GOING SOLAR

Action Plan To Tap Gurugram's Solar Rooftop Potential

Centre for Science and Environment
New Delhi, India

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CONTENTS

LIST OF ABBREVIATIONS

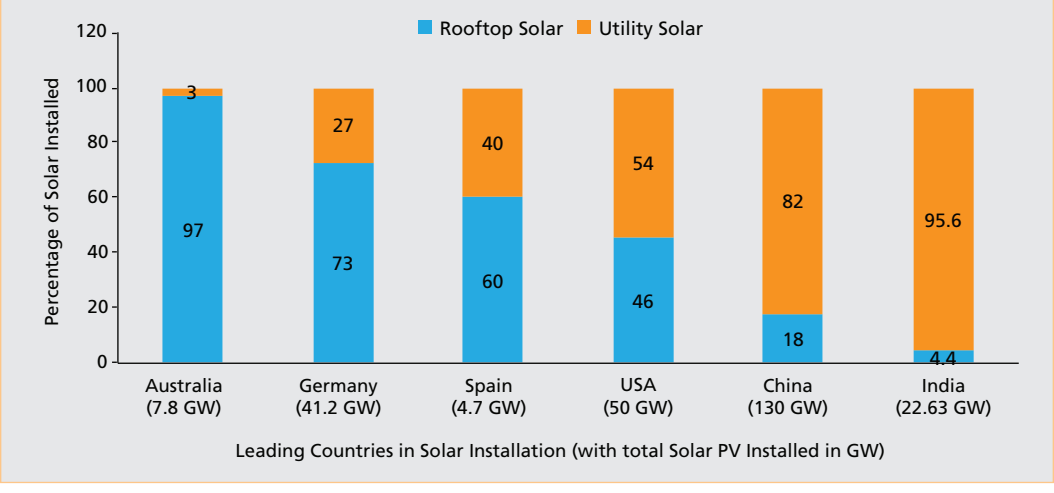
ADC	Office of the Additional District Commissioner
AT&C	Aggregate technical and commercial losses
CAPEX	Capital expenditure
CSE	Centre for Science and Environment
DHBVNL	Dakshin Haryana Bijli Vitran Nigam Limited
DISCOM	Distribution company
DLF	Delhi Land and Finance
FAR	Floor area ratio
FY	Financial year
GW	Giga-watt
HAREDA	Haryana Renewable Energy Development Agency
HERC	Haryana Electricity Regulatory Commission
HPGCL	Haryana Power Generation Corporation Limited
HSIIDC	Haryana State Industrial and Infrastructure Development Corporation Limited
HVPNL	Haryana Vidyut Prasaran Nigam Limited
kVAh	Kilo-volt ampere hours
kW	Kilo-watt
kWh	Kilo-watt hours
MCG	Municipal Corporation Gurgaon
MNC	Multinational companies
MNRE	Ministry of New and Renewable Energy
MU	Million units
MW	Mega-watt
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RESCO	Renewable Energy Service Company
RWA	Residential welfare association
SDO	Sub-Divisional Officer
SRT	Solar rooftop
T&CP	Town and country planning
UHBVNL	Uttar Haryana Bijli Vitran Nigam Limited

1. THE GLOBAL ROOFTOP SOLAR SCENARIO

Global solar photovoltaic (PV) continues on a period of exceptional growth. According to the PR NewsWire (Dublin) the global solar PV installation was more than 350 GW in 2017; its installed capacity in 2017 alone was 101 GW, almost double the 51 GW installed in 2015. Growth post-2020 is further expected to increase up to 145 GW by 2025. Overall, rooftop solar installations form about 42 per cent of overall global solar power.[1] Most developed economies started their solar program by targeting households and they still have a sizeable share of installations in the rooftop segment. On the other hand, China and India have used large scale solar installations to drive sharp capacity growth and also to simultaneously push down costs and tariffs.

GRAPH 1: COMPARISON OF ROOFTOP AND UTILITY SCALE SOLAR IN DIFFERENT COUNTRIES

India has the least rooftop solar segment



Australia: http://pv-map.apvi.org.au/analyses; Germany: https://1-stromvergleich.com/strom-report/photovoltaik/
Spain: http://www.ree.es/es/estadisticas-del-sistema-electrico-espanol/series-estadisticas/series-estadisticas-nacionales
USA: http://gvwire.com/2018/01/25/the-5-big-questions-about-solar-after-trumps-tariffs/
China: https://www.pv-magazine.com/2018/01/22/chinas-cumulative-pv-capacity-hits-130-gw-to-reach-250-gw-by-2020/
India: Ministry of New and Renewable Energy (MNRE)

India, within its framework of National Action Plan for Climate Change (NAPCC), has formulated the National Solar Mission (NSM). Initially, the NSM had a relatively modest target of 22,000 MW (20,000 MW for large solar and 2,000 MW for solar rooftop). India revised its NSM targets in 2015 with plans to add a massive 100,000 MW of solar by the year 2022. Out of this, 40,000 MW is to be realized through solar rooftop systems (SRT). The Ministry of New and Renewable Energy (MNRE) has earmarked specific targets for different states to enable the country to meet this goal.

The research firm Bridge to India[2] estimated that the technical potential of rooftop solar power alone in the residential, industrial, and commercial segments is 64 GW, 40 GW and 8 GW respectively. However, residential rooftop installations have been minimal so far; most rooftop solar installations are in the industrial and commercial segments. Against a target of 40,000 MW of solar rooftop by the year 2022, cumulative capacity addition of solar rooftop

stands at only approximately 1,933 MW of which grid-connected rooftop solar is 1,211 MW and off-grid solar systems is 723 MW as of May 2018. During the nine months (April to December 2017) only 271 MW was added.

Both the residential and non-residential (industrial and commercial) segments, despite their large potential, are lagging behind in solar power additions. It raises questions as to why the SRT segment is not gaining pace and what needs to be done.

2. WHY CHOOSE GURUGRAM FOR THIS STUDY?

Gurugram is the second largest district of Haryana. It has rapidly transformed during the past few decades into Haryana's largest urban agglomeration with the establishment of numerous multinational companies (MNCs), IT/BPO and manufacturing units. With a growing middle class comprising white collar professionals, Gurugram has one of the highest per-capita incomes among Indian cities. The existing population of Gurugram is estimated to be around 2.5 million which is expected to swell to 4.3 million by 2020.

Given a combination of sizable commercial and industrial activity and relatively rich residents, Gurugram's per capita consumption of electricity is around 4000 kWh per annum. With projected continued strong economic growth, electricity consumption is expected to increase to 6,400 kWh per person per annum by 2022. DHBVNL's electricity supply is driven by urban demand. Of 3,024,921 DHBVNL's customers/connections 245,206—around 8 per cent—are from Gurugram district. But, of DHBVNL's annual electricity sales of 22,761 million kWh (MU) Gurugram city's annual share is 28 per cent. Urban focus means that Gurugram's demand peaks in the afternoon with air conditioner use—according to the DHBVNL data the average demand of electricity in Gurugram is around 1,125 MW, however, during peak summer afternoons the power consumption in Gurugram reaches around 1,700 MW.

Gurugram's housing sector is dominated by relatively new high-rise residential complexes. Given the frequent power outages, these societies promise uninterrupted power supply to its well-off residents through diesel generator (DG) sets to market their apartments. (The back-up supply ranges from a fraction of household load to almost all its demand, depending on whether it is a middle income or ultra-rich consumer residential complex.) CSE's survey of few dozen societies showed that most of them faced power cuts ranging from 30 minutes to around an hour per day. The cuts are higher in summer, notwithstanding the DHBVNL claim of no power cuts. The result is significant use of DG sets in Gurugram to supply electricity.

CSE's December 2016[3] study showed that the DG-based electricity supply is extremely expensive (up to Rs 30 per unit if we include the capital investment in the DG that is being run for less than an hour per day). Electricity from rooftop solar, in contrast, is around Rs 5–6 per unit. Second, DG is extremely polluting in its immediate vicinity—there have been instances when the DG has been operated for several hours continuously. This means children and women, who typically spend a lot of time in the building, are particularly vulnerable.

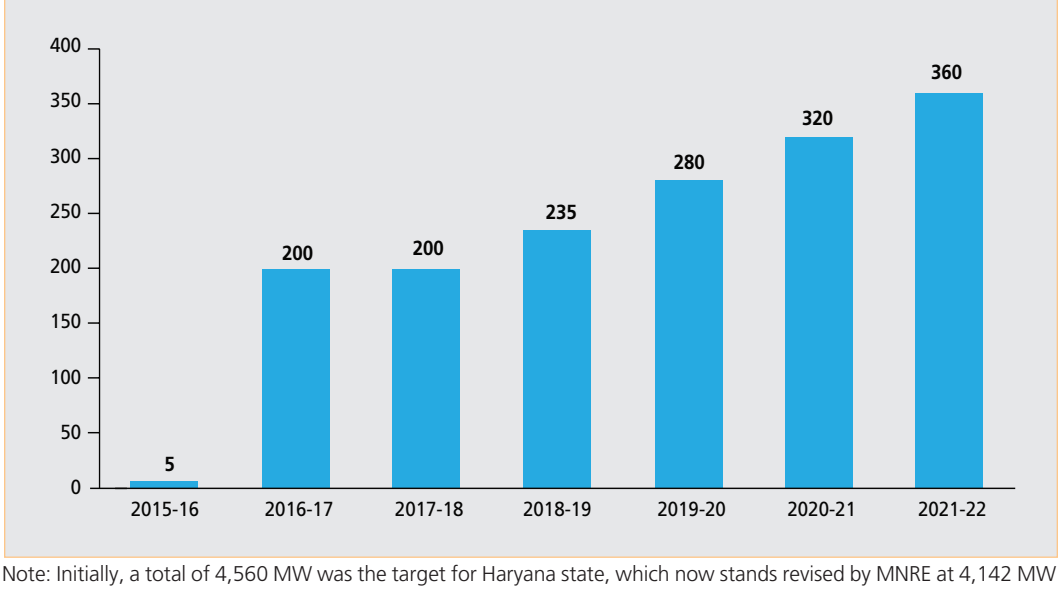
For all these reasons solar rooftop can drastically cut—if not fully eliminate—DG use in a city like Gurugram. One reason solar rooftop has not gained traction in the country is the high upfront cost of installation. But this is less of an issue for well-off residents in high rise residential buildings. Moreover, the government has introduced fairly progressive policies to push solar rooftop in the state.

The purpose of this research is to understand the reasons behind slow penetration of solar rooftop (SRT) and propose actionable solutions to expedite its diffusion in Gurugram. This template can likely be used for other Indian cities, most of whom have a similar profile of rising middle class, growing commercial spaces and multi-storied residential buildings.

3.SOLAR ROOFTOP IN HARYANA

The government of Haryana has a target of 4,142 MW of total solar power of which 1600 MW is rooftop by the year 2022. However, the state has cumulatively added only 134.8 MW out of which both solar rooftop and ground mounted solar is 85 MW and 49.8 MW[4], respectively. (See *Graph 2: Year-wise targets for solar rooftop in Haryana*)

GRAPH 2: YEAR-WISE TARGETS FOR SOLAR ROOFTOP IN HARYANA



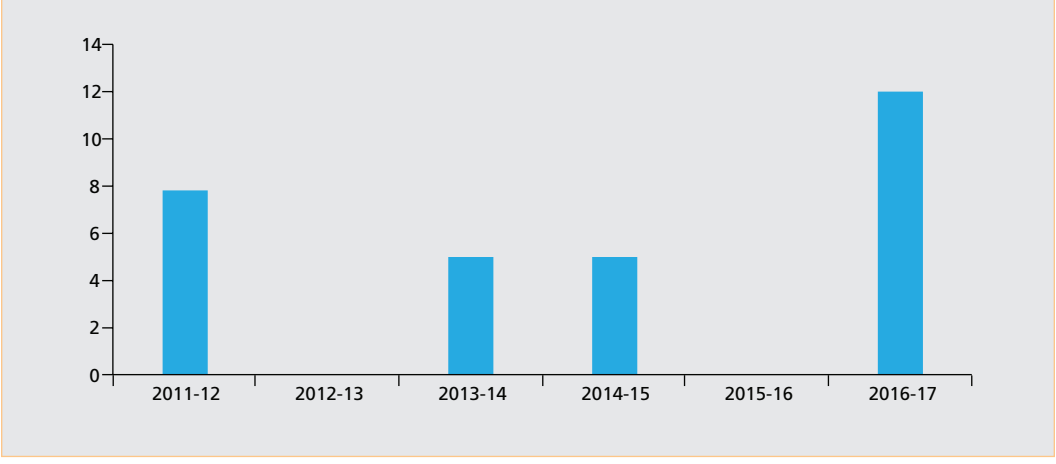
Note: Initially, a total of 4,560 MW was the target for Haryana state, which now stands revised by MNRE at 4,142 MW
Source: Ministry of New and Renewable Energy (MNRE)

Solar rooftop in Gurugram

The Gurugram district has installed a total of 24 MW solar rooftop systems. Of this 8 MW is grid connected solar rooftop and 16 MW is off-grid SRT. It doesn't appear that the pace of installation has increased meaningfully over the last couple of years. There are no city-based targets for rooftop but arguably Gurugram should target around 200MW, in line with its around 15 per cent share of Haryana's total energy consumption (See *Graph 3: Year-wise achievements for solar in Haryana*).

GRAPH 3: YEAR-WISE ACHIEVEMENTS FOR SOLAR IN HARYANA

Growth was not in pace with the targets



Source: Department of Renewable Energy, Haryana (HAREDA)

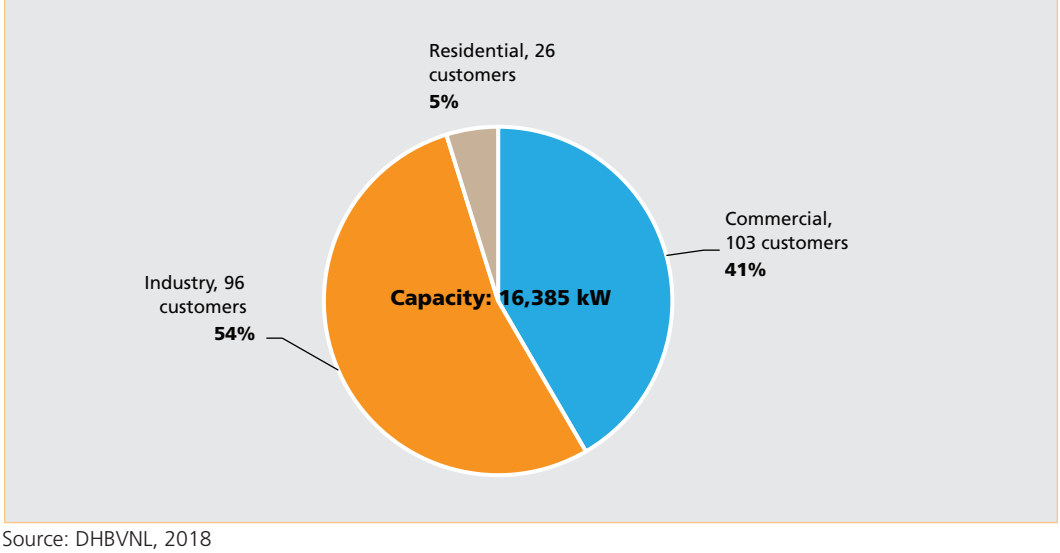
3.1 Off-grid solar rooftop systems

Ninety-five per cent of the off-grid solar rooftop systems were installed by the industry and commercial customers (see *Graph 4: Off-grid solar rooftop systems—Customer category*). That residential customers have not opted for off-grid is not surprising. Connecting to grid makes it possible for consumers to obtain capital subsidy (30 per cent of investment) and also generate revenues by feeding excess supply to the grid.

Over half of the installed capacity comprises plants of large size (100 kW and above (see *Graph 5: Off-grid solar rooftop system—Size profile*). One could question whether these fall under the rooftop category from the perspective of 'distributed generation', which is targeted at the small scale residential or commercial sector. Globally, solar rooftops of smaller size are the norm. For instance, Italy through its solar rooftop program, has been promoting rooftops of size 20 kW and below.[5]Israel promotes rooftops of sizes 15–50 kW.[6]

GRAPH 4: OFF-GRID SOLAR ROOFTOP SYSTEMS—CUSTOMER CATEGORY

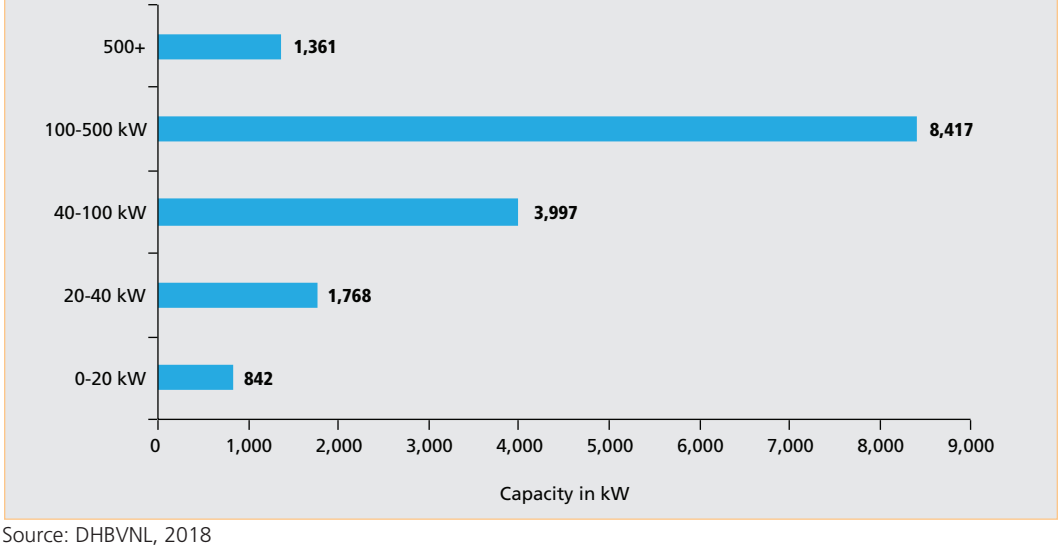
Residential customers' share is a tiny fraction



Source: DHBVNL, 2018

GRAPH 5: OFF-GRID SOLAR ROOFTOP SYSTEM—SIZE PROFILE

Significant share of solar rooftop contributed by large systems



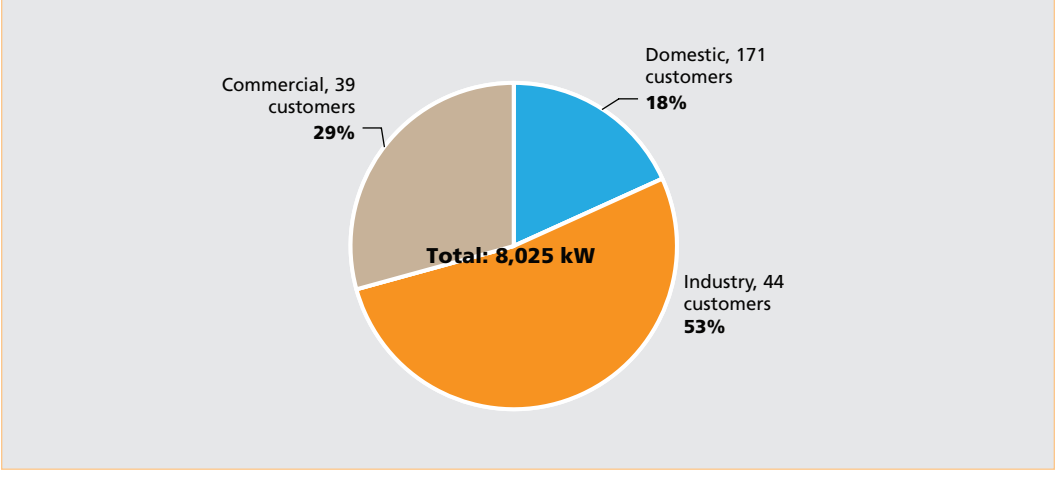
Source: DHBVNL, 2018

3.2 Grid connected solar rooftop systems

Gurugram has over 8 MW installed net-metered solar rooftop systems. The state allows customers to install grid connected solar rooftop systems of capacity equivalent to the sanctioned load. The net-metered segment is more balanced at least in terms of number of customers with residential consumers dominating (67 per cent of the total). But capacity installation was dominated by industrial/commercial consumers (see *Graph 6: Net metered solar rooftop systems – Customer Category*) given their larger size systems.

GRAPH 6: NET METERED SOLAR ROOFTOP SYSTEMS— CUSTOMER CATEGORY

Despite sizable number of retail consumers small share of capacity

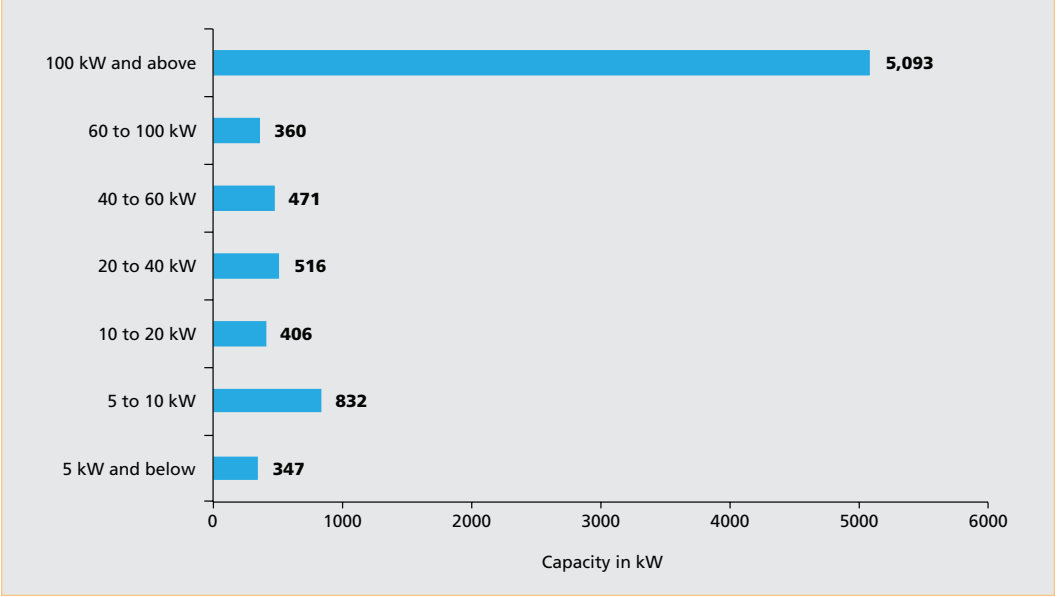


Source: DHBVNL, 2018

A sizeable 5 MW of capacity was installed by just 19 customers (see *Graph 7: Net-metered solar rooftop systems—Size profile*). This dominance of commercial/industrial sector in the rooftop category clearly shows that rooftop is making economic sense. While some of the installation may well be displacing back-up diesel based power, cost of solar rooftop is lower than grid for industrial and commercial consumers. It means that an effective communication and awareness campaign could give a boost to the residential segment also.

GRAPH 7: NET-METERED SOLAR ROOFTOP SYSTEMS—SIZE PROFILE

A sizeable capacity was installed by few customers



Source: DHBVNL, 2018
*data not comprehensive

4. DHBVNL'S ROLE IN SOLAR ROOFTOP

HAREDA coordinates the implementation of the rooftop solar program in Gurugram with the state-owned discom, Dakshin Haryana Bijli Vitran Nigam Limited (DHBVNL). DHBVNL distributes power in Gurugram district where it has 3,024,921 domestic, commercial, industrial and agricultural consumers as of FY 2016. Power is procured through Haryana Power Purchase Center (HPPC). For the financial year (FY) 2016–17, the power allocation ratio was 44 per cent and 56 per cent for Uttar Haryana Bijli Vitran Nigam Limited (UHBVNL) and DHBVNL, respectively. Power is wheeled through the state transmission utility—Haryana Vidyut Prasaran Nigam Limited (HVPNL)—on the payment of transmissions charges approved by Haryana Electricity Regulatory Commission (HERC), the power regulator.

5. UNDERSTANDING THE CUSTOMERS SEGMENTS

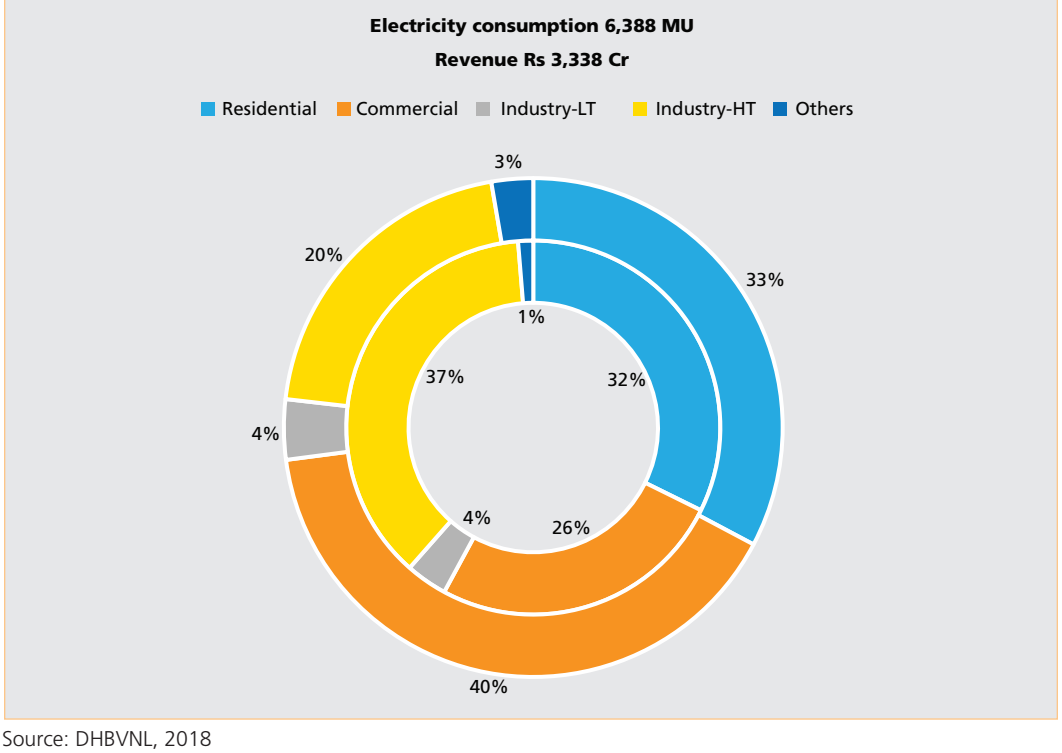
DHBVNL has 245,206 customers under various categories in Gurugram city. For financial year (FY) 2017–18, the annual energy sale to these customers in the district was 6,388 million units (MU). The revenue generated was Rs 3,338 crores. The industrial and residential segments consume 40 percent and 25 percent of electricity, respectively.

However, in terms of revenues the shares are reversed— commercial segment contributes 25 per cent of revenues while industrial consumers contribute around 40 per cent. Industrial revenues are larger because of around 1,000 high tension (HT) customers who have large connected load and energy consumption (see *Graph 8: Electricity supply and revenues from Gurugram*).

Residential consumers are 84 per cent of the total in number but consume around a third of electricity, and are responsible for around a third of DHBVNL's Gurugram-related revenues (see *Graph 9: DHBVNL's Gurugram customers*).

GRAPH 8: ELECTRICITY SUPPLY AND REVENUES FROM GURUGRAM

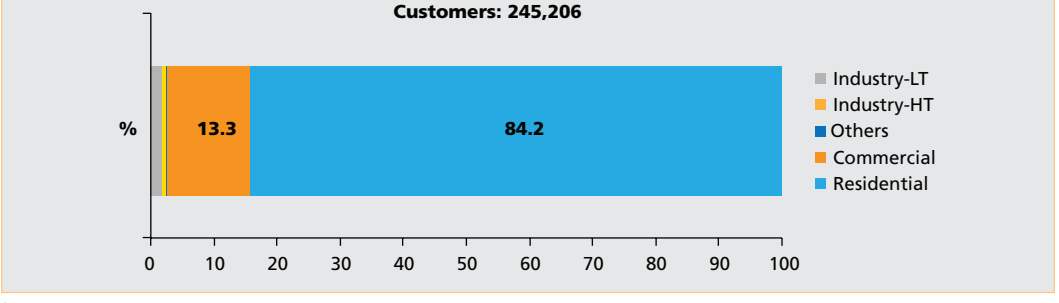
Commercial and industrial customers consume two-thirds of power



Source: DHBVNL, 2018

GRAPH 9: DHBVNL'S GURUGRAM CUSTOMERS

Residential sector is the largest, yet generates a third of revenues



Source: DHBVNL, 2018

5.1 Residential

Residential customers are charged according to their connected load and electricity consumption. The tariff structure of DHBVNL has three categories of domestic supply for which the load and energy consumption charges vary. Load charges vary between Rs 75 and 125 per kW and energy charges between Rs 2.7 a unit and Rs 7.10 a unit. Nearly 75 per cent of the residential consumers in Gurugram have under 10 kW connected load (see *Table 1: Gurugram's residential customers—Distribution by load*). Regulators are pushing policies to encourage power supply at 11 kV to the residential society customers to reduce losses. For instance, the HERC allows a rebate of 4 percent to the society in case of single point supply at 11 kV. In Gurugram just 138 complexes are responsible for a quarter of the residential supply; in fact the number may even be higher since a number of societies have multiple connections. Targeting these societies can be an efficient strategy to scale up the solar rooftop. In addition, around 35,000 customers (17 per cent of this segment) have loads of more than 10 kW. These consist of a mix of large houses, multi-flat building etc and have potential to add large capacity—the large houses are also likely to benefit more from solar rooftop. The largest category of less than 10 kW load (83 per cent of the segment) includes sizable number of customers with 5 kW to 10 kW load as well as apartments in the residential complexes – solar rooftop is a viable alternative for these too.

TABLE 1: GURUGRAM'S RESIDENTIAL CUSTOMERS—DISTRIBUTION BY LOAD

Large customers (over 10 kW of load) consume 40 per cent of power

Load in kW	Number of consumers	Electricity sold (million kWh)	% of total sold by DHBVNL	Revenue (in crores)
Under 10 kW	171,172	1,229	19.2	530
10–20 kW	34,234	389	6.1	282
20–30 kW	320	7	0.1	6
30–50 kW	484	17	0.3	14
Above 50 kW	26	3	0.1	3
BLDS	138	416	6.5	260
	206,374	2,061	32.3	1,094

Source: DHBVNL, 2018

5.2 Commercial

Commercial segment comprises office spaces, shopping malls, banquet halls, cinemas, hospitals, clinics, ware houses, guest houses, hotels and restaurants etc. This segment consumes electricity mostly during the day and they will benefit from solar rooftop given the fact that their demand overlaps with solar generation. The fixed charges vary between 170 and 225 per kW/kVAh load and energy charges between Rs 6.35 and Rs 7.05 a unit. HERC has assumed a power factor of 0.8 for conversion of kVAh into kWh. (See *Table 2: Load-wise category of commercial customers in Gurugram*).

TABLE 2: LOAD-WISE CATEGORY OF COMMERCIAL CUSTOMERS IN GURUGRAM

Vast majority of customers had less than 20 kW load

Load in kW	Number of consumers	Electricity sold (million kWh)	% of Total sold by DHBVNL	Revenue (in crores)
Up to 20 kW	29,508	1,789	4	176
20 kW– 50 kW	1,433	1,050	2	79
50 kW–1,000 kW	1,363	4,894	7	401
Above 1,000 kW	207	7,136	13	685
	32,511	14,869	26	1,341

Source: DHBVNL, 2018

5.3 Industrial

Broadly, the industrial segment is categorized based on the power supply voltage –HT/high voltage customers and low tension (LT)/low voltage customers. Tariffs are set such that the fixed charges are normalized across various categories. For instance, the HT consumers with supply at 66 kV are charged 10 paisa less than those supplied at 11kV and 33 kV. Nearly three-fourth of the LT consumers have load of about 20 kW and over 95 percent of the HT consumers are supplied power at 11 kV (see *Table 3: Load-wise category of industrial customers in Gurugram*). Given their large load and significant energy consumption, solar rooftop can only meet a fraction of their needs. Yet, the total potential installation, given their roof space, could add up to a large number.

TABLE 3: LOAD-WISE CATEGORY OF INDUSTRIAL CUSTOMERS IN GURUGRAM

HT consumers consumed fair bulk of electricity

Load in kW	Number of consumers	Electricity sold (million units)	% of total units sold by DHBVNL	Revenue (in crores)
LT consumers	4,627	229	4	131
HT consumers	1,006	2,377	37	683
	5,633	2,606	41	814

Source: DHBVNL, 2018

6. GURUGRAM'S POWER SUPPLY POSITION

If one were to go by the DHBVNL reports, there is virtually no load shedding in Gurugram. The reason for this is that load shedding is defined as 'four hours per power cut per day for four continuous days'. The DHBVNL field engineers refer to sporadic power outages as 'regular maintenance or line faults'. Not surprisingly, the performance report by DHBVNL for Gurugram district indicates zero load shedding. System average interruption duration index(SAIDI), defined as the average duration of interruption per consumer, is a globally used indicator to identify the electric power utilities' reliability of power supply. The SAIDI for the Gurugram District from April 2016 to March 2017 was around 4.41 hours –surveys suggest cuts that are much higher.

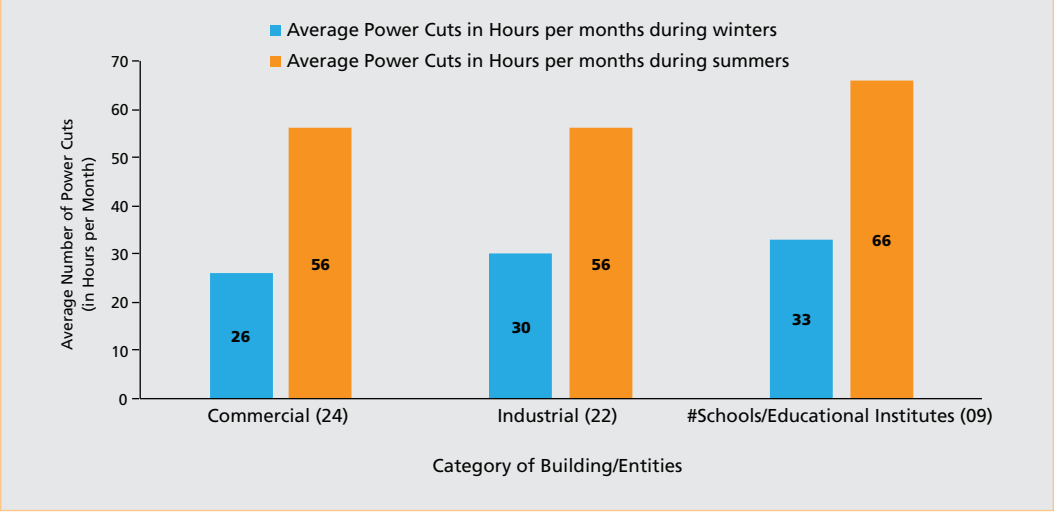
According to DHBVNL officials, the distribution company has a sufficient power supply to meet the power demand. However, CSE's December 2016 survey showed that power cuts in housing societies ranged between 30–60 minutes per day. CSE conducted another survey in Jan 2018 that looked at power supply for several commercial, industrial and institutional consumers.

Our survey clearly shows regular power cuts and widespread use of DG in Gurugram. In addition, DG usage is high in Gurugram because of some unusual reasons. There is anecdotal evidence that certain buildings don't even have an electricity connection because the feeder can't take on the additional load so these buildings run entirely on DGs. There is also some evidence of power cuts in residential buildings to increase DG use, which allows the building owner/managers to collect steep rates from office or apartment occupants. (See *Graph 10: Average power cuts in different category of buildings*).

Overall, power cuts were around 30 minutes per day in winter and around an hour per day in summer. The 24 commercial entities covered in the survey included offices, hotels, banquet halls and medical establishments. Power supply was a serious concern with more than 85 per cent of the surveyed consumers facing cuts in excess of two hours a day. The average diesel consumption for these 24 entities was 473 litres per month. (See *Graph 11: Average diesel consumption by entities in litres per month).*

GRAPH 10: AVERAGE POWER CUTS IN DIFFERENT CATEGORY OF BUILDINGS

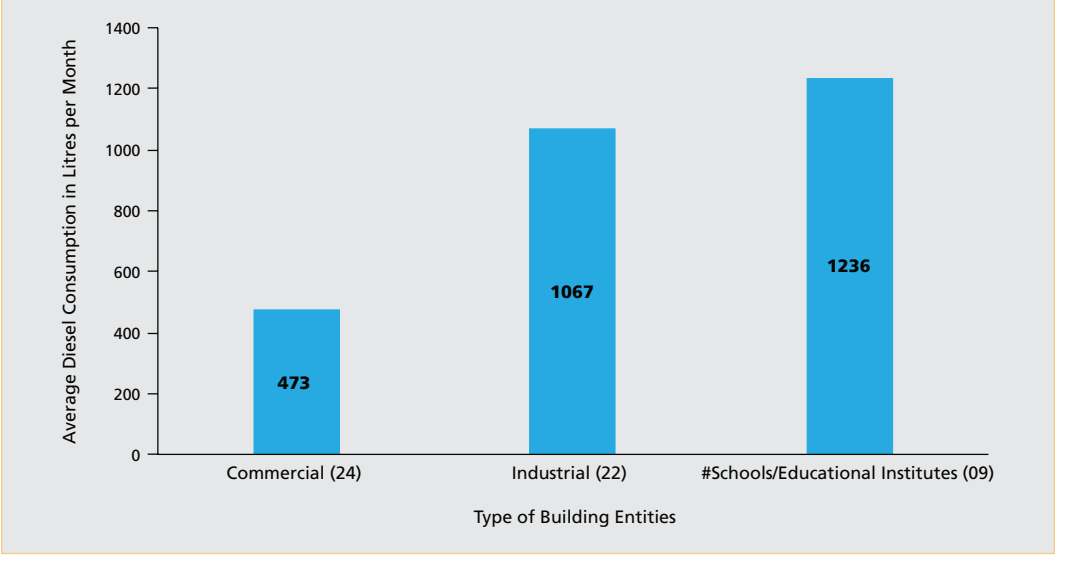
Duration of power cuts double during summer season



Source: CSE, 2018

GRAPH 11: AVERAGE DIESEL CONSUMPTION BY ENTITIES IN LITRES PER MONTH

Large consumption by institutions – potentially large benefit of solar



Source: CSE, 2018

The industrial segment faced power cuts of roughly the same levels as the commercial sector. But their average diesel consumption was seen at 1,067 litres per month because of their higher load. In schools/educational institutes's category the average power cuts for comes at 33 and 66 hours in winters and summers, respectively. The average diesel consumption was 1,236 litres per month. One notable issue is that the power cuts vary widely. There are pockets which have a comparatively better power supply with power cuts of less than 10 hours per month. Others face power cuts exceeding five hours a day during peak summer months.

6.1 DHBVNL efforts to tame power cuts

The DHBVNL officials assert that power cuts are frequently as a result of transformer failures and line faults. DHBVNL operates a total of 961 feeders in Gurugram district. This includes industrial/independent feeders (509), urban/mix-urban (266), substation (44), rural/agriculture (60) and rural/domestic (82) feeders. The discom is strengthening its distribution network by adding new transformers. Rapid growth of the city necessitating more than 20,000 new connections every year can exacerbate this problem.

Diesel Generator Use

Given the unreliable power supply and immense growth of the city, DG sets are almost becoming essential for power back-up. According to an online marketing repository (India Mart) there are more than 1500 registered diesel genset dealers in Gurugram. Further, as per the Times of India report based on the RTI data collected by Mr Asem Takyar, there are around 10,552 diesel gensets in Gurugram.

7. EXISTING POLICIES FOR SOLAR ROOFTOP IN HARYANA

The state Government of Haryana (HAREDA order dated 21st March 2016) has made it mandatory for certain category of buildings to instal solar rooftop power plants. Quantum of sanctioned load (in kW) has been used to determine the minimum solar rooftop installation that is required for all commercial, industrial and institutional consumers. For the residential consumers, plot area has been used in addition to the connected load to determine required rooftop installation. However, rooftop systems are required for only new residential buildings (See *Annexures*).

According to the HAREDA order, authorities such as Town and Country Planning Department/ HUDA, Municipal Corporation, HSIIDC and various government departments (police, PWD etc) are responsible for ensuring that these mandates are complied with. These agencies were required to incorporate within three months relevant provision in their departmental bye-laws to facilitate the implementation of the rooftop order. However, many of them have not done so. In fact survey of consumers revealed that the relevant government body had not even informed them about the requirement. None of these implementing agencies were monitoring installation let alone taking action to enforce the HAREDA mandate.

7.1 Government schemes

The Haryana government has invited tenders for installing around 50 MW of solar rooftop system in various government departments and buildings. The Delhi Metro Rail Corporation (DMRC) has also taken initiatives to DMRC instal solar plants under the power purchase agreement (PPA) mode. For instance, they have signed a 25-year PPA agreement with solar energy developer for the plant at HUDA City Centre metro station. Although the quantum of the power generated through this program will be limited, such initiatives go a long way in promoting visibility for the consumers in Gurugram.

In the recent months, two state government departments of Haryana—Health and Education—have floated tenders for commissioning of solar off-grid power plants. The health department plans to instal solar PV system of 5 and 10 kW capacities at primary and community health centres (PHC and CHC) in Haryana. It is a significant step as it will aggregate around 1,650 kW or 1.65 MW of solar electricity. Similarly, the Department of School Education of the state of Haryana has cleared the tendering for solar rooftop capacity for over 4,600 government schools in the state.

8. FUTURE POTENTIAL

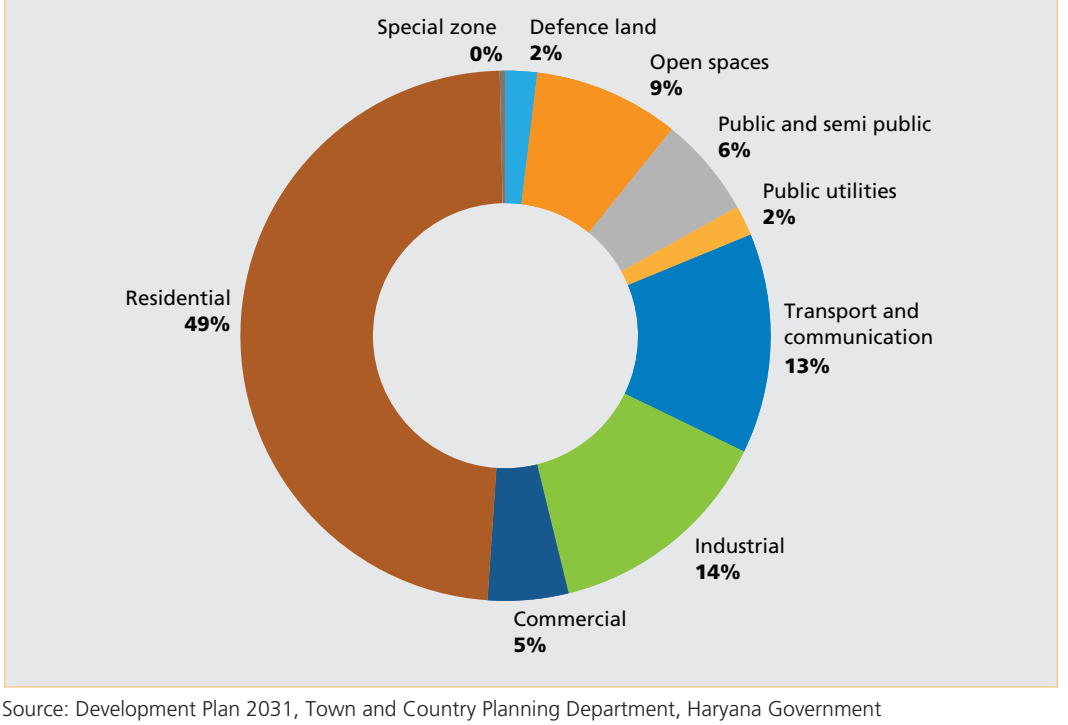
Gurugram has a huge potential for solar rooftop. Although, there is no city-specific target for rooftop solar, the Gurugram master plan, 2014, has set a goal of saving 155 million units[7](MUs) from renewable energy installation, which amounts to around 100 MW of rooftop solar installation. As per CSEs analysis of the floor area under the Gurugram Master Plan–2031, around 200 MW of solar rooftop can be installed just in the city.

8.1 Scope of the built area

According to the Development Plan, 2031, for the Gurugram-Manesar urban complex, almost 50 per cent of the area has been set aside for residential development (see *Graph 12: Proposed land use in Gurugram-Manesar urban complex*). According to the Haryana Urban Development Authority (HUDA), 8,000 hectares of residential sector has been developed in Gurugram and an additional 8,000 hectares would be used by the residential sector. The new residential sector, when developed, will have more than 800 MW potential rooftop capacity based on fairly conservative estimates of rooftop use. There are another 13,000 hectares under commercial, industrial, transport and communication, public utilities, and public and semi public areas which could also be utilized significant solar rooftop capacity.

GRAPH 12: PROPOSED LAND USE IN GURUGRAM-MANESAR URBAN COMPLEX

Almost half the land use has been set aside for residential development



Source: Development Plan 2031, Town and Country Planning Department, Haryana Government

8.2 Potential based on the HAREDA order

As per the data provided by DHBVNL, out of the total 245,206 consumers there were around 6,200 commercial, industrial and institutional consumers who were required to instal a prescribed amount of solar rooftop as per the HAREDA Orders.

Looking at the detailed breakdown of these customers in various categories, there is a potential of over 62 MW of solar rooftop installations. This is a low end of potential rooftop installations.

TABLE 4: ESTIMATES OF POTENTIAL AS PER THE HAREDA ORDER

62 MW rooftop potential exists as per the HAREDA order

	Connected load	Total load in MW	Solar mandate (min kW/ % load)	Number of customers	Estimated roof top potential (in MW)
Commercial	50 kW–1000 kW	334.4	10/5	3,957	21
	Above 1000 kW	434.7	50/3	207	14
Industrial	50 kW–1000 kW	265	10/5	1,769	21
	Above 1000 kW	156.5	50/3	69	5
Educational institutes	Above 30 kW	14.6	5/5	146	0.7
Government buildings	Above 30 kW	8.5	2/5	106	0.4
				6,254	62.1

Source: DHBVN, 2018

8.2.1 Commercial/industrial segment

HAREDA's criteria for mandatory installation of the solar rooftop for both the industrial and commercial segment is same—customers with a sanctioned load between 50 kW–1000 kW are required to instal solar rooftop system equalling the higher of 10 kW or 5 per cent of their load. Customers with connections above 1,000 kW systems are required to instal solar rooftop system which is the higher of 50 kW or 3 per cent of their load.

An industrial or commercial unit with less than 50 kW connected load is not obligated to instal solar rooftop unit. The commercial segment has over 32,000 customers but the mandate is applicable to only 4,164 customers, less than 15% of the total. In the industrial segment, less than half of approximately 5,600 customers are covered by the mandate. If customers with loads in excess of 10 kW are included, the potential rooftop would increase significantly.

Government buildings

There are 106 government buildings which are required to comply with this order. As per the laid criterion for this order, the government building section shows a limited potential of 0.27 MW. The reason for this meagre potential lies in the minimal mandate set for compliance by the government buildings.

Private educational institutes

Private educational/training institutes that have connected load exceeding 30KWas per DHBVN data, need to comply with the HAREDA order. The estimated potential for this segment is only to 0.78 MW. However, it is likely that some of these customers have been classified under commercial and their potential has been captured in that category. Educational institutes are prime candidates for installing lot more than 5 per cent.

TABLE 5: DISCOM REVENUE LOSS

Potential loss to the DISCOM is not very significant

Category	Criteria	Electricity consumed units in MU	Revenue generated by DISCOMS in crores	Million units generated by proposed SRT
Commercial	50 kW–1000 kW	458	427	30.9
	Above 1000 kW	854	685	21.1
Industrial	50 kW–1000 kW	477	385	31.5
	Above 1000 kW	2,018	358	7.5
Educational institutes	Above 30 kW	NA	NA	1.10
Government building	Above 30 kW	NA	NA	0.64

Source: CSE, 2018

8.2.2 DISCOM revenue loss

There is an alarmist view that installing rooftop will result in revenue loss for discoms and will worsen their already weak financial condition. However, even if all the consumers instal roof top as per the current mandate they will generate only 2.3 per cent of their current electricity consumption. Since these customers pay higher than the average tariff, the impact on profits may be somewhat higher. But the proposed levels of roof top penetration will not have a material impact on discoms (see *Table 5: DISCOM revenue loss*).

9. COMPLIANCE WITH THE HAREDA ORDER

According to the HAREDA order, over 6,200entities—whose connected load capacity is more than 30 kW (institutional) or more than 50 kW (industrial/commercial segment)—were supposed to instal solar rooftop systems. However, as per the data provided by DHBVNL's metering and protection (M&P) report, only 254entities have applied for the net-metering connection. Of these, only 83 are industrial and commercial customers. Another 199 industrial and commercial entities have installed off-grid solar. Taken together it is a small fraction of the number of consumers that were required to instal solar rooftop.

The HAREDA order had asked the discoms to disconnect the electricity connections— a severe and perhaps impractical measure—in the event of non-compliance of this order within six months after serving due notice on expiry of the deadline. DHBVNL officials claim that technical glitches at state DISCOMs inhibited smooth net-metering and administrative services; therefore the penal provision was withdrawn by the State discom DHBVNL in June 2017. However, this reasoning seems to be self-serving. Discoms are not keen to disconnect electricity for consumers who are paying bills and have been accused of slow net metering approval process; therefore, they seem to be more than willing to give up the enforcement tools they were given.

10. IMPLEMENTATION CHALLENGES

HAREDA's order for mandatory SRT installation across industrial, commercial and new residential apartments has had limited impact so far. This is partly due to the reluctance among consumers across residential, commercial and industrial categories to instal rooftop panels due to many reasons, and partly it is due to the government's failure in ensuring effective implementation of net metering policy and HAREDA's mandate. Implementation has been further derailed due to inadequate avenues for raising low-cost funds and an underdeveloped RESCO market.

Consumer reluctance: Consumers in Gurugram (like in the rest of the country) have been reluctant to adopt SRT plants due their unwillingness/inability to invest in high cost panels, limited trust in technology and a lack of effective incentives.

- High upfront costs (Rs 50,000–Rs 60,000 per kW) make an SRT installation impractical for households even with a 30 per cent subsidy. Commercial and industrial consumers shy away from spending large amounts on a non-core business activity.
- Perceived technology risk—Consumers are unsure about reliability of technology, performance and life of panels.
- Doubts exist regarding the expertise and credibility of rooftop installers as most are small in size with limited track record. Concerns over operations and maintenance over the 20–25 year lifetime.
- Reluctance to use rooftop space, a valuable asset in India, for installing solar panels.
- Unsuitability of industrial rooftops which are often unstable and lightweight. Reluctance to incur additional cost for making structural changes to accommodate solar panels.
- Limited knowledge regarding government programmes, subsidy availability, eligibility and application process. Fear of bureaucratic hassle and red-tape while availing government programmes.
- Doubts regarding net metering—Efficiency of implementation, ambiguity over future tariff rates and associated commercial benefits.

Governance issues: There has been a serious lapse in communication as a sizable portion of the target consumer segment has limited knowledge of the HAREDA mandate. In fact, senior officials in certain nodal agencies also remain unaware of the order or of their role in implementing it. Most agencies have not even amended their bylaw to ensure compliance to the mandate. There is a complete lack of co-ordination among various departments and agencies. Monitoring mechanisms have not been put in place to track compliance and penalize non-compliance.

10.1 Issues specific to leading implementation agencies

HAREDA's Gurugram office

- Limited staff (of two officers) and resources allocated for implementing 120 MW plus of SRT mandate
- Lack of capacity to engage in strategic activities—Communication with other departments, advising interested ones, coordinating with stakeholders to build customer awareness, monitoring and reporting progress etc.
- Unable to identify and target consumers included in the HAREDA mandate due to incomplete/non-existent data set/contact information.

DHBVNL

- Reluctance to SRT promotion/support—Incremental task with no commercial benefits. In fact, clear dis-incentive due to resulting migration of high-paying consumers.
- Missing systems and processes for effective net metering implementation—Long time taken for net metering application processing and approval, inadequate sourcing of bi-directional meters, inadequate transformer capacity for net-metering, and faulty billing due to software-hardware of glitch, etc.
- Inadequate workforce and technical capacity of staff across three junior tiers (SDO/JE, lineman and meter reader).
- Withdrawal of penalty to enforce compliance (disconnection of power supply of customers that have not installed rooftop solar).

Other nodal agencies

- Most state nodal agencies, including Haryana State Industrial and Infrastructure Development Corporation (HSIIDC), have not incorporated mandatory SRT provisions in respective customer categories as per the HAREDA order.
- Only T&CP and MCG have incorporated clause of additional floor area ratio (FAR) for new buildings with SRT, primarily because customers (builders) started asking for it. However, the monitoring and penalty mechanism has not been specified for possible default by such consumers.

10.2 Inadequate funding sources

Lack of low-cost funding is a major impediment for all consumer categories for the large scale adoption of SRT. Government has taken measures to support SRT installations in residential segment though concessional housing loan, which has not taken off due to perceived development, operations and performance risks. Some of the key financial/market related impediments are:

- Banks and FIs are not keen to lend for solar rooftop projects on a standalone basis. Large industrial and commercial firms may be able to raise money on their financial strength but they may hesitate to divert funds that they can use for their business.
- Banks may lend to homeowners against property but homeowners may not be keen on the upfront investment in solar rooftop. Banks are unlikely to extend loan to residential society for rooftop project
- RESCOs are unwilling to serve small/residential consumers and enter into long term PPAs with them due to their unknown credit profile and lower profitability. RESCOs are also unwilling to take the risk of having to repossess rooftop equipment if the customer defaults.
- Limited bank debt financing available to RESCOs, especially if they increase their exposure to the consumer segment.

11. SOLAR FINANCING

Limited access to low cost finance presents a huge barrier for SRT growth. Overall, funding requirement for meeting the national target of installing 40 GW of SRT systems by 2022 is massive—estimated to be over Rs 2.8 lakh crore.

There are clear benefits in encouraging households to instal rooftop solar systems relative to large scale renewable such as financial benefits to households, reduced T&D losses, energy independence and perhaps even grid stability given demand matching at source. However, sizable installation (in existing capacity terms) as well as future focus appears to be towards larger scale (commercial, industrial and institutional). Clear evidence of this is the 5 GW of SRT target set for the residential sector, despite its high potential, under the draft solar rooftop scheme (SRISTI) against the commercial and industrial (C&I) sector target of 20 GW.

Funding is an important barrier to SRT adoption among households. Even for installing 5 GW of residential SRT capacity, an aggregate investment of Rs 35,000 crore will be required. Capital subsidy support from the government of 30 per cent will cover about Rs 10,500 crores of this cost; households will be required to raise the remaining Rs 24,500 crore, which will need to come from bank.

In recent years, the government has taken steps to improve availability of debt for SRT projects. The Reserve Bank of India has identified SRT as a priority sector for lending. Eight public sector banks have included SRT systems under the housing or housing improvement loans. Significantly, multilateral banks are providing concessional loans against sovereign guarantee to public sector banks to support subsidized lending to the segment. In 2017, the collective lending from World Bank, Asian Development Bank and New Development Bank to State Bank of India, Punjab National Bank and Canara Bank for SRT financing was $1.4 billion.[8]

However, despite improving availability of low cost bank loans, residential consumers are likely to be reluctant to take sizable loan to set up rooftop plant. Given this scenario, renewable energy service companies (RESCOs) are best positioned to serve the residential SRT market. RESCOs instal, own and operate SRT assets at consumer premises, and sell the generated power to the consumers under a long-term PPA. Such a business arrangement shifts a number of the risks from the consumers to the developer—including that of high initial financial burden and development, performance, and O&M risks—who are better positioned to manage these.

The RESCOs raise funds (debt or equity), and instal, own and operate SRT assets. These companies may undertake the entire range of activities—market their services; assess customer's credit risk, enter into a long term contract to supply power, set up roof top plant, maintain and operate it for the life of the deal, bill customer and collect payment.

At present, there is a limited penetration of the RESCO model. Nearly 84 per cent of India's estimated SRT capacity of 1.25 GW (as of December 2016) is set up through the capital expenditure (CAPEX) model of self financing,[9] while the remaining 16 per cent is put up by RESCOs. Furthermore, even this small share is focused on large consumers. Commercial and

industrial consumers are showing a preference for RESCOs (either through PPAs or rooftop leasing or PV system leasing) due to the capping of accelerated development benefit at 40 per cent since April 2017 (in addition to the advantages of transfer of technology and performance risk).

Government institutions are also signing PPAs with RESCOs to avoid upfront investments. BNEF estimates that over 70 per cent of the 1 GW of SRT projects auctioned by various government bodies in the first nine months of 2017 were awarded to RESCOs.[10]

RESCOs have generally stayed away from domestic consumers due to high risks associated with enforceability of PPAs, difficulty in repossessing rooftop assets in case of default and assessing customer credit risk.

So far RESCOs have primarily raised the funding from equity sources. However, their success going forward will depend on their capacity to raise funding from banks and other FIs at reasonable rates. Third party financing is one of the key drivers for SRT growth in major markets, especially in the US. It helps resolve some of the key investment barriers—high upfront costs, low debt access of individual consumers, and development and operation risks. For growth in the segment to pick up, urgent measures are needed to improve debt availability to RESCOs, implementation efficiency of net metering policies and the effectiveness of consumer credit assessment:

- To increase debt availability, capacity of banks and FIs should be built to evaluate SRT project applications. Standardized financing products, instruments and guidelines should be put in place to allow easy access to debt and reduce cost of transactions.
- To ensure payment security for RESCO, discoms need to be made business partners. Existing capabilities of discoms can easily be leveraged for various services, such as sale support, customer aggregation and even O&M of assets. Discom consumer data on load patterns and payment history can also help RESCOs in optimum system sizing and assessing off-taker credibility.
- Discoms can play a vital role in managing customer risk for RESCOs by billing and collecting on behalf of RESCO. Essentially, the consumer's bill would have two components—one for the electricity supplied by the discom and another for the supply by the RESCO. Discom must be compensated appropriately for providing these services.
- To reduce credit risk, repossession of SRT assets in case of default needs to be made simpler and easier. This can be achieved through standardized PPAs and enforcement by local specialized courts to fast track dispute resolution. However, this will remain challenging given India's legal system.
- Develop and implement consistent net metering policies across all states. Further, discoms must be incentivized to effectively implement net metering though higher RPO credit or stronger penalties.

Securitization of SRT projects: The bond market provides an alternative source for raising funds for installation of SRT systems, which can be developed over the coming years. Raising low cost funds through the bond market would require aggregation of credit-worthy SRT projects by a financial aggregator to sufficiently increase the deal size. For instance, the aggregate funding requirement of 1,000 customers for setting up 5 kW installations each

would be around Rs 30 crores, which can be raised from the bond market. Private investment facilities can be set up to aggregate projects and raise funds through the green bonds market. Alternatively, municipal entities can be trusted with this responsibility through municipal bonds.

Municipalities have several advantages in their potential role as finance aggregators for SRT projects due to defined institutional goals under the solar city programme; and better access to debt capital market compared to developers due to larger balance sheets, superior credit profiles and diverse revenue sources. However to make securitization of SRT projects possible through municipalities or even private finance aggregators, innovative transaction structures would need to be developed.

12. ACTION PLAN

Successful implementation requires a fair amount of support from the state level including policy changes, budgetary support etc. In this document we will try to focus on steps that district level officials need to take:

1. Based on the Haryana RE goals and Gurugram's master plan, a clear rooftop target and timelines with annual targets need to be established. We believe solar rooftop installations of 200MW by 2022 are achievable.
2. Targets for the government are low and need to be increased by at least 3–4 times. It is essential that the government leads from the front since it will help the government understand firsthand the administrative bottlenecks and market/installer pitfalls.
3. A nodal office headed by the Deputy Commissioner should co-ordinate efforts between different key implementation departments—MCG, HUDA/Town and Country planning, DHBVNL, HSIIDC—and also monitor progress.
4. HAREDA, with assistance from DHBVNL and other govt departments needs to prepare an exhaustive list of consumers who are required to instal solar rooftop as per the order and also current installations.
5. All implementing departments need to incorporate the HAREDA order into their guidelines/orders within 90 days which should be sent to the relevant consumers within 30 days. Agencies should confirm this to the DC office.
6. Consumer grievance cell, preferably in DC office, should be established at least till the teething problems associated with subsidy approval, net metering connection, billing issues, installers/panel quality etc., are sorted out. The cell should have a mix of retired judicial officers, technical people and representatives from the DC office, HAREDA and DHBVNL to quickly resolve such issues.

RESCO model promotion

DHBVNL can play a key role in supporting the RESCO model, which in turn can resolve financing issues, especially for the residential sector. HAREDA can empanel RESCOs based on a certain criteria (financial strength, consumer feedback, installed capacity etc.). DHBVNL may enter into an agreement with RESCOs to collect their dues from customers (based on PPAs that the RESCOs have signed) along with the discom's electricity bills. DHBVNL can provide this service for a fee (say 10 to 25 paisa per unit). Residential societies are unlikely to default on their electricity bills, which makes it easier for RESCO to offer their services to the residential sector.

Incentives and penalties

1. HAREDA's order empowers discoms to disconnect electricity in case of non-compliance. The provision is too harsh to be practical and has actually been withdrawn by DHBVNL. One option is to have a monetary penalty that increases over time—say Rs 125 per KW of mandated solar capacity per month after a six-month delay (roughly translates to just under Rs 1 per unit of expected solar generation), Rs 250/KW after 12 months, and Rs 500/KW after 2 years.
2. According to the HERC order an incentive of Rs 1/kWh was given by the discoms starting from August 2016, till March 2017, an. As per the latest discussion paper of HERC these incentives are further recommended for an extension.
3. HERC's 2018 RE tariff paper suggests several incentives for solar rooftop under net meter such as: a) Banking facility to carry forward of excess energy generation from one billing

cycle to the next billing cycle and also to the next financial year, b) exemption of wheeling and cross subsidy charges, c) permit sale of electricity to utilities should be exempted, d) allow solar rooftop capacity of up to 100 per cent of transformer capacity, d) customers be allowed to instal more than their sanctioned load.

4. Approvals by various authorities—consent to operate by PCB, license by HSIIDC, occupancy certificate/completion certificate by HUDA/municipal authorities.

Awareness building program

Public awareness is considered to be one of the biggest impediments in development of solar in Gurugram. A number of officials and RWA representatives and PV installers believe lack of public awareness is one of the biggest impediments in the spread of solar rooftop. This view is supported by the fact that solar rooftop installations are dominated by the industrial/commercial sector and even within the residential sector in larger, well-off societies.

1. After Gurugram announced its vision to become a solar city, MNRE gave a Rs 47 lakh financial assistance out of which Rs 20 lakh were to be used for promotional activities, trainings, workshops and study tours within the first three years. Not much appears to have been spent.
2. Gurugram is home to many large companies that can be persuaded to use CSR obligations to promote solar.
3. Gurugram also has a very active civil society interested in environmental issues. HAREDA should actively solicit their cooperation to push rooftop in residential buildings.
4. HAREDA/HSIIDC must also engage with industry associations like local wings of CII, FICCI, ASSOCHAM and trade groups.
5. Gurugram is home to many renewable energy companies that are focussed on large scale solar. HAREDA should encourage them to participate in local rooftop market—their inputs on issues that are blocking rooftop growth could help accelerate growth.

HAREDA

1. The organization needs to add far more people to pay an effective role in coordinating, monitoring and creating awareness, none of which are currently possible given the organization appears to be overwhelmed with the approval of rooftop applications.
2. Monitoring and reporting—an online portal should be created and reports from all agencies as well as consolidated reports can be posted. The portal should have a) list of all consumers and capacity they need to instal, b) quarterly progress report by various agencies and a consolidated report by HAREDA. The report can act as a source of information and give a positive message to the consumers.
3. Awareness about the program by organization of solar *mela* or camps by the coordination of various stakeholders.
4. Assistance in bid documents contract writing for certain govt offices—police, hospitals, schools etc.

DHBVNL

DHBVNL's top management needs to be on board to aggressively push solar rooftop, the proposed SRISTI scheme, notwithstanding its shortcomings, incentivizes discoms for promoting solar and partly compensates them for the potential revenue loss.

1. Smoothening of net-metering process—approval of application, purchase and connections and removal of billing glitches are urgently needed. Management should establish timelines (less than 30 days to approve and install net meter) and monitor actual performance.

2. Training of staff especially of engineers/technicians as well as staff involved in approval of net metering applications so they are fully conversant with the net metering process.

Additional FAR—New residential complexes

An order dated 31 May 2017, issued by the Town and Country Planning (T&CP) Department made changes in the Haryana Building Code, 2017. It makes provisions for an additional Floor Area Ratio (FAR) for applicants using solar power plant. If a building generates 15–25 per cent of its total connected load from solar, it provides a three per cent additional FAR for all building uses. These additional FAR ranges from 3–12 per cent depending on the electricity supply from solar installations (from 15–100 per cent). However, this incentive is tricky to administer. T&CP department may be unable to maintain a database in terms of FAR granted and if the building owner indeed set up a solar plant of agreed capacity. If the builder sells the building/apartments, the new owners may resist paying penalty that is on account of the builder/previous owner. These issues are problematic because it takes three to five years for a building project to get completed.

TABLE 6: ADDITIONAL FAR FOR INSTALLING SOLAR PV POWER PLANT

Regulations exist but hardly monitored

Generating power in respect of total connected load of building from solar photovoltaic power plant	15– 25%	26– 50%	51–75%	76 –100%
Additional FAR for all building uses (except plotted residential)	3%	6%	9%	12%

Source: Haryana Building Code, 2017

ANNEXURES

TABLE 7: MANDATE FOR ROOFTOP SOLAR PV INSTALLATION

S. No.	Category of buildings/area	Qualification	Size of the system
1	New residential buildings	Built on a plot size of 500 square yards	Minimum 1 KWp or 5% of sanctioned load, whichever is higher
2	Private educational institutes	Sanctioned load of 30 KW and above	Minimum 5 KWp or 5% of sanctioned load, whichever is higher
3	Government buildings and offices	Sanctioned load of 30 KW and above	Minimum 2 KWp or 5% of sanctioned load, whichever is higher
4	Private hospitals and nursing homes, industrial establishments, commercial establishments	Sanctioned load of 50 KW to 1000 KW	Minimum 10 KWp or 5% of connected load, whichever is higher
		Sanctioned load above 1000 KW	Minimum 50 KWp or 3% of sanctioned load, whichever is higher

Source: Haryana Government Renewable Energy Department

TABLE 8: CRITERIA MENTIONED BY HAREDA ORDER FOR MINIMUM SOLAR INSTALLATION REQUIRED FOR THE NEW RESIDENTIAL SEGMENT

All new residential buildings	Above 500 square yard plot size	1kW/5% of the sanctioned load
All new housing complexes		
A	0.5–1 Acre	10 kW
B	1–2 Acre	20 kW
C	2–5 Acre	30 kW
D	Above 5 Acre	40 kW

Source: HAREDA

REFERENCES

1. http://www.iea.org/publications/freepublications/publication/MTRMR2016.pdf, as accessed on .
2. "Beehives or Elephants? How should India drive its Solar Transformation", Bridge to India, 2014, New Delhi.
3. Priyavrat Bhati and Rajan Kalsotra 2017, Solar Rooftop: Replacing diesel generators in residential societies, Centre for Science and Environment, New Delhi
4. Haryana Renewable Energy Development Agency, HAREDA (2018)
5. Emiliano Bellini. Israel to reintroduce FITs for rooftop PV up to 50 kW, December 21, 2017
6. https://www.pv-magazine.com/2017/12/21/israel-to-reintroduce-fits-for-rooftop-pv-up-to-50-kw/
7. https://mercomindia.com/development-banks-loaned-indian-solar-rooftops-2017/
8. "India Solar Handbook 2017", Bridge to India, New Delhi.
9. Accelerating India's Clean Energy Transition, Bloomberg New Energy Finance, November 2017
10. "Solar Rooftop Policy Coalition: Unleashing Private Investment in Rooftop Solar in India", The Climate Group, 2015, New Delhi.

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