather makes the respondents apprehensive of the device. However, the concept appeals them. Other disadvantages as mentioned by the respondents include the inability of the system to power higher capacity appliances, such as air-conditioners, apprehensions regarding proper servicing and maintenance mechanism in place, etc. Interestingly, a large number of respondents also point out that special care should be given to equipment to protect the panel from monkeys, a menace in many Indian cities.

Models for adoption

Modes of financing

Given the chance, respondents would like to have government subsidy as well as easy financing options through bank loans with less interest rate to purchase rooftop solar PV equipment. However, government subsidy was found to be the most suitable mode of financing. Around 60 per cent of the respondents in all the three segments prefer this mode.

Revenue earning models

On-grid rooftop solar PV equipment can be a revenue earner for the operator / owner through various models. These models have been discussed before. Figure 32 presents the preference for various models of revenue earning by installing rooftop solar PV. Percentage indicates the difference in the number of respondents who called a particular model best and those who called it worst.

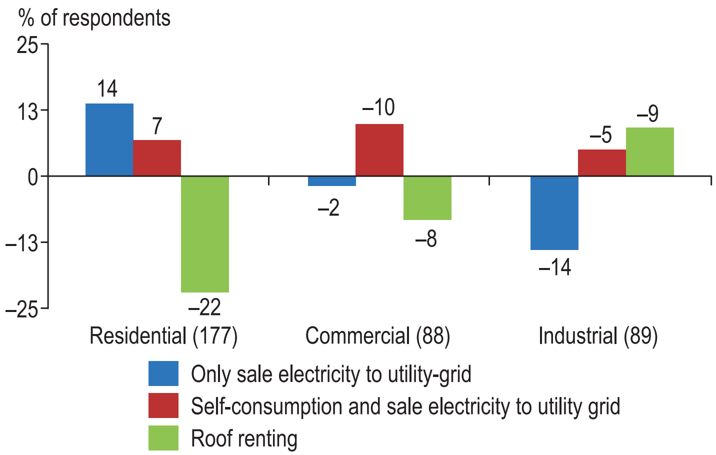

Figure 32: **Most preferred revenue earning model from rooftop solar PVs**

City wise preference is presented in Table 17.

***Table 17:* City wise preference for most suited revenue earning mechanisms for various segments**

Segment	Only sale electricity to utility-grid	Self-consumption and sale electricity to utility-grid	Roof renting
Residential	Delhi/NCR, Bhubaneswar, and Gandhinagar	Chandigarh, Pune, and Bangalore	
Commercial	Delhi/NCR	Bhubaneswar, Pune, and Gandhinagar	Chandigarh and Bangalore
Industrial	Gandhinagar	Pune and Bangalore	Delhi/NCR, Chandigarh, and Bhubaneswar

Table 18 presents the major reasons given for the choices.

***Table 18:* Reasons why a particular revenue model is best or worst**

Model	Why Best?	Why Worst?
Only sale electricity to utility-grid	• Two meters in the model will help in keeping separate record for consumption and production. • Higher revenue due to higher feed-in-tariff rates.	• Perception that installation of two meters will be more complicated and may require more maintenance. • Feed-in-tariff doesn't ensure fixed income as it does in roof-renting model. • High investment cost to install the system.
Self-consumption and sale electricity to utility-grid	• Installing and maintaining one meter is more convenient. • Direct reading can be made and bill paid / revenue earned without making complex calculations.	• Will not be able to distinguish between amounts of electricity produced and consumed. • Perception that a single meter may be dangerous as two-way current may damage it. • Feed-in-tariff doesn't ensure fixed income as it does in roof-renting model. • High investment cost to install the system.
Roof renting	• Fixed income can be received by fixing the rate of the roof beforehand itself. • No installation costs by the owner of the roof. Roof tenant will install the system. Also, no maintenance required.	• Benefit of electricity during power cut may not be available. • Due to third-party involvement, disputes may arise in future. Clear-cut government policy on roof-renting needed. • May lose roof usage rights. • Loss of privacy due to constant intrusion by operators.

About Authors

Sudhakar Sundaray, Reseach Associate, TERI

Lovedeep Mann , Reseach Associate, TERI

Ujjwal Bhattacharjee , Senior Fellow, TERI

Shirish Garud, Associate Director, TERI

Arun K Tripathi, Director, MNRE

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Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. Shakti works in sectors with the maximum potential for energy and carbon savings: Power, Transport, Energy Efficiency and Climate Policy. A Section 25 non-profit organization under the Companies Act, Shakti is governed by a national board of directors, and supported by both Indian and international philanthropies. It convenes NGOs, universities, business, think tanks, and domestic and international experts to design and implement smart energy policies in India.

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A dynamic and flexible organization with a global vision and a local focus, TERI was established in 1974, with initial focus on documentation and information dissemination. Research activities, initiated towards the end of 1982, were rooted in TERI's firm conviction that efficient utilization of energy and sustainable use of natural resources would propel the process of development.

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Ministry of New and Renewable Energy, Government of India

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