POLICY BRIEF

SOLAR ROOFTOP

Replacing Diesel Generators in Residential Societies

Centre for Science and Environment
New Delhi, India

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INTRODUCTION

Across India, diesel generators, commonly known as DG sets, are used by factories, commercial establishments, residential societies and individual households for power backup. Due to easy availability in the market, small space requirement for installation and low cost of diesel, DG sets in India have become the preferred choice for providing backup power during outages.

According to estimates given by Central Electricity Regulatory Commission (CERC), in 2014, DG sets installed across India had a cumulative capacity of 90,000 MW, which is estimated to be increasing by 5,000 to 8,000 MW per year. Therefore, DG installed capacity constitutes, at present, around one-thirds of the total size of the grid-connected capacity in India. Such a large installed capacity of DG sets is due mainly to power deficits and erratic power supply across India. Although grid-based supply has increased considerably over the last decade, it is still inadequate to meet the electricity needs given sharp increase in consumer, commercial and industrial demand and weak financial condition of distribution companies (discoms) who are unable to purchase sufficient power.

DG sets—a 'default' option for residential societies

New urban housing in India, particularly in the suburbs of metropolitan cities and mini-metropolitan cities, is being largely built in the form of cooperative residential societies which provide several resources with power backup being one of the most important ones.

Most of these societies are equipped with DG sets to supply electricity during power outages and are essentially functioning as 'mini-grids', providing a mix of diesel-based and grid-based electricity to their residents. However, diesel-based power supply in the societies is not only costly but also causes significant damage to environment and health.

Environmental burden

A multi-pollutant emission inventory prepared by Dr Sarath Guttikunda and Dr Giuseppe Calori in 2010 found that DG sets contributed 6 per cent of $PM_{2.5}$, 4 per cent of PM_{10} and SO_2, 25 per cent of NO_X and 7 per cent of CO levels in the NCR region. Inside residential societies where DG sets are installed, the impact on air pollution is even higher. Toxic fumes emitted by burning diesel in DG sets have serious health implications. In 2012, International Agency for Research on Cancer (IARC), a part of the World Health Organization (WHO), classified diesel engine exhaust as carcinogenic to humans.

Although emission norms for DG sets, issued by Central Pollution Control Board (CPCB) in 2002 and revised in 2013, are in place, no one checks for compliance. Environmental experts have recommended minimizing the use of DG sets in urban areas of the country, given the serious levels of air pollution in most Indian cities.

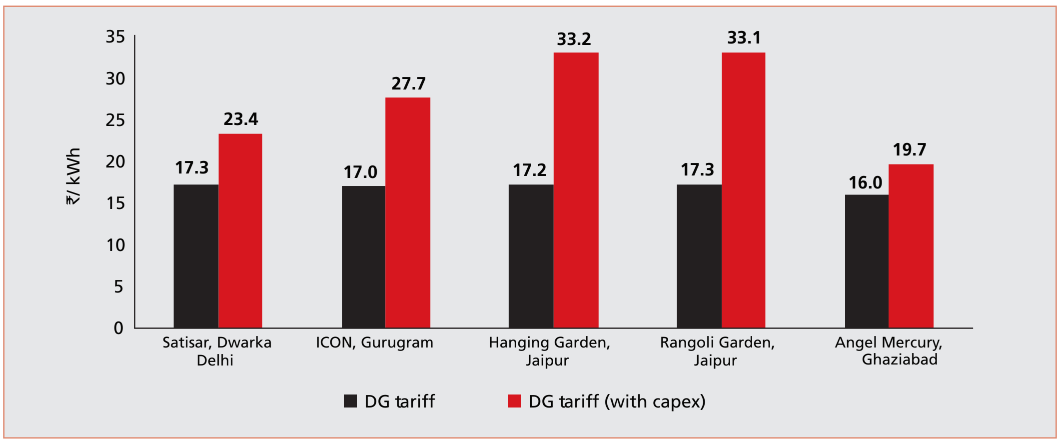
DG sets are also a major source of noise pollution in residential areas. On account of the immense noise generated by DG sets, Delhi government has banned the use of DG sets of more than 4 KW capacities between 10 p.m. and 6 a.m. in residential areas.

Financial burden

In addition to the environmental cost, the power generated by DG sets is expensive. The approximate cost of generation from a DG set is ₹16 to 17 per unit (kWh), not including the capital cost of the DG set. If we consider the capital cost of the DG set, which is included in the price of the flat, the cost of generation will rise to ₹27–33 per unit. This is around four times the cost of electricity supplied through the grid to residential societies. Total DG generation cost is related to DG utilization—lower the utilization, higher the cost of generation (see *Graph 1: DG tariff in different societies*). The financial burden is further highlighted by the significant investments in DG sets that various societies have made to ensure backup power (see *Graph 2: Capex for DG sets*).

GRAPH 1: DG TARIFF IN DIFFERENT SOCIETIES

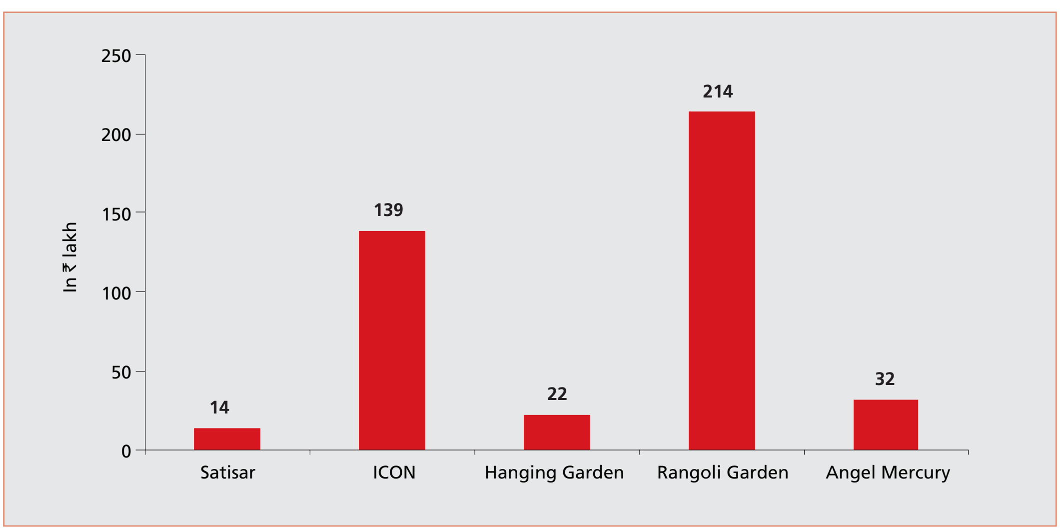
Low utilization means very high cost of generation



Source: CSE survey

GRAPH 2: CAPEX FOR DG SETS

Middle and high income housing societies spend substantial amount to ensure power backups



Source: CSE survey

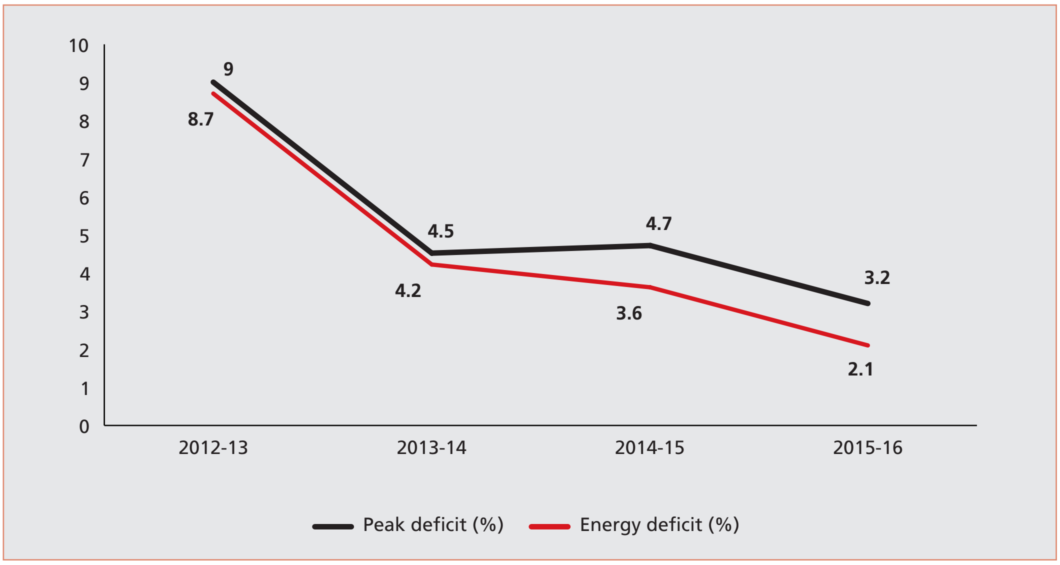
Power backup need

Over the last few years, the energy and power deficit in India has been steadily reducing (see Graph 3: *Peak and energy deficit*). Falling deficits, in turn, have helped to bring down the number and duration of outages and power cuts in the country. Currently, the average power cuts in many Indian cities are less than one hour per day (see *Graph 4: Average daily power cuts in Indian cities*). Accordingly, the use of DG sets in residential societies has declined to only 200–300 hours per year. Hence, DG sets are not providing meaningful benefits anymore.

A major reason for recurring power outages in most Indian cities is the weak financial position of discoms due to which they are unable to buy power from power generators. Due

GRAPH 3: PEAK AND ENERGY DEFICIT

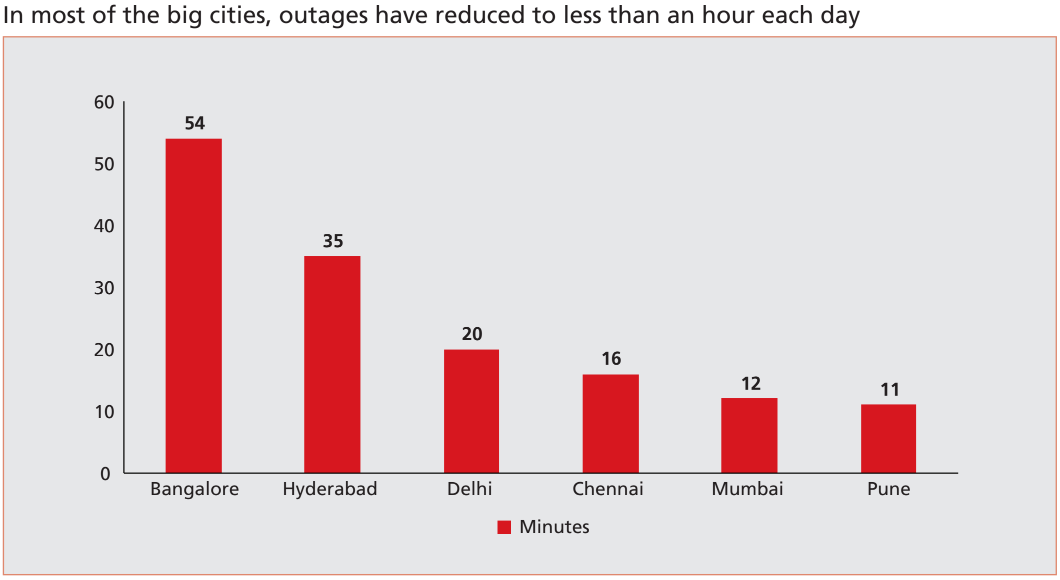
For the past several years, the energy and power deficit in India has been steadily decreasing



Source: Central Electricity Authority (CEA)

GRAPH 4: AVERAGE DAILY POWER CUTS IN INDIAN CITIES (NOVEMBER 2015–OCTOBER 2016)

In most of the big cities, outages have reduced to less than an hour each day



Source: Prayas Energy Group, Electricity Supply Monitoring Initiative

to financial weakness, inadequate investment has been made to upgrade and expand the transmission and distribution infrastructure, which also plays a role in worsening power cuts. But with the introduction of Ujwal Discom Assurance Yojana (UDAY) scheme, financial condition of discoms is expected to improve in the next few years. Hopefully, this should help in curbing power cuts in the future and further reduce the usage of and need for DG sets.

Therefore, a combination of reducing power shortages, high cost of electricity from DG sets and worsening air quality in cities means time has come for residential societies to consider alternatives to DG for backup needs.

SOLAR ROOFTOP—A REPLACEMENT FOR DG SETS IN RESIDENTIAL SOCIETIES

Historically, one major reason why individual houses and residential societies have not considered solar rooftop for backup power is its high cost of generation. Residential consumers were also not comfortable with solar technology—relatively small installed base and limited operational history made people skeptical of solar's reliability and life. But with the prices of solar panels, which account for 50–55 per cent of the total project cost, sharply falling in the last few years (see *Graph 5: PV module prices*), solar rooftop has emerged as a viable option for providing power backup in residential societies. The cost of electricity generation through solar rooftop (with battery backup) is significantly lower than the cost of electricity supplied through DG sets. In addition, solar rooftop can reduce the monthly power bill of the consumers as the extra units generated through solar rooftop can be exported to the grid—DG sets provide no such benefit.

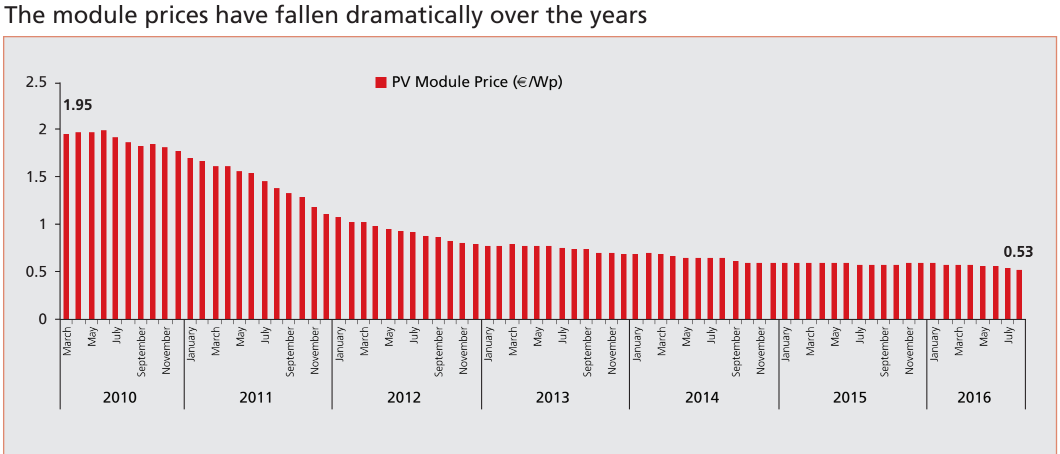
Meanwhile, solar photovoltaic (PV) technology has steadily gained wider acceptance with significant global capacity growth and satisfactory operating performance in recent years. The policy environment in India is also very supportive of solar rooftops. In fact, the government's ambitious plan to achieve 100 GW of total solar capacity by 2022 rests on 40 GW of solar rooftop capacity.

Incentives for both capital investment and power generated by solar rooftops have encouraged the growth of the full spectrum of solar rooftop ecosystem—panel manufacturers, suppliers, installation companies and RESCOs (Renewable Energy Service Company, which install and provide power to consumer under a contract). Various policy inducements have translated into lower generation costs. If a consumer opts for a power purchase agreement (PPA) with a RESCO, technology risk can also be largely mitigated. Despite all these advantages, solar rooftop installations, especially in residential sector, has not yet picked up.

During 2015–16, only 166 MW of solar rooftop was installed, not even meeting the modest target of 200 MW. According to a report published by Bridge to India, a Delhi-based research company, total installed solar rooftop capacity in India was only 1 GW as on September 2016 (see *Graph 6: Solar rooftop installed capacity*). The targets have been increased dramatically to 4.8 GW for 2016–17 and the coming years to enable the country to achieve 40 GW rooftop solar capacity by 2022 (see *Graph 7: Solar rooftop PV—targets and achievements*). Meeting these targets will be extremely challenging unless concerted steps are taken.

GRAPH 5: PV MODULE PRICE

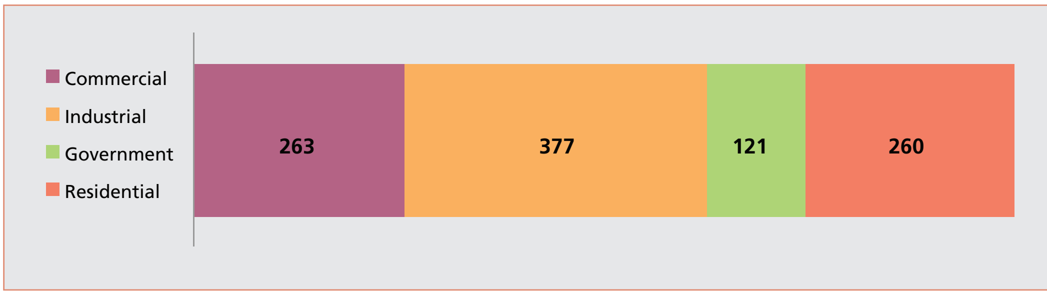
The module prices have fallen dramatically over the years



Source: pvXchange.com

GRAPH 6: SOLAR ROOFTOP INSTALLED CAPACITY (IN MW)

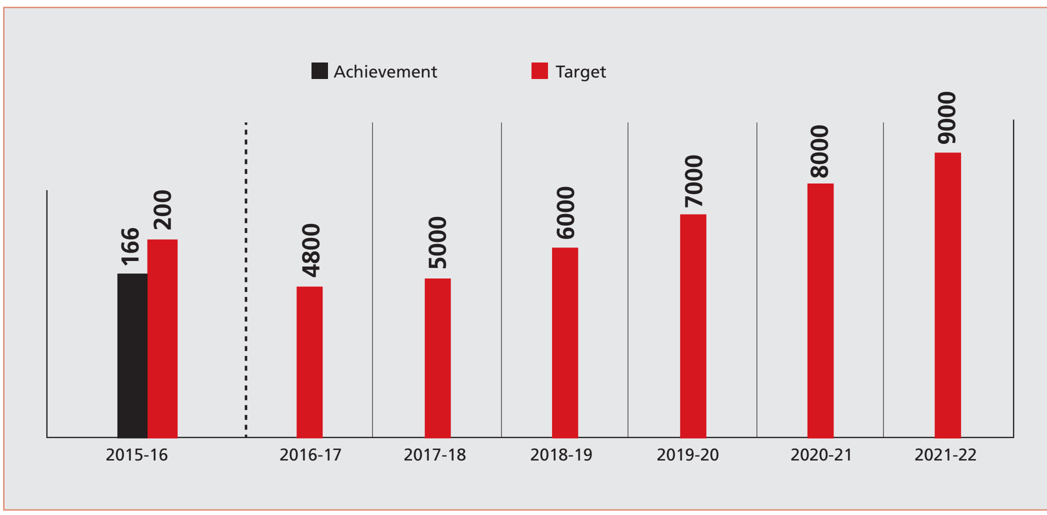
Till now only one-fourth of the capacity installed is in the residential sector



Source: Bridge to India

GRAPH 7: SOLAR ROOFTOP PV—TARGETS AND ACHIEVEMENTS (IN MW)

Solar rooftop targets increases exponentially



Note: Graph not to scale
Source: MNRE

WHAT IS HOLDING BACK GROWTH?

Lack of awareness

Lack of awareness among consumers is one of the biggest hurdles in the implementation of solar rooftops in residential areas. People in urban areas are familiar with solar thermal applications like the solar water heater; however, they have little knowledge about the reliability, performance and life of the PV technology. Most don't know anything about the capital incentives for rooftop solar, or generation benefits such as net and gross metering systems. Therefore, aggressive marketing of rooftop PV systems is critical for its successful development.

Lengthy approval process

Getting approval for a rooftop PV plant is a time-consuming process. Normally, it takes as much as six months for consumers to get a connection for net or gross metering. One surprising reason for this is that discom officials lack good understanding of these connections and the approval process. To make the process efficient, states like Andhra Pradesh have promised a fixed time-frame in their net metering policy, claiming that a consumer can sign an agreement with the discoms for net metering within three weeks. While a good idea, it's not known if these states have been successful in implementing such policies.

Frequent policy changes

Government has repeatedly revised policies over the past few years, leading to confusion among developers, and project delays. For a programme to succeed, policy elements have to function for a period of time so that we can observe their efficiency and impact.

For instance, the amount of capital subsidy has been revised back and forth between 15 and 30 per cent during 2015. Small-scale PV developers were unaware of the changes in the capital subsidy due to which the process of their subsidies was delayed by several months, affecting the liquidity of their finances.

Discoms issues

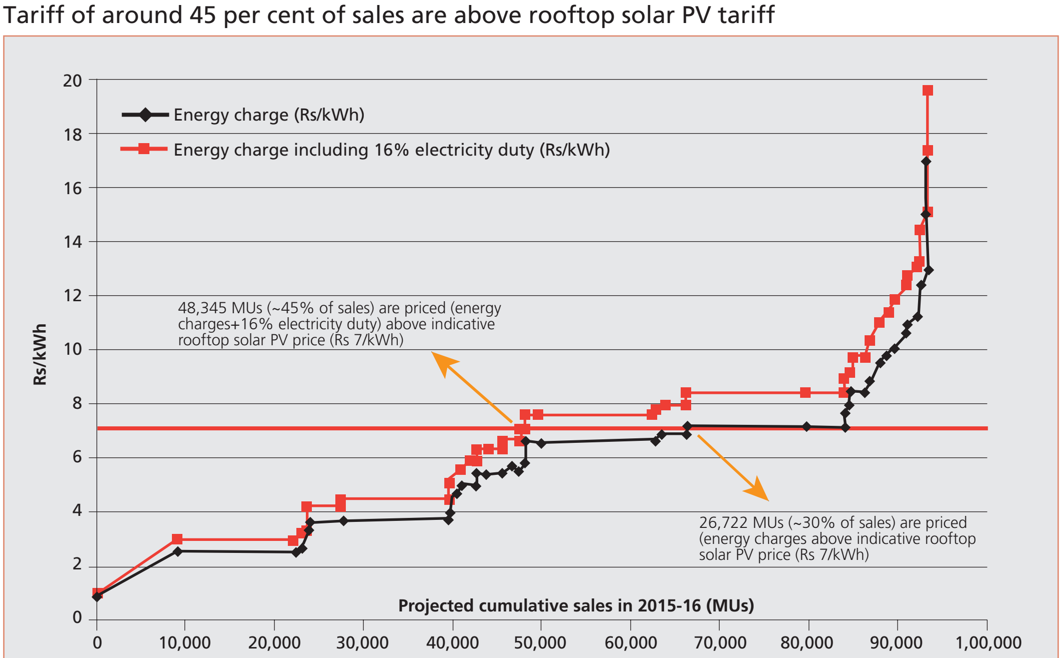
In India, discoms are generally not in favour of solar rooftops. One of the main concerns of discoms is the fear of losing their most profitable consumer base, which comprises of both commercial and industrial consumers.

At present, commercial and industrial users, and a small segment of well-off consumers (falling in the highest tariff slab), pay more than the cost of supply to cross-subsidize other categories of consumers such as low-income households, agriculture etc. It is possible that in the near future such consumers will partly or wholly offset their electricity needs through captive generation from solar rooftops. Therefore, this will have a major impact on the finances of discoms, already suffering from huge financial losses.

An analysis by Prayas Energy Group shows that around 45 per cent (48,345 MU) of the Maharashtra State Electricity Distribution Company's (MSEDCL) cumulative sales in 2015–16 were above the rooftop solar PV tariff of ₹7 per unit (see *Graph 8: Potential MSEDCL sales with tariffs above rooftop solar costs*). Therefore, even if a small percentage of the 48,345 MU is replaced with solar rooftops in the future, it can cause huge revenue losses to the discoms.

GRAPH 8: POTENTIAL MSEDCL SALES WITH TARIFFS ABOVE ROOFTOP SOLAR COSTS

Tariff of around 45 per cent of sales are above rooftop solar PV tariff



Source: Prayas Energy Group

Rooftop potential in residential societies

Over the next decade, increased urbanization and rising incomes are expected to result in an exponential growth in housing, much of which will be met by multi-storied residential complexes.

As per a Bain and Company estimate, the organized residential sector in 2015 totalled 748 million square feet. Assuming an average size of a flat to be 750 sq feet, one million flats would be added every year. Given the recent Ministry of Environment, Forest and Climate Change policy requires 1 per cent of demand load to be met through renewable energy sources, and assuming 5 kW load per household, average size of a rooftop solar plant mandated per household would be around 250–300 watts. This translates to a potential of almost 3 GW of rooftop in just residential high rises in the next 5–7 years.

Given the sizable projected construction of housing complexes, implementation of solar rooftops in residential societies would be crucial to achieve the ambitious target of installing 40 GW rooftop solar power capacity in India by 2022.

SOLAR ROOFTOP VS DG SETS

CSE, along with ckinetics, a sustainability and capital advisory firm, conducted a study across Delhi, Haryana, Uttar Pradesh and Rajasthan to assess the feasibility of solar rooftops in residential societies. The research aimed to understand several issues; economic considerations including financing and generation cost; architectural and roof space preferences and building bye-laws; consumer resistance due to lack of awareness about government schemes or technology performance; bureaucratic hurdles to obtain subsidy; and lack of support from discoms due to fear of potential revenue loss.

Societies selected for the study

The societies were selected in a manner ensuring that they cover a broad cross-section of the market in terms of DG capacity being installed for backup. The idea was for the sample to cover a range of consumer preferences (in terms of quantum of backup load, which overlapped with income level and ability to pay); grid supply (in terms of outages), size and type of society etc.

- **Income group of the residents:** This was perhaps the most important parameter which drove the size of DG backup. Societies falling within the high income group have installed large capacity DG sets to provide full backup while lower income societies have installed smaller DG sets (see *Table 1: Overview of the societies*).
- **Type of the residential complex:** The sample covered a range of societies in terms of apartment size, number of floors, rooftop use and architectural considerations etc. which determined the available rooftop area and potential solar capacity per flat.
- **Hours of outage:** Outage hours is an important factor in sizing rooftop solar PV, especially the battery, which needs to supply the required amount of energy during the outage hours, thus impacting the capex of the solar rooftop system. Therefore, to get wider estimates on the capex of solar rooftop system and cost of electricity generation, we have selected societies with varying outage hours.

TABLE 1: OVERVIEW OF THE SOCIETIES

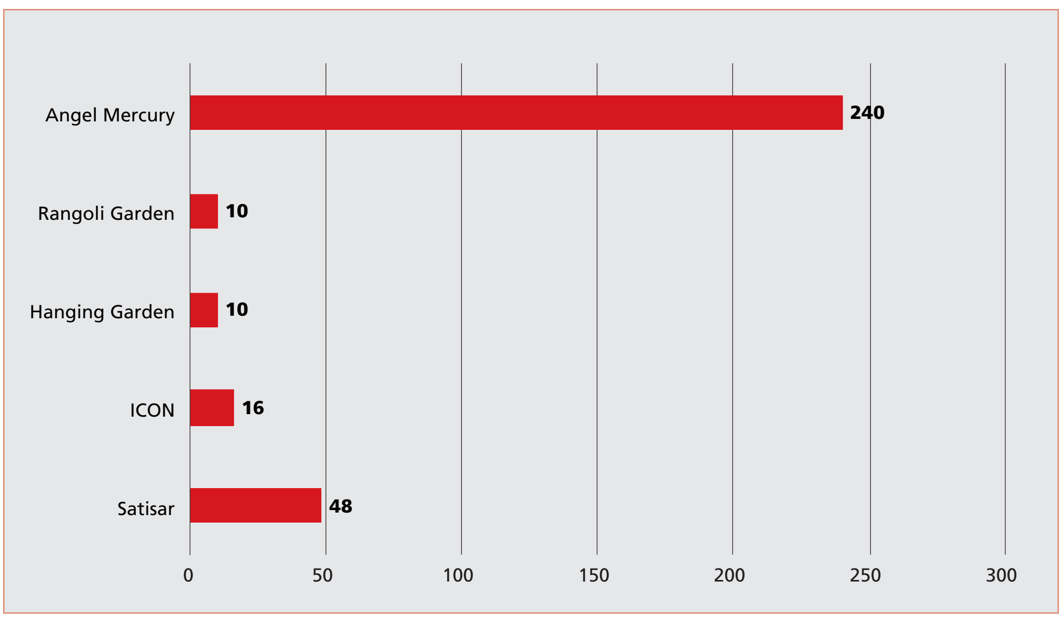
Sample reflects a wide range of societies

Society	No of flats	Connected load (KW)	Common area load (KW)	"Stated" backup	DG size (KW)	Annual grid electricity consumption (kWh)
Satisar, Dwarka (Delhi)	245	1,924	180	Partial (common area load + 800 Watt to each apartment)	112	1,510,550
ICON, Gurugram (Haryana)	344	1,998	550	Full Back up for all loads	1,112	4,005,450
Hanging Garden, Jaipur (Rajasthan)	400	4,218	183	Back up only to common loads	180	304,512
Rangoli Garden, Jaipur (Rajasthan)	1,300	10,635	555	Partial (common area load + 750 Watt to each apartment)	1,712	2,390,625
Angel Mercury, Ghaziabad (Uttar Pradesh)	280	363	142	Common area load + 1 kW and 3 KW backup provided to apartment	256	1,146,627

Source: CSE survey

GRAPH 9: CURRENT OUTAGES (MINUTES/ DAY)

The outages in most societies add upto less than an hour per day



Source: CSE survey

DG backup—sub-optimal size and unclear benefits

Notwithstanding the various societies' claims of the size of the DG backup, we note the actual backup is far less: ICON, which asserts it provides full backup, has a DG capacity of a little over half of the grid-connected load. Similarly, Satisar claims to provide 800 watt per flat, however, installed DG wouldn't be able to provide even half of the claimed load. For societies providing partial backup, DG capacity is around 15 per cent of the connected load.

Interestingly, both our sample study and anecdotal evidence strongly suggests that DG size is often unconnected to outage. DG size appears to be related to the society type (i.e. upper and middle income) basically reflecting the society's "status". For example, ICON, an upscale society, which experienced outage of only 16 minutes per day on an average, provided "full backup" (see *Graph 9: Current outages*).

Solar rooftop—backup alternative?

The first step to assess the feasibility of replacing DG sets with solar rooftop in residential societies was to look at various configurations based on combination of rooftop area, load needs and average outage:

- The size of the solar PV is based on the actual rooftop area available.
- Inverter size is based on the connected load. We have considered two possibilities, a) inverter size based on minimum load needed per flat, and b) inverter size is based on minimum load needed per flat plus common area load.
- Battery size is based on the energy required during outage. This leads to two possibilities based on the inverter size, a) backup battery size based on the inverter capacity (based on minimum load) and twice the average outage hours, and b) backup battery based on the inverter capacity (which is based on minimum load per flat plus common area load) and two times the average outage hours. This capacity is further adjusted for system efficiencies and minimum state of charge to be maintained in the system.
- Energy generated by a DG set is calculated considering 60 per cent loading of the diesel generator during the actual operating hours.

Based on these parameters, the plausible scenarios have been detailed (see *Table 2: Description of different scenarios* and *Table 3: Rooftop configurations for the two scenarios*).

TABLE 2: DESCRIPTION OF DIFFERENT SCENARIOS

Selected scenarios based on key parameters

Case	Description
Scenario 1	1) Solar PV based on actual rooftop area available, 2) inverter size is based on the assumption of 0.3 KW per flat, and 3) backup battery is aligned with the inverter capacity and sizing based on twice the average outage hours.
Scenario 2	1) Solar PV based on actual rooftop area, 2) inverter size is based on the assumption of 0.3 KW load per flat plus common area load, and 3) backup battery aligned with the inverter capacity and sizing based on two times the average outage hours.

TABLE 3: ROOFTOP CONFIGURATIONS FOR THE TWO SCENARIOS

Scenario 1 is the most plausible – conventional sizing

Society	Scenario 1			Scenario 2		
	Solar PV size (KWp)	Inverter (KW)	Battery capacity (KWh)	Solar PV size (KWp)	Inverter (KW)	Battery capacity (KWh)
Satisar	138	74	118	138	254	406
ICON*	72	104	56	72	303	161
Hanging Garden	179	120	40	179	303	101
Rangoli Garden	342	390	130	342	945	315
Angel Mercury**	42	84	672	42	226	1,808

* ICON is an upscale society in which common area load is 25 per cent of the connected load; for other societies common area load is less than 10 per cent of the connected load. For sizing the inverter in ICON, we have considered 10 per cent of the connected load for our calculations, since this supports comfortable level of shared facilities.
** In Angel Mercury's case, solar PV will not be able to supply the amount of energy needed during outage hours

We looked at the two models—Capex and RESCO—to estimate the viability of the two scenarios. In the capex model, investment for installing solar rooftop is made by the societies who also own the system. The installer is responsible for operation and maintenance (O&M) for the first five years. Thereafter, the responsibility of O&M of the system lies with the societies for 20 years.

In the RESCO model, solar rooftop installation is carried out by the developer who then owns the entire system. Societies pay a pre-decided tariff on a monthly basis to the developer for the life of a contract (20–25 years). Responsibility of O&M for the contract's life lies with the developer.

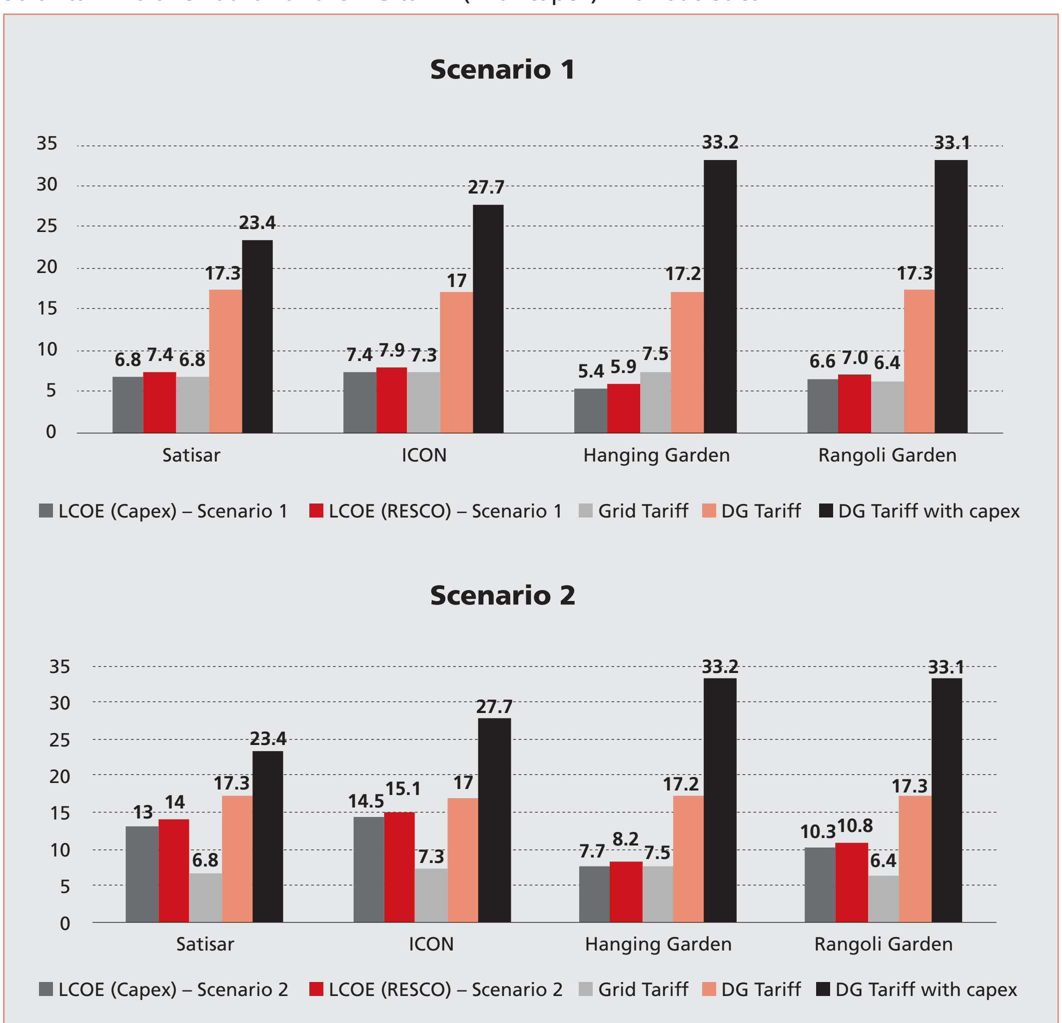
Tariff comparison

For the capex model, we calculated the Levelised Cost of Electricity (LCOE). For the RESCO model, an Internal Rate of Return (IRR) of 15 per cent is assumed to calculate the tariff.

The results show that solar rooftop is financially a substantially better option. The cost of supply for scenario 1 is around one-fourth the cost of supply of DG sets if we include the capex of the DG sets. For scenario 2, the cost of supply is between one-third and half of the cost of supply through DG sets (see *Graph 10: Tariff comparison*).

GRAPH 10: TARIFF COMPARISON (₹/ kWh)

Solar tariff is one-fourth of the DG tariff (with capex) in all societies



Source: CSE analysis

Demand met by solar rooftop

Our study shows that for most societies, solar rooftop would be able to meet basic load for individual flats and for common area loads ("partial load" in industry parlance), which is what some of the mid-range societies provide. But solar rooftop may not be able to fully replace DG sets for a few societies which provide "full backup", which typically means luxury common facilities, common household needs plus use of one energy-intensive appliance such as ACs. Although inverter size can be increased to meet the higher load, it is not a practical solution, since it will significantly raise the solar rooftop cost.

Perhaps "full backup" was considered a basic need by upscale societies when the outages often lasted several hours a day. However, with outages down to less than an hour per day on an average, even upscale societies may be comfortable with lower level of backup. **If a supporting load of 0.3 KW is supplied to every home in the society, which is typically sufficient for common household needs for a time period lasting tens of minutes, solar rooftop should be able to meet the needs for most societies**.

Savings from solar rooftop

In the case of the capex model, the payback period for all the societies is around five–seven years (except ICON and Rangoli Garden, for scenario 2), which means for around 18 years (considering 25 years' lifespan of solar rooftop); the residents will get electricity at no cost due to minimal operating expenses for a solar rooftop system. However, societies will have to replace inverters and batteries every five–10 years, requiring investment that can be easily supported by savings.

Total annual savings for a society, in the capex model, are calculated (for Satisar, Dwarka and Hanging Garden, Jaipur) in the following manner: solar rooftop will replace the units generated by DG sets; remaining units are consumed by society itself or fed into the grid. The total annual savings through solar rooftops range between ₹29.64 lakh for Rangoli Garden, Jaipur and ₹7.4 lakh for ICON Gurugram (see *Table 5: Annual savings through solar rooftop).*

TABLE 4: PAYBACK PERIOD (CAPEX MODEL) IN YEARS

Short payback period reflects significant cost benefit

Society	Scenario 1	Scenario 2
Satisar	6	7
ICON	6	9
Hanging Garden	5	6
Rangoli Garden	7	9

TABLE 5: TOTAL ANNUAL SAVINGS THROUGH SOLAR ROOFTOP

Substantial savings over the life of the rooftop system

Society	Annual DG electricity generation (kWh)	Estimated solar electricity generation (kWh)	Annual savings through solar rooftop (in ₹ lakh)
Satisar	14,515	168,236	12.96
ICON	64,051	100,915	7.40
Hanging Garden	6,480	245,660	18.96
Rangoli Garden	61,632	463,119	29.64
Angel Mercury	1,547,14	57,181	3.14

Other observations from the survey

1. There is not enough awareness among resident welfare associations (RWAs) about the solar rooftop implementation process and there is also a perception that installation of solar rooftop is a time consuming process.

2. Even with lesser lifetime savings, RWAs and residents prefer a PPA-based RESCO instead of a CAPEX model due to:
   - High upfront investment required in the capex model
   - Need for regular maintenance etc. makes the capex model seem as operationally cumbersome
   - An apprehension that getting subsidies would be onerous. When societies explore the capex model, they prefer that suppliers take the responsibility to collect the subsidy. For this service, suppliers often demand higher prices. To avoid uncertainties emerging from this, societies prefer the power purchase agreement (PPA)-based model.
   - RWAs don't see any value in deploying corpus funds or raising loans to fund such projects, since they are doubtful about the payback period.
   - RWAs are not able to enjoy tax incentives such as accelerated depreciation (AD). Since RESCOs can take advantage of AD benefits, their bids can be competitive in comparison to the capex model

3. Some of the potential pre-conditions typically sought by developers in the PPA-based arrangements include:
   - PPA-duration of at least 20 years.
   - Around six to 12 months of expected solar sale as security deposit.
   - Rooftop space provided by the society at no cost.
   - Society commits to net metering etc. being undertaken by the ESCO.

RECOMMENDATIONS

Immediate steps to be taken

1. Installation of solar rooftops should be made mandatory for all upcoming residential societies. The government should consider banning the installation of DG sets in new multi-storied residential buildings. This policy should at least be strictly enforced in metropolitan cities and highly polluted urban areas.

2. Discoms in most of the states are supporting solar rooftop to meet their Renewable Purchase Obligations (RPOs). But most of the rooftop solar installations are currently being carried out in institutional and commercial sector due to superior financial viability and faster sales cycle.

   Our analysis shows that solar rooftop can cut discoms revenue since their most profitable customers may partly or fully migrate to solar. Therefore, it is vital that discoms be financially supported to encourage them to push solar rooftop.

3. Currently, capital subsidy of 30 per cent is provided only for grid connected solar rooftop systems without battery. Therefore, to incentivize replacement of DG sets with solar rooftop in residential societies, subsidy should also be provided for hybrid solar rooftop systems, i.e. solar rooftop systems with battery backup.

4. To increase awareness among RWAs about the solar rooftop implementation process:
   - Single window information needs to be available to the consumers, particularly regarding technical elements (grid interconnectivity, net and gross metering), fiscal support (subsidy and other incentives) and policies (regulations on metering).
   - Awareness campaigns targeting residential societies and engagement of RWAs need to be undertaken on a large scale by the state nodal agencies.

5. Our experience reveals that, to fulfill the mandatory building norms, many solar water heater systems are installed, and the buildings even obtain the required initial clearances. But in many cases these systems have not been functioning effectively. Consequently residents aren't able to see much value in them. Thus, for solar rooftop implementation to be successful, and be seen of value, proper monitoring should be done by the respective regulatory authorities.

Other policy recommendations

1. **Regulations on buildings**

   In order to ensure wider uptake of solar rooftop systems in residential societies, following aspects may be considered:
   - New constructions seeking approval of urban development authorities should have a provision for a certain fraction of plinth area to be shadow free for implementation of solar rooftop systems.

- Incentives such as additional floor–area ratio for builders who exceed certain solar rooftop capacity per flat in their project at construction stage itself may be provided—a provision along these lines has been introduced in Jaipur recently and is gaining some interest from the housing developer community. In this arrangement, builders may charge residents for some capex money towards solar rooftop implementation as part of the facilities.

2. Other provisions

- Since RWAs seems less inclined to opt for solar rooftop implementation by pursuing a capex investment despite potentially higher savings (viz. long term PPAs or third-party financing), introduction of alternate fiscal incentives should be considered for the societies by the government to augment the momentum of uptake. This could be in the form of rebate on building tax, for instance.
- Respective state nodal agencies responsible for solar rooftop implementation should organize trainings for banking staff to make them aware about the various aspects related to solar rooftop projects. The trainings will help the banking staff to do better assessment of solar rooftop projects which will ultimately lead to easier processing of solar loans.

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