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SHAKTI SUSTAINABLE ENERGY FOUNDATION

CEEW THE COUNCIL

Scaling Rooftop Solar

Understanding Consumer Perspectives in East Delhi

Report | July 2019

Selna Saji, Neeraj Kuldeep, and Kanika Chawla

Image: Neeraj Kuldeep/CEEW

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Council on Energy, Environment and Water
Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India

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The Council on Energy, Environment and Water (CEEW) is one of South Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain - and change - the use, reuse, and misuse of resources. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public.

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About the authors

Selna Saji
selna.saji@ceew.in

Selna is a research analyst at the Council on Energy, Environment and Water (CEEW). She is an energy and environmental analyst who focusses on renewable energy technologies. At The Council, she is working towards developing business models and tools that will facilitate the adoption of rooftop solar in India. Selna holds a dual postgraduate degree in Management and Engineering of Environment and Energy from Queen's University Belfast and Universidad Politécnica de Madrid.

"Some of the findings from the survey are very interesting, and they are helping us design the next phase of our work—piloting a community campaign intervention and three innovative business models in the BYPL licence area."

Neeraj Kuldeep
neeraj.kuldeep@ceew.in

Neeraj Kuldeep is a programme lead at The Council. He has worked and published extensively on renewable energy markets. He is currently leading the rooftop solar programme and piloting new utility-led business models to accelerate rooftop solar deployment. Neeraj holds an undergraduate degree in Energy Science and Engineering, and an M. Tech in Energy Systems from the Indian Institute of Technology (IIT), Bombay.

"The study highlights that the general awareness around rooftop solar is not entirely effective in creating demand. The focus should be on building an in-depth understanding of the solar photovoltaic (PV) technology, and its benefits and incentive schemes. This would require new tools and approaches to bridge the gap."

Kanika Chawla
kanika.chawla@ceew.in

Kanika Chawla is a policy specialist working at the intersection of renewable energy and financial markets. She is the Director of the CEEW Centre on Energy Finance and also manages The Council's research and outreach in renewable energy policy, regulation, markets, and socio-economic value. She is actively engaged with private and public enterprises within and outside India in designing and developing financial de-risking instruments. Kanika has an MSc in Economics and Development Economics from the University of Nottingham, and an undergraduate honours degree in Economics from Miranda House, University of Delhi.

"Consumers are a critical, and possibly the least addressed pillar of the energy transition. It is essential to drive a behavioural shift in consumer choices to realise India's rooftop solar ambition. This analysis makes clear the urgent need to sensitise consumers and provide them with accessible, comprehensible, and reliable information that can aid their decision-making."

Image: Envato

Contents

List of figures

List of tables

Abbreviations

AC	alternating current
BYPL	BSES Yamuna Power Limited
C&I	commercial and industrial
CAPEX	capital expenditure
CAPI	computer-assisted personal interviewing
CSO	customer service officer
DC	direct current
EEREM	Energy Efficiency and Renewable Energy Management Centre
EMI	equated monthly instalments
GBI	generation-based incentive
GHI	global horizontal irradiation
GNCTD	Government of National Capital Territory of Delhi
GW	gigawatt
IPGCL	Indraprastha Power Generation Company Limited
kW	kilowatt
LCOE	levelised cost of electricity
MW	megawatt
MNRE	Ministry of New and Renewable Energy
NCT	National Capital Territory
O&M	operations and maintenance
PV	photovoltaic
RESCO	renewable energy service company
RTS	rooftop solar
RWA	residents' welfare association

Identifying solar vendors who can ensure quality of components and installation is a challenge for residential consumers.

Image: Pixabay

Executive summary

As part of its ambitious energy transition goals, the Government of India has set a target of achieving 100 gigawatt (GW) of solar energy by 2022, of which 40 GW are to come from rooftop solar (RTS) energy. However, the performance of the RTS sector over the last few years has been underwhelming, with an installed capacity of only 3.4 GW as of 31 December 2018—just 8.5 per cent of the target. Of this, the residential sector contributed the least—15 per cent of the total capacity despite its high technical potential.

The slow uptake of RTS in the residential sector could be explained by multiple reasons. For instance, the technology is not very economically feasible for a large proportion of residential consumers who pay a subsidised electricity tariff. Several non-economic barriers also plague the sector, such as a lack of awareness, high upfront costs, lack of access to suitable roof spaces, and so on. To address these market challenges and increase the adoption of RTS among residential consumers, the Council on Energy, Environment, and Water (CEEW), in partnership with BSES Yamuna Private Limited (BYPL), an electricity distribution company in New Delhi, designed three discom-led innovative business models to target different consumer segments.

Before deploying the business models and developing a comprehensive deployment strategy, the discom needed to gauge how consumers perceive the technology and their levels of awareness and willingness to accept new business models. With this objective, CEEW administered a survey to residential consumers in the BYPL distribution area; the findings are summarised in this report. A better understanding of these aspects would enable advances in the residential rooftop market.

A detailed view of the study's objectives are as follows:

a) Identify the roof usage patterns of residents in the East Delhi area.

b) Understand awareness levels surrounding RTS among residential consumers in the area, and their readiness to adopt the technology.

c) Understand the drivers and barriers for the adoption of RTS, as perceived by residential consumers.

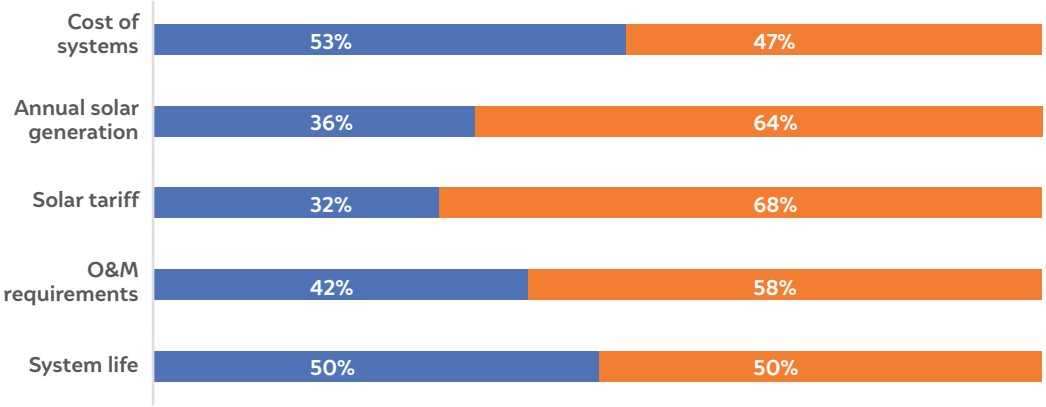
d) Gauge consumer acceptance of innovative business interventions, such as on-bill financing, solar subscription, shared solar, and third-party owned models.

The technology is not very economically feasible for a large proportion of residential consumers who pay a subsidised electricity tariff

Key findings

The study presents insights from data collected from 419 households in the BYPL licence area.

Lack of awareness: Lack of awareness emerged as a key barrier to increasing the adoption of RTS in the residential sector. While around 78 per cent of the consumers surveyed were aware that RTS systems were being installed in the city, less than half of the respondents knew any specifics regarding the technology, such as its cost, maintenance requirements, performance, and system life. Therefore, it is necessary to create more awareness among residential consumers so that households can make informed investment decisions while considering RTS as a viable option.



ES1: Consumer knowledge on rooftop solar technology

Source: Authors' analysis

Sources of information for residential consumers: Word of mouth was identified as the most common source of information on RTS for residential consumers, followed by solar vendors, television, and the discom. Given that word of mouth and social influence play an important role in increasing awareness among consumers, targeted campaigns and neighbourhood programmes may be effective avenues for the discom to engage residential communities.

Low willingness to pay: Only 25 per cent of consumers expressed a willingness to pay the current rates (after capital subsidy) for RTS. This might be due to a poor understanding of the economic benefits of installing an RTS system. This finding reiterates the need to foster consumer awareness and develop innovative market mechanisms to accelerate market growth.

Drivers and barriers: The study identified environmental consciousness and the potential reduction in electricity expenditure as the key drivers for installing RTS among surveyed consumers. Lack of knowledge about the technology, lack of ways to vet solar vendors, scepticism regarding the system's performance, lack of knowledge about processes to install the system, and high upfront costs emerged as the top barriers to installing RTS systems.

Acceptance of new business models: A significant share of the surveyed consumers expressed an interest in new business mechanisms, such as shared systems, on-bill financing, third-party ownership, and solar subscription models. Discoms can capitalise on this finding and design and implement suitable market interventions in various consumer categories to increase adoption among residential consumers.

Despite the high technical potential for rooftop solar in the residential sector, its adoption by households is very low, compared to the commercial and industrial sectors.

Image: Pixabay

1. Introduction

The vast majority of India gets year-round sunshine; therefore, there is immense potential for harnessing electricity from solar energy. The global horizontal irradiation (GHI) in India ranges from around 4 kW/m²/day in less sunny regions to around 5.6 kW/m²/day in the hottest areas.[1] To leverage this advantage, the country had set a target to achieve 100 gigawatt of solar by 2022 and has increased its total installed capacity to 28.1 gigawatt (GW), as of 31 December 2018.[2] However, 24.2 gigawatt of this total comes from utility-scale plants. The rooftop solar (RTS) sector has not grown at the expected pace.[3,4] The residential sector contributes the least—only 15 per cent of the total 3.4 GW of installed rooftop capacity.[5] This is despite the sector's high technical potential of 289 GW.[6]

There are multiple reasons for the slow uptake of RTS in the residential sector; the primary reason is its low economic feasibility. Around 70 per cent of the Indian urban households consumes less than 300 units of electricity a month on average.[7] The electricity tariff for residential consumers is highly subsidised—average consumers pay about INR 4.5 per unit.[8] This figure can go as low as INR 1.5 per unit after additional state subsidies. The situation is no different in Delhi where around 80 per cent of residential consumers use less than 400 units a month on average, and pay INR 2.5–4 per unit after the state subsidy.[9] Low electricity tariffs would mean low returns and long payback periods if consumers were to invest in an RTS system.

As a result, most current RTS systems are installed in the homes of people who have higher than average consumption, and who pay higher than average tariffs for grid electricity. However, even in such consumer categories, the adoption of the technology is minimal.[10]

Low adoption of rooftop solar can be attributed to high upfront capital investment requirements, a lack of access to easy financing, a lack of awareness about RTS and also lack of access to suitable roof spaces

1 The World Bank Group (2019) "Global Solar Atlas," available at https://globalsolaratlas.info/, accessed on 12 February 2019.

2 Bridge to India (2019) India Solar Compass Q4 2018 - Executive Summary,https://bridgetoindia.com/report/india-solar-compass-q4-2018-february-2019/.

3 Realistic technical potential for rooftop solar PV in urban settlements.

4 TERI (2014) Reaching the Sun with Rooftop Solar, New Delhi: The Energy and Resource Institute, p. 62.

5 Bridge to India (2018) "India Solar Rooftop Map 2018," available at https://bridgetoindia.com/reports/, accessed on 12 February 2019.

6 TERI (2014) Reaching the Sun with Rooftop Solar, New Delhi: The Energy and Resource Institute, p. 62.

7 Prayas (Energy Group) (2016) Residential Electricity Consumption in India: What Do We Know?, Pune: Prays (Energy Group).

8 Authors' analysis.

9 Authors' analysis, ARR 2018-19 BSES Yamuna Private Limited (BYPL).

10 Authors' analysis based on BYPL data.

This low adoption can be attributed to a number of market challenges that residential consumers face.[11] For instance, high upfront capital investment requirements, a lack of access to easy financing, and a lack of awareness about RTS. In urban areas, challenges such as lack of access to suitable roof spaces and the 25-year roof lock-in requirement limit adoption.

Despite these perceived challenges, there is great potential for RTS in the residential sector, and increasing its adoption has far-reaching benefits. RTS is an ideal source of renewable power in urban areas where land is a constraint. It also encourages consumption at the source, hence reducing transmission and distribution losses that distribution companies incur. Distribution companies will also benefit from reduced cross-subsidy burdens if more subsidised residential consumers switch to RTS.

Recognising these benefits, BSES Yamuna Private Limited (BYPL), a Delhi-based distribution company, has been actively promoting RTS among its residential consumers. Around 76 per cent of BYPL consumers fall in the domestic category, which comprises around 58 per cent of BYPL's demand.[12] Current RTS installations generate 18 megawatts (MW) for the discom, of which 1.25 MW comes from the domestic sector.[13] BYPL, in partnership with the Council on Energy, Environment, and Water (CEEW), undertook a study to design innovative discom-led business models to accelerate the deployment of RTS in the residential sector (described in detail in Annexure A). The proposed business models address existing market challenges and offer accessible and affordable ways for all consumer categories to adopt RTS systems. However, in order to deploy the business models and develop a comprehensive deployment strategy, the discom needs to gauge consumers' perceptions on the technology, their levels of awareness, and their willingness to accept new business models.

To understand consumers' interest in and awareness of RTS technology, the drivers and barriers for installing RTS systems as perceived by consumers, and their willingness to accept new business models, CEEW surveyed residential consumers in the BYPL distribution area. The objectives of the study were as follows:

a) Identify roof usages patterns of residents in the East Delhi area.

b) Understand the levels of awareness about RTS among residential consumers in the area and their readiness for the technology.

c) Understand the drivers and barriers for the adoption of RTS as perceived by residential consumers.

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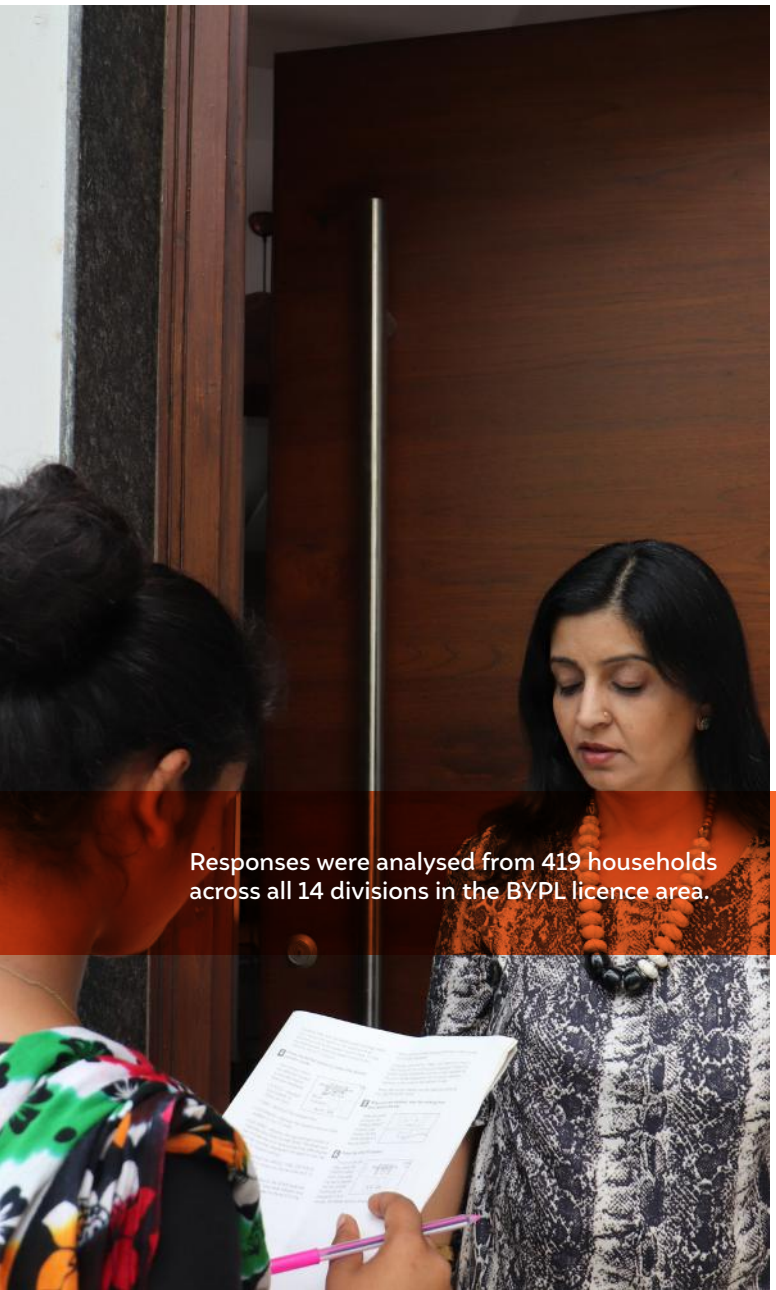
11 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs, New Delhi: CEEW.

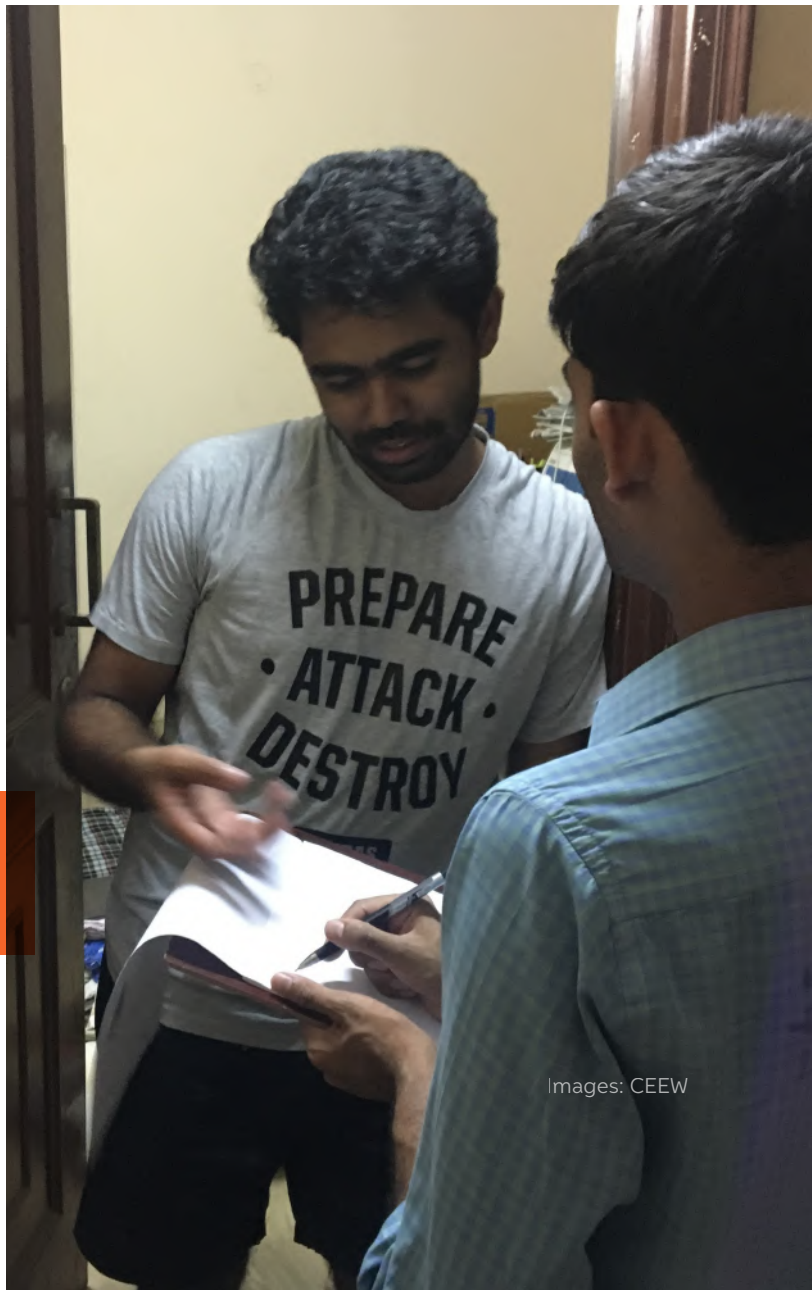
12 ARR 2019-20 BYPL.

13 BYPL (2019).

A better understanding of these aspects and insights from the survey could enable advances in the residential rooftop market. The survey findings are described in Chapters 2–6. Chapter 2 describes the methodology used for the survey design, the sampling process, data collection, and analysis of the survey data. Chapter 3 details roof ownership and usage patterns of consumers in the East Delhi area. Chapter 4 examines the market characteristics of the residential sector by analysing their awareness levels and readiness for RTS technology. Chapter 5 describes the drivers and barriers for the adoption of RTS, as perceived by residential consumers, and Chapter 6 analyses consumers' perceptions and acceptance of the new business models that were developed for BYPL. Chapter 7 summarises key findings and lists related recommendations.



Responses were analysed from 419 households across all 14 divisions in the BYPL licence area.



Images: CEEW

2. Methodology

For this study, CEEW conducted a primary survey of residential consumers in the BYPL licence area. BYPL serves about 1.6 million consumers across eastern and central Delhi. This consumer density of 8,250/km² in the BYPL licence area is the highest among the five discoms operating in Delhi. The BYPL licence area is about 200 km², with 14 subdivisions (see Figure 1).[14]

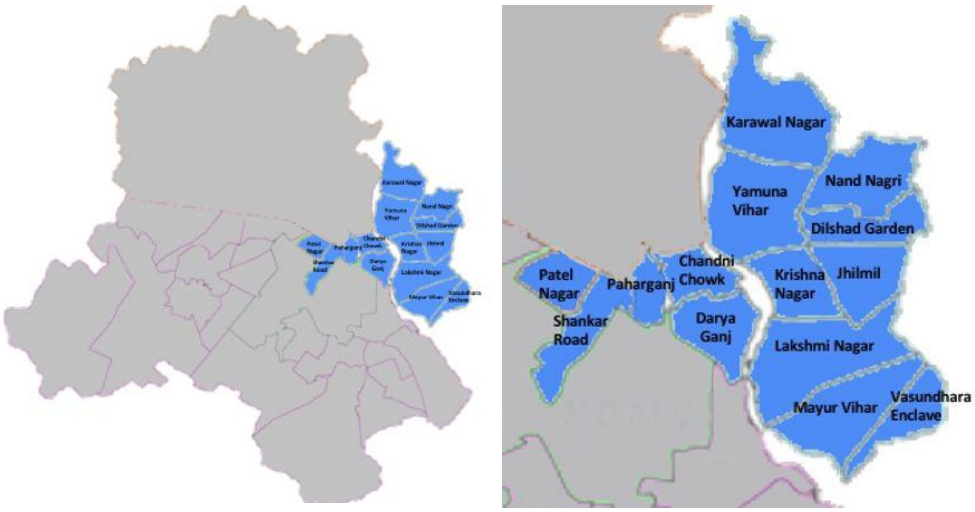


FIGURE 1: BSES Yamuna licence area in the National Capital Territory (NCT) of Delhi

Source: BSES, 2017

A detailed questionnaire with 58 questions was developed to capture household awareness of and interest in RTS, various market barriers and drivers, and acceptance of new RTS business models. An extensive review of the literature was carried out to finalise parameters to assess consumer awareness and perceptions of RTS. The survey has six subsections, which are designed to capture the physical and behavioural attributes that influence a consumer's decision to adopt RTS.

A. Demographic details

Electricity expenditure, property ownership, and building structure are essential considerations for purchasing an RTS PV (photovoltaic) system. This section captures basic details on property ownership (rented/owned), the building structure (total floors and occupancy), building type, electricity consumption, and bill amount.

14 BYPL (2018) "About BSES," available at https://www.bsesdelhi.com/web/bypl/about-bses, accessed on 21 March 2019

B. Roof ownership and usage patterns

In Delhi, a large number of buildings have more than two floors, which restricts roof ownership to only some households. In case of residential societies and high-rises (more than four floors), roofs are shared by occupants. This section captures roof ownership and usage patterns by the family and other occupants of the building to understand how these aspects influence RTS adoption.

C. Consumer interest in RTS

This section assesses consumer interest in RTS by quantifying their curiosity, and by determining whether they have tried to gain more information about RTS systems. Additionally, this section looked at the different platforms (online and offline) that consumers use to source information, and the influence of social circles.

D. Consumer perception of RTS

In recent years, multiple channels are being exploited to build awareness in order to promote RTS among residential consumers. This includes efforts by discoms, state nodal agencies, and RTS developers. At times, information from multiple sources conflict and might be outdated. This section captures consumer awareness and perceptions by asking questions related to the RTS PV system, such as the cost per kilowatt, life of systems, maintenance requirements, and payback periods.

E. Consumer acceptance of new business models

CEEW, in partnership with BYPL, has previously designed three utility-led business models for residential consumers to promote the adoption of RTS. The three business models are: community solar, on-bill finance, and solar partners.[15] The key features of each were presented to respondents to understand the potential for their acceptance.

F. Market drivers and barriers

An exhaustive list of various market drivers and barriers based on an extensive literature review and our interactions with rooftop developers was presented to respondents. Households were asked to rank each driver and barrier on a scale of 1–5. If the respondent was unaware of a particular driver or barrier, they could pick “not aware” as their answer.

We collected responses from a total of 630 households across all 14 divisions in the BYPL licence area. Different teams of enumerators were sent out to collect data. Households were selected using a heterogeneous purposive sampling methodology to ensure diverse responses. Customer service officers (CSO) were consulted in each of the 14 divisions to capture the demographic spread in every locality. Further, ground, first, and top floor occupants were surveyed to understand roof ownership and usage patterns.

15 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) Scaling Rooftop Solar: Powering India’s Renewable Energy Transition with Households and DISCOMs, New Delhi: CEEW.

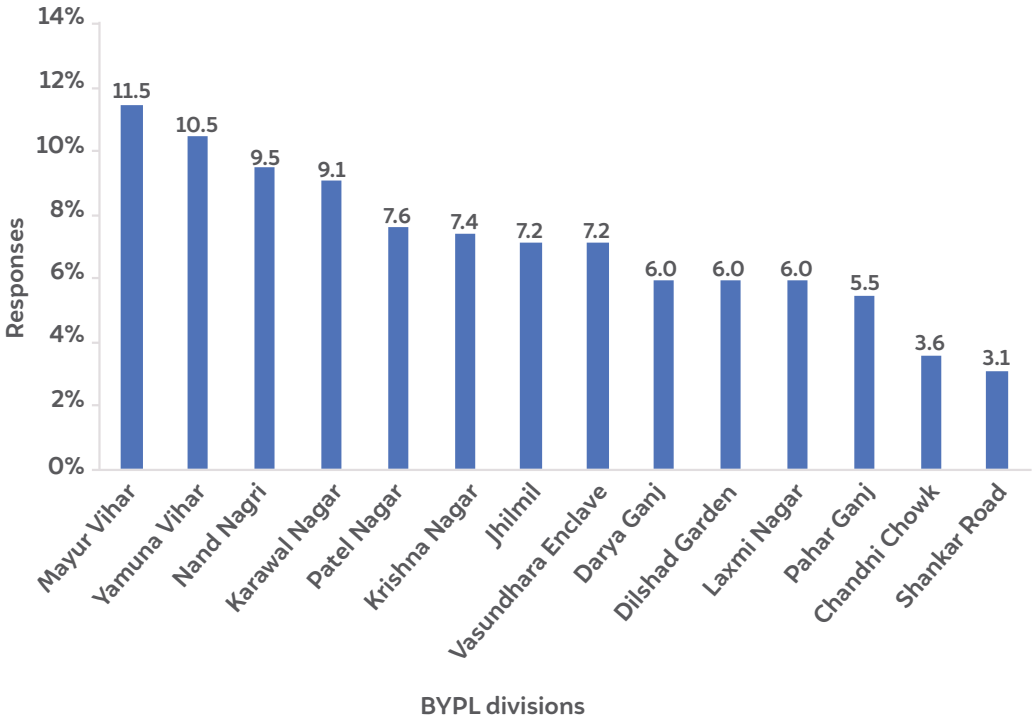


FIGURE 2:
Percentage split of total responses across 14 divisions

Source:
Authors' analysis

We used the computer-assisted personal interviewing (CAPI) technique to gather responses from households. Enumerators used a handheld device (tablet) to record data. The devices could be used to record responses in either Hindi or English, and respondents could choose between the two languages. Despite quality checks, responses from many households were inconsistent or incomplete. Such responses were discarded during the data validation and cleaning process to ensure consistency. As such, a total of 419 responses were included in the analysis. The share of households in each consumption slab was compared to the slab-wise share of total registered consumers in the BYPL licence area (see Figure 3). Although the sample had a slightly higher proportion of consumers in slab 2 (201–400 units) compared to slab 1, there are more consumers in slab 1 in the BYPL licence area.

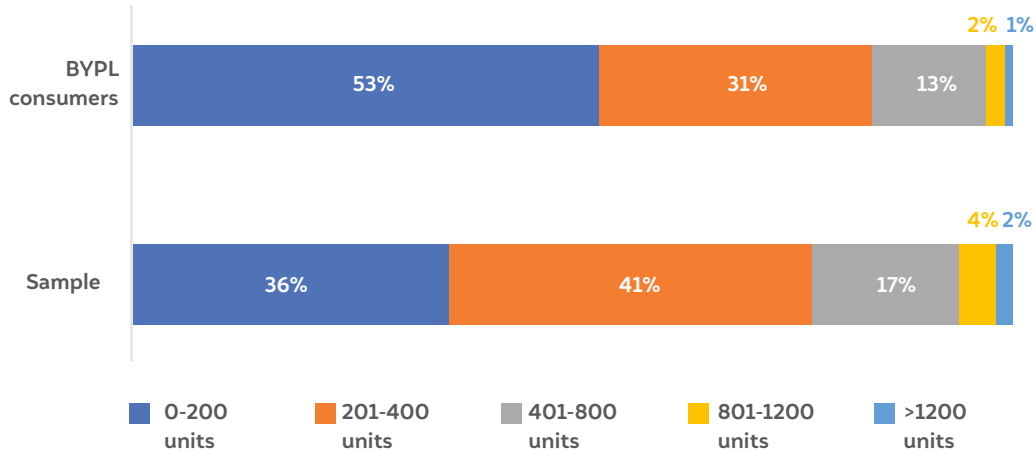


FIGURE 3:
Energy slabs of BYPL residential consumers and survey sample

Source:
Authors' analysis, BYPL

Most of the consumers we surveyed owned the houses they were living in, and lived on the ground or first floors. Figure 4 shows the distribution of respondents in terms of house ownership and the building floor they live on.

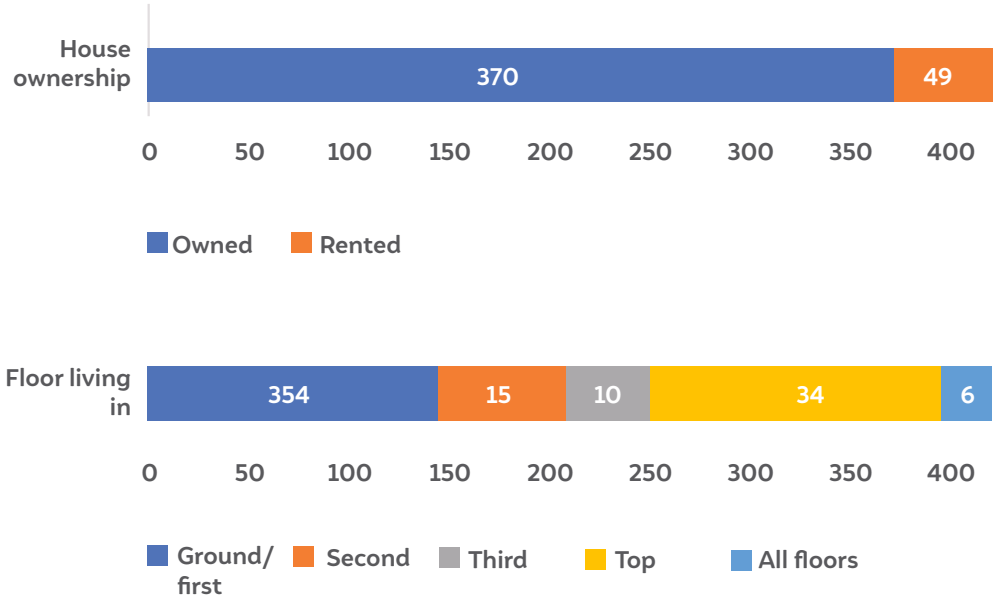


FIGURE 4:
House ownership and building floor of respondents

Source:
Authors' analysis

Since the study considered people only in the BYPL licence area, findings from the current dataset are not applicable to the entire population of Delhi or beyond.

3. Scanning the residential rooftops

Roof ownership and usage patterns in East Delhi

A large proportion of the Indian urban population lives in high-rise buildings. The BYPL licence area is a densely populated region; most residents occupy multi-storey buildings. Four-storey and high-rise buildings (with more than four floors) are prominent in most BYPL serviced neighbourhoods. As such, the roof is shared or belongs to a single family, with the latter system being more common in four-storey buildings.

Since the RTS PV system is installed on the roof and remains there for an extended period of time (25 years), it restricts roof usage for alternative activities, such as social gatherings, sunbathing in winter, and storage. This is considered a significant deterrent to the adoption of RTS in residential areas. The survey covers roof ownership and usage patterns.

Of the consumers surveyed, 73 per cent own their rooftop or have exclusive access; only four per cent share their rooftop with other building occupants. The remaining 23 per cent reported that their rooftop is owned either by the top floor occupants, the housing society, or the builder. In the case of self-owned rooftops, 71 per cent of consumers mentioned that they frequently use the rooftop; 14 per cent use their rooftops occasionally for family functions or during the winter; and the rest rarely access their rooftops (see Figure 5).

Of the consumers surveyed, 73 per cent own their rooftop or have exclusive access

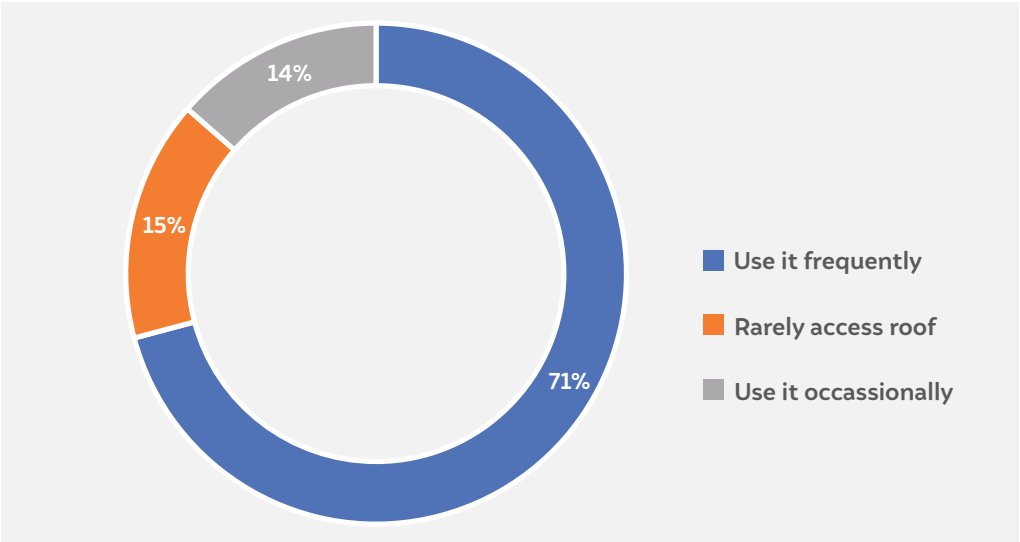


FIGURE 5:
Roof usage patterns for self-owned rooftops

Source:
Authors' analysis

Of the respondents who do not own their rooftops, 14 per cent use them frequently and 27 per cent use them occasionally (see Figure 6). Around 59 per cent of respondents either rarely access their roofs or cannot access them at all. Frequent multipurpose usage of rooftops in the case of single ownership could deter RTS adoption. However, measures such as elevated rooftop installations are increasingly common nowadays; perhaps they will ensure higher rates of adoption because they provide a dual benefit to consumers.

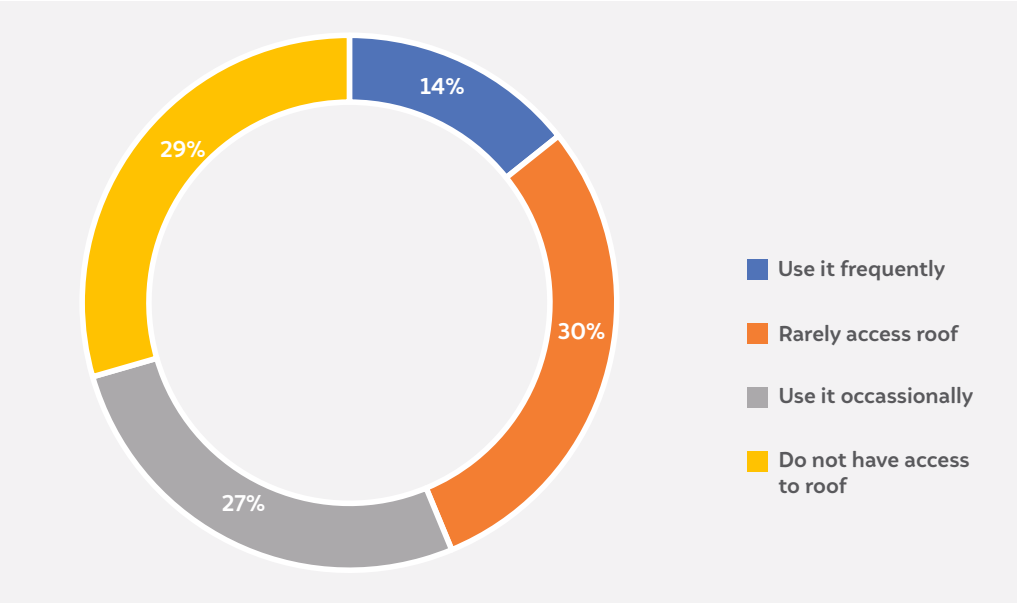


FIGURE 6:
Roof usage patterns of consumers without exclusive roof rights

Source:
Authors' analysis

4. Are households ready for rooftop solar?

Residential market characteristics

Key findings

- While consumers have heard about RTS technology, they remain unaware of its multiple benefits, procurement processes, subsidies, and other characteristics. This lack of in-depth awareness impedes market growth.
- Some consumers are interested in installing solar plants on their roofs. However, only a small proportion are willing to bear the capital expenses of doing so at current market rates.
- Findings suggest that word of mouth is effective for spreading information on RTS technology. Solar vendors, television, and discoms are the next best sources of information on RTS, according to the consumers surveyed.
- Most consumers are not concerned about falling panel prices—they do not consider it a major barrier—and the 25-year roof lock-in period. However, this could be the result of a lack of awareness of the technology.

As of December 2018, the total installed capacity of RTS by 160 residential consumers of BSES Yamuna—which is less than 1.5 per cent of residential consumers in the higher energy slabs (using more than 1,200 units a month)— was around 1.25 MW.[16] Evidently, the vast majority of the residential market in Delhi remains unexplored even though RTS is economically beneficial for these high-paying customers.

16 BYPL and authors' analyses (2019).

In order to increase the adoption of RTS in the untapped residential sector and develop effective market mechanisms, it is necessary to understand the characteristics of this market. The survey tried to explore this aspect by measuring consumers' awareness of and interest in RTS systems, and the value that consumers attribute to them. This chapter summarises key findings and insights on the characteristics of the residential market for RTS in the BYPL licence area.

4.1. Awareness about rooftop solar technology

Consumer awareness is a key factor in determining the adoption rate of any new technology. However, awareness does not mean mere knowledge of the existence of a technology; it also involves knowledge of characteristics that will aid the consumer in making a decision. The survey gauged the levels of consumers' awareness of RTS technology and their knowledge of additional information, such as its cost, product life, maintenance, and benefits. The survey explored existing sources of information on RTS, their effectiveness in generating interest, and the level of interest among consumers in installing RTS systems.

How much do consumers know?

Given the increasing popularity of renewable energy technologies and the growing number of major renewable energy project announcements, there is a high degree of awareness among the consumers about RTS systems being installed in the city. 78 per cent of the consumers surveyed responded that they are aware of RTS. However, when probed on the specifics of the technology and its benefits, more than half did not have accurate information. Consumers were quizzed on their knowledge of RTS characteristics—average system cost, operations and maintenance (O&M) requirements, solar output, and levelised cost of the system (LCOE). Around 53 per cent of consumers knew the current market price of RTS systems; only 42 per cent were aware of the O&M requirements. Less than 40 per cent knew about solar output and LCOE (see Figure 7).

78 per cent of the consumers surveyed responded that they are aware of RTS. However, when probed on the specifics of the technology and its benefits, more than half did not have accurate information

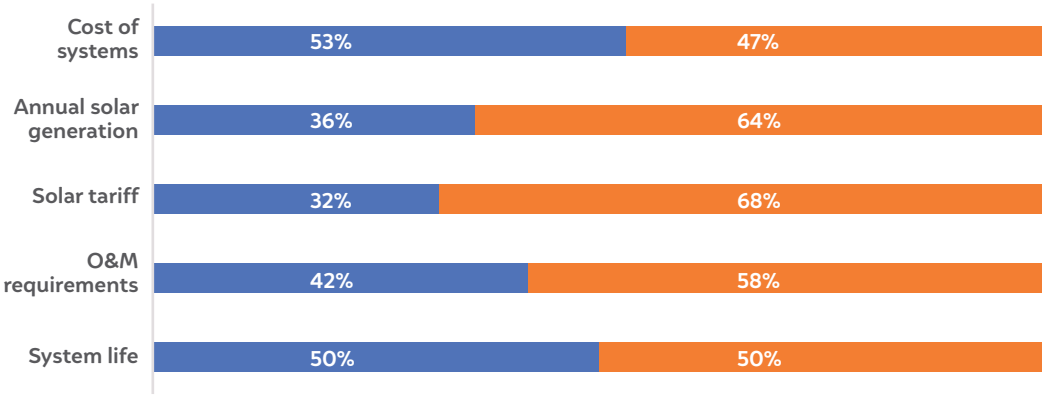


FIGURE 7: Consumer knowledge on rooftop solar technology

Source: Authors' analysis

Figure 8 provides a visual comparison of consumers who are aware of RTS and their awareness of the characteristics of the technology. Evidently, while 78 per cent are aware of RTS technology, only 41 per cent know specific details about at least one of its characteristics, such as the system cost, the maintenance required, system life, and performance.

Consumers must consider installing an RTS system as a long-term investment; a major resulting benefit is the reduced expenditure on electricity. Therefore, consumers have to be aware of the specific details of the technology to make informed investment decisions. The survey data indicate that while there is a general level of awareness among consumers about RTS systems, reliable and relevant information on the technology and its benefits is still lacking.

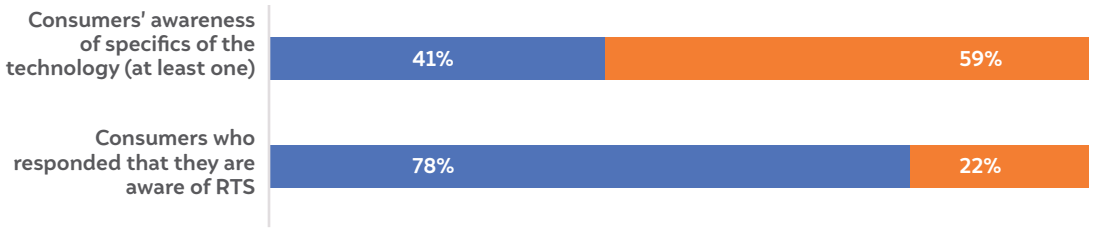


FIGURE 8:
General awareness vs. knowledge of the technology

Source:
Authors' analysis

What are the top sources of information?

The top sources of information for residential consumers include word of mouth, television, solar vendors, newspapers, and the discom, in that order. Solar vendors seem to communicate effectively and convincingly—92 per cent of consumers who mentioned solar vendors as their primary information source also considered installing RTS. The discom is able to reach a decent number of people, but it is unable to garner enough consumer interest—only 35 per cent of consumers who received information from the discom considered installing RTS. However, one caveat is that discoms and solar vendors probably run advertisements on other media, such as newspapers or television, and the survey does not capture this.

Figure 9 shows consumers' different information sources and their effectiveness in generating interest in RTS by considering the proportion of people who did and did not consider installing RTS.

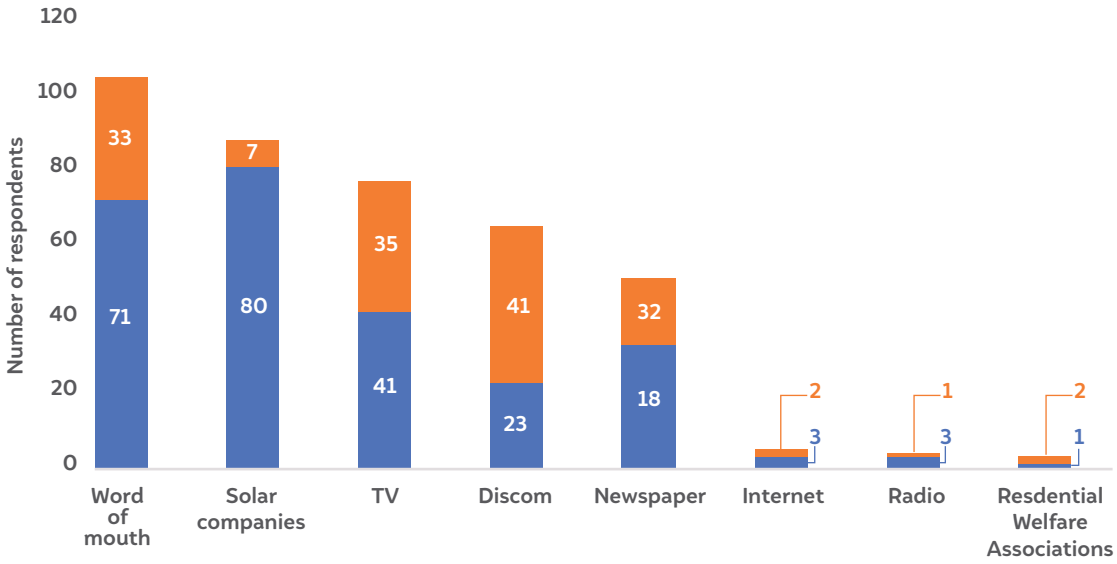


FIGURE 9:
Consumers who did and did not consider installing RTS against their primary information source

Source:
Authors' analysis

Of the 328 respondents who are aware of RTS technology, 250 respondents considered installing it. Only 45 per cent of the consumers surveyed said that they had sought out more information on RTS systems. Of those who tried to get more information, 55 per cent reached out to solar vendors. Existing consumers and the internet were other popular information sources; only very few consumers reached out to the discom. Figure 10 shows the different sources that interested consumers sought out for more information on RTS.

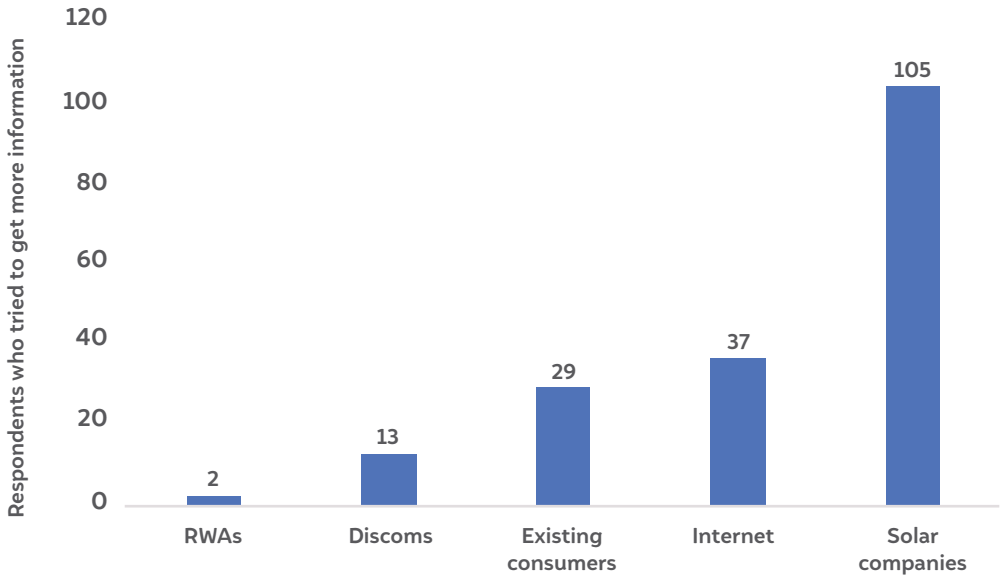


FIGURE 10:
Different sources consumers consulted for more information on RTS

Source:
Authors' analysis

Word of mouth was the primary information source for 64 per cent of consumers who knew about system costs; 45 per cent of consumers who did not know about system costs had received information from solar vendors. A similar trend is observed in the case of maintenance requirements.

Findings indicate that word of mouth is a powerful tool for creating consumer awareness of RTS. Awareness strategies such as community mobilisation and community-based campaigns would be effective ways to increase consumers' awareness. Workshops and demonstrations that educate consumers on the features and benefits of RTS systems are also necessary.

The discom should continue to use their customer care officers to reach out to and engage regularly with consumers to increase their awareness of RTS technology; it is best placed to provide consumers with reliable information. Under Phase-II of the Grid-Connected Rooftop Solar Programme, there is a provision for paying performance-based incentives to discoms based on the RTS capacity they achieve in a financial year.[17] A part of this financial support could be directed towards enhancing awareness-building efforts; for instance, by focussing on in-depth awareness.

Workshops and demonstrations that educate consumers on the features and benefits of RTS systems are also necessary

17 Press Information Bureau (PIB) (2019) Cabinet Approves Phase-II of Grid Connected Rooftop Solar Programme for Achieving Cumulative Capacity of 40,000 MW from Rooftop Solar Projects by the Year 2022, New Delhi: PIB.http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1565282.

4.2 Readiness for rooftop solar technology

The second residential market characteristic is market readiness for the technology, which is a function of the value consumers attribute to RTS, and their willingness to buy the product at the current market rate. To understand this aspect better, the survey asked consumers about their willingness to pay; roof lock-in acceptability, which would indicate the perceived opportunity cost of the roof area; and investment deferment tendencies. The findings are described in this section.

How much are consumers willing to pay for an RTS system?

Currently, the Ministry of New and Renewable Energy (MNRE) benchmark price for residential rooftop systems is INR 60,000–70,000/kW. Actual market prices can be as low as INR 40,000–50,000/kW for large systems. However, given residential roof sizes and sanctioned loads, typical residential systems will be up to 10 kW; therefore, they will cost around INR 55,000–60,000/kW. Even with a 20–40 per cent capital subsidy, it will cost at least INR 40,000/kW for a residential consumer to install RTS.

Only 25 per cent of respondents indicated a willingness to spend over INR 40,000/kW to install an RTS system (see Figure 11). As much as 55 per cent reported a willingness to pay a maximum of INR 20,000/kW, which indicates that many consumers are unwilling to pay for RTS systems at the current market rates. This might be because of a lack of awareness of the benefits of an RTS system. Around 64 per cent of respondents who mentioned that they were willing to pay less than INR 40,000/kW also said that they were unaware of the costs, potential savings, or monthly power generation of an RTS system. Thus, accelerated residential market development cannot be envisaged with a business proposition wherein consumers have to make a payment upfront. It is imperative to develop business mechanisms which relieve consumers of upfront investments and long-term commitments.

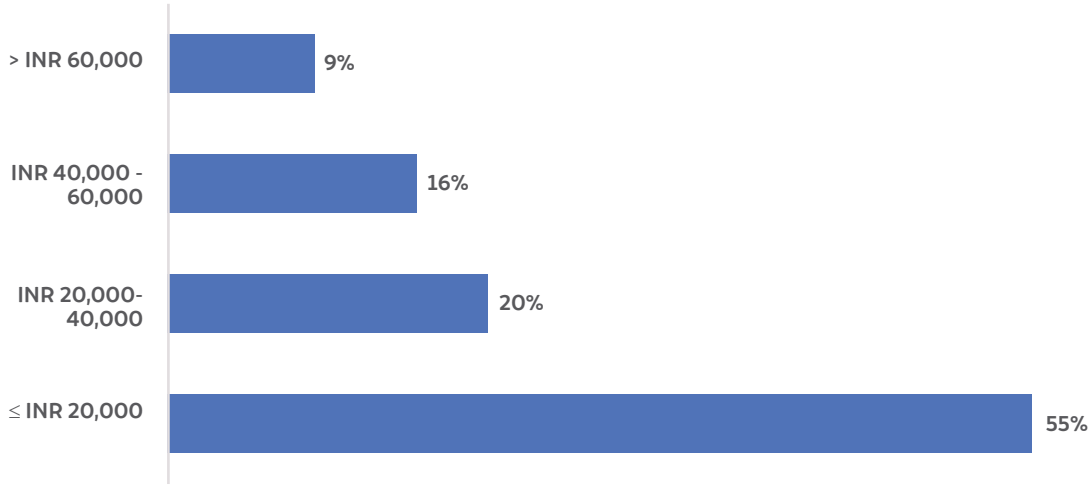


FIGURE 11:
Willingness to pay for a 1 kW rooftop solar system

Source:
Authors' analysis

Are consumers deferring their investments due to falling panel prices?

There has been a steep decline in the price of solar modules in the last decade and a subsequent decline in solar tariffs. That consumers are deferring their investments in RTS because of this falling price has been considered a major market challenge. However, consumers in the BYPL licence area do not seem to be affected by this issue, mostly owing to a lack of awareness of the falling prices. Only 26 per cent of consumers were aware of the decreasing trend in system costs. Of those who were aware, only 27 per cent thought of it as a reason to defer their investments. But it is possible that as more consumers become aware of the RTS market, the situation might change.

Are consumers worried about the 25-year roof lock-in period?

A typical rooftop system has at least a 25-year lifetime, and it is not easy to relocate a system without depreciating its value. Also, it is difficult to use roof spaces for other purposes once an RTS system is installed. Nowadays, even though RTS systems are installed on elevated structures, roof usage is still limited. Thus, RTS effectively occupies the roof for the system's entire lifetime. Most respondents indicated that they frequently use their rooftops for a variety of reasons.

About 73 per cent of consumers considered a 25-year roof lock-in as acceptable, as shown in Figure 12. Only 11 per cent would not accept a roof lock-in even for short durations. Thus, it is possible that most consumers will not be worried about the long roof lock-in time once they are convinced of the benefits of installing an RTS system.

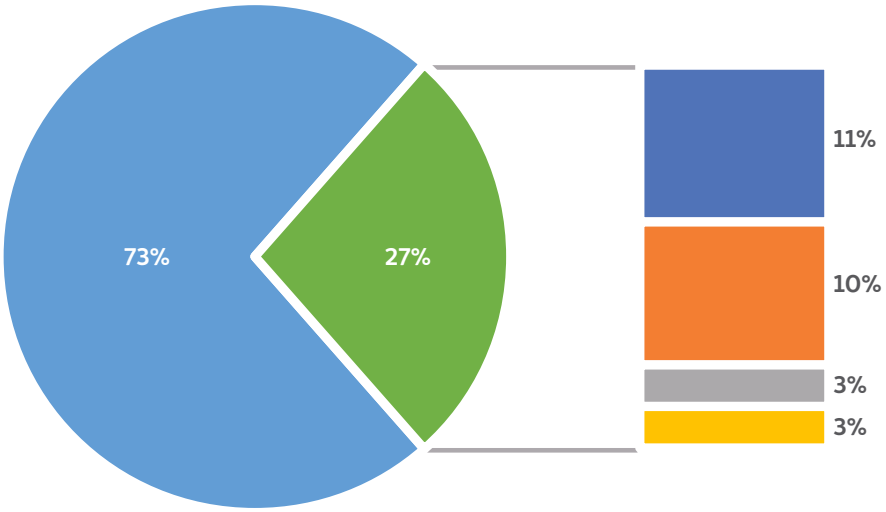


FIGURE 12:
Roof lock-in acceptability

Source:
Authors' analysis

The findings on residential market readiness reveal a lack of sufficient knowledge about the technology among residential consumers. It would be useful to measure consumers' willingness to pay for the technology and the perceived value of RTS once there is more awareness of the technology, and the majority of consumers know about the benefits and costs associated with it. Until then, the residential market will not mature.

5. What is on the consumer's mind?

Drivers and barriers as perceived by consumers

Key findings

- The two major drivers for installing rooftop solar systems are the potential reduction in expenditure on electricity and environmental consciousness.
- The major barriers faced by consumers in the installation of rooftop solar systems are lack of awareness of the technology and its performance and processes, lack of information about trusted solar vendors, high capital expenditure, and lack of easy financing.

The sluggish growth of rooftop solar systems (RTS) in the residential sector is generally attributed to several market challenges such as the high upfront cost, a lack of awareness, and the long roof lock-in period. However, what the consumer perceives as a challenge might vary from region to region based on demographic characteristics. The survey tried to identify the major drivers and barriers for adopting RTS as perceived by consumers in the BYPL area. This section summarises those key findings.

5.1. Drivers for rooftop solar adoption

Savings on electricity bills and environmental consciousness are the major drivers

Savings on electricity bills is almost always advertised by solar developers as a major benefit of installing a grid-connected RTS. The generation of clean energy is most likely to come second in terms of customer appeal in this market. The findings from this survey do not contradict this, as 78 per cent of respondents ranked monthly savings on their electricity bill as the top reason for installing a system, and environmental benefit was ranked as the second major driver. Figure 13 shows some of the drivers and their ranking in terms of importance for respondents.

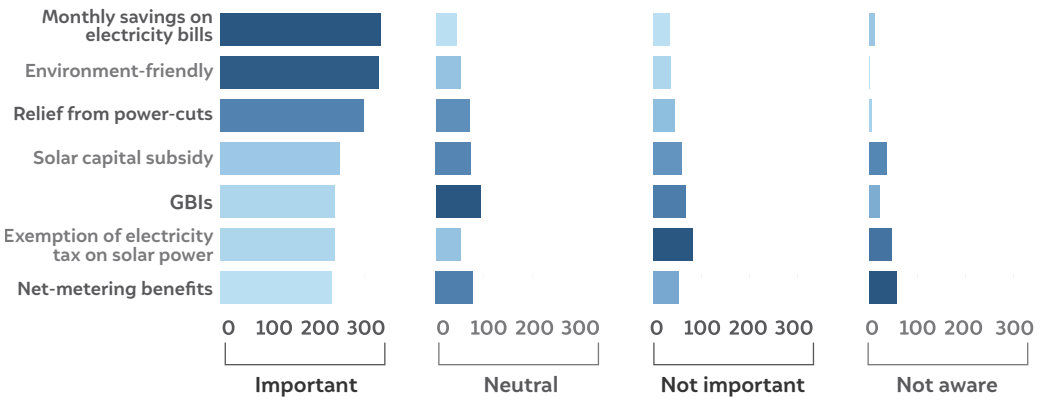


FIGURE 13:
Major drivers for rooftop solar

Source:
Authors' analysis

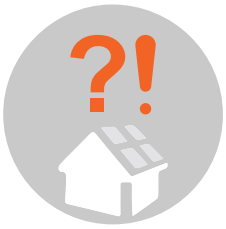
Will a rooftop solar system work during power cuts?

There is a general perception that RTS can generate electricity during power failures and can act as a backup system; however, this is not true for all systems. The inverter, which converts the current from DC to AC, constantly matches the voltage of the electricity generated and hence needs a reference voltage at all times. Therefore, unless the inverter connected to the system is a hybrid one which manages power from two or more sources such as a grid, a battery, or a diesel generator, the system will have no reference voltage during a power outage and therefore will shut down to prevent the malfunctioning of the connected equipment.[18]

As seen from Figure 12, the third major driver for RTS installation is relief from powercuts, indicating a lack of clarity regarding this feature of grid-connected RTS systems. This further indicates that there might be a market for grid-connected hybrid systems with backup or storage.

Lack of awareness as a hindrance to installing RTSs

The lowest-ranked drivers (from least to most important) were net-metering benefits, generation-based incentives (GBIs), electricity tax exemptions, and capital subsidies. Ironically, each of these parameters leads to savings on electricity bills, which was the most important priority for most of the respondents. These are also either a policy-related aspect or an existing incentive scheme in Delhi. The results further reiterate the need to educate consumers about the technology and the associated policies and incentives.



Two out of the top five barriers to adopting rooftop solar identified by the respondents were issues related to insufficient awareness

5.2 Barriers to rooftop solar adoption

Awareness is key

Lack of awareness again emerges as the key issue, as two out of the top five barriers identified by the respondents were issues related to insufficient awareness. Other barriers identified by respondents include existing challenges in the market such as difficulty in choosing a trustworthy developer, poor performance of the systems, and high upfront costs. Figure 14 lists the barriers according to their overall ranking. This final ranking is calculated by taking a weighted average of the ranking that respondents gave to each of the barriers. Figure 15 depicts the distribution of the respondents' ranking in terms of importance.

18 "Does rooftop solar PV generate power during a power failure?" Solar Mango. Available at http://www.solarmango.com/faq/9. Accessed on 6 April 2019

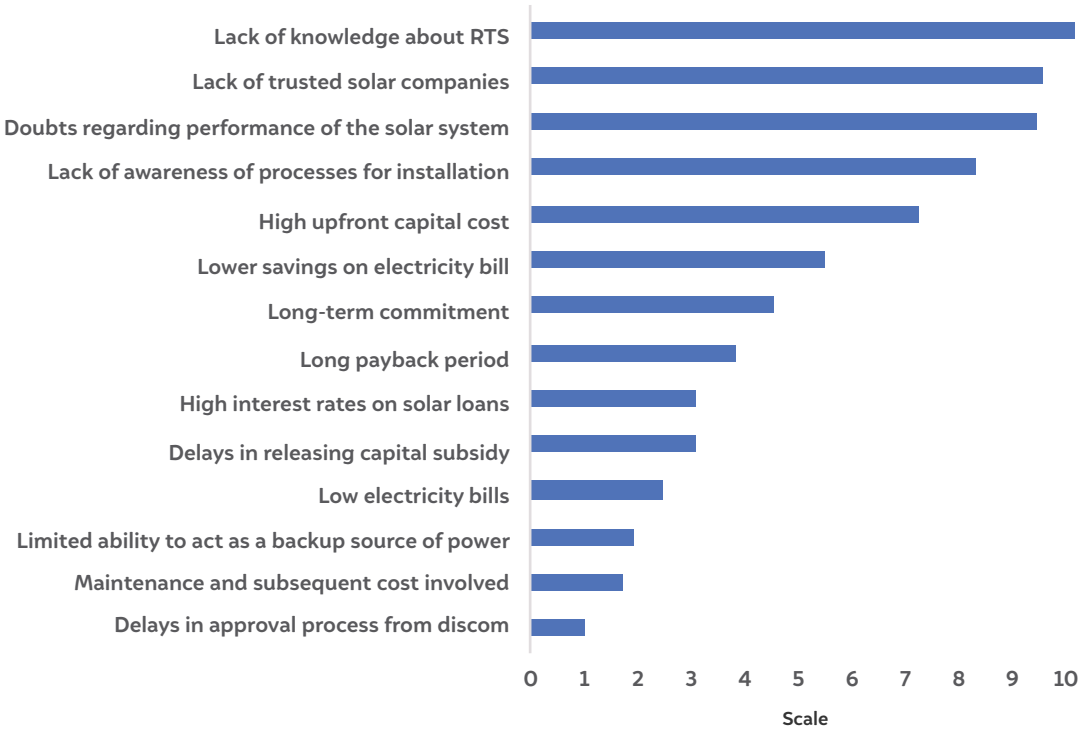


FIGURE 14:
Barriers as ranked by respondents

Source:
Authors' analysis

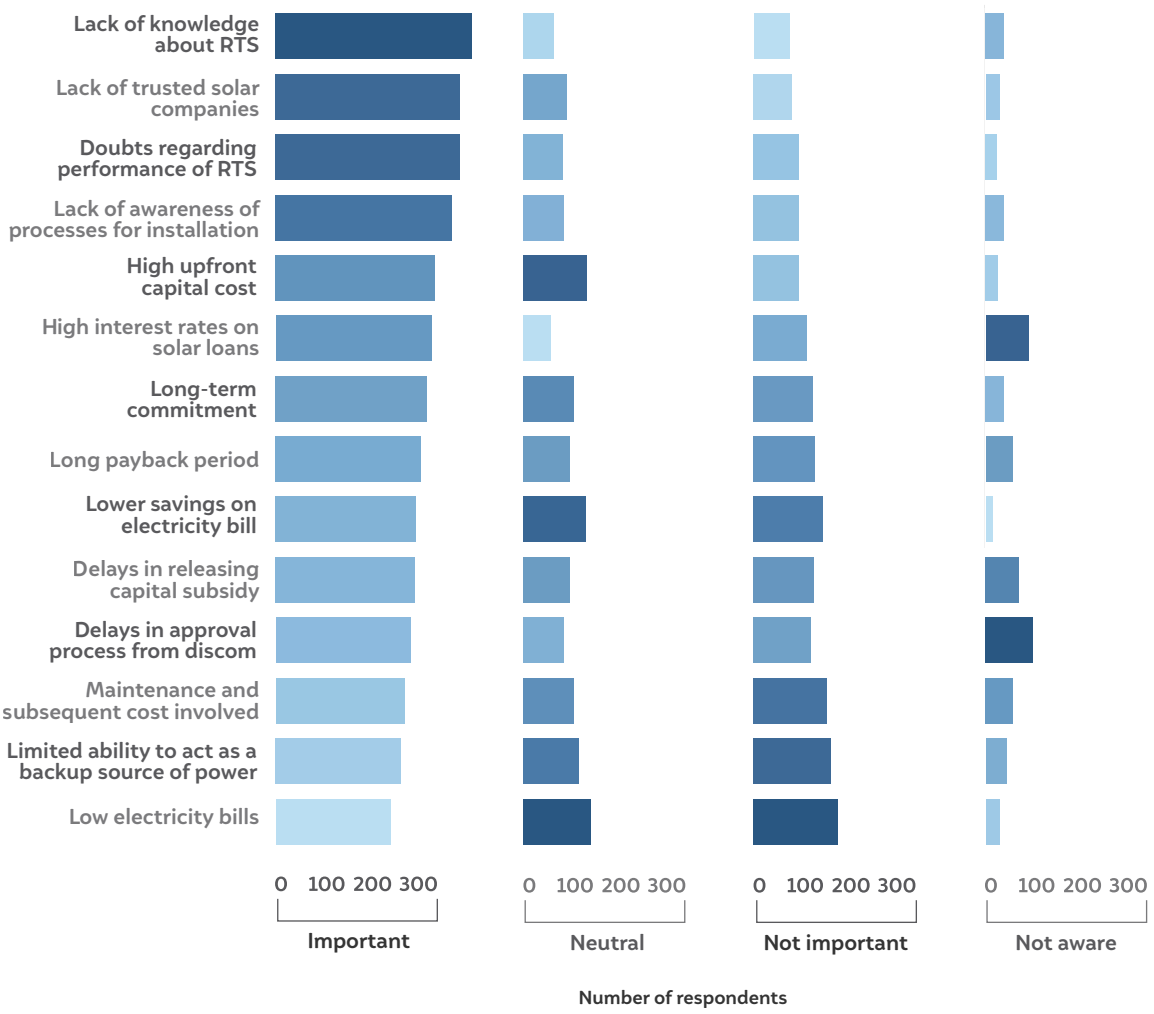


FIGURE 15:
Barriers to adoption of rooftop solar as ranked by respondents in terms of importance

Source:
Authors' analysis

Number of respondents

Lowest Highest

Choosing a solar vendor

1. Options for those availing subsidy

In order to avail of the central government subsidy to install an RTS system, a residential consumer in New Delhi has to make the purchase from a vendor empaneled by Indraprastha Power Generation Company Limited (IPGCL), the agency nominated by the Government of NCT of Delhi (GNCTD). By filling out a simple form, the consumer can express their interest on the Delhi Solar Rooftop Portal (maintained by the Energy Efficiency and Renewable Energy Management Centre [EEREM] of the GNCTD, the state nodal agency in Delhi). Once the form is filled out, the consumer can choose three to five vendors from an existing list of vendors based on their quoted price and category (which will vary according to the business model and system size). The portal then forwards the contact information of the interested consumer to the selected vendors, who in turn contact the consumer. Each vendor will individually conduct a site assessment and put forward a proposal to the consumer, and the consumer is then free to choose from among them. Because of the lack of awareness among consumers, however, making this final choice—while ensuring that they receive the best quality product and service—is a major challenge.

2. Options for those not availing capital subsidy

If a consumer wishes to install an RTS system without availing a capital subsidy, they can reach out to the multitude of solar vendors who operate in the market. However, the prices offered by the vendors will vary significantly according to the quality of the components and installation. There are no uniform standards for quality of product and after-sale services that is enforced for the residential market and consumers will be unable to identify trustworthy developers on their own. There have been increasing instances of systems installed in the residential sector that perform poorly after a few years.

Source: Delhi Solar Rooftop Portal

The main barriers to installing RTS systems have been found to be consistent across the different consumer categories

The main barriers to installing RTS systems have been found to be consistent across the different consumer categories. Figure 16 shows the ranking of barriers by consumers who use more than 400 units of electricity a month. The top five barriers identified by this categoryare the same as the top five barriers identified by the respondents overall. This points to the fact that the residential RTS market is plagued by non-economic barriers (rather than economic feasibility) that are slowing down growth. Interventions that can address these challenges are necessary in order to increase the adoption of RTS in the residential sector.

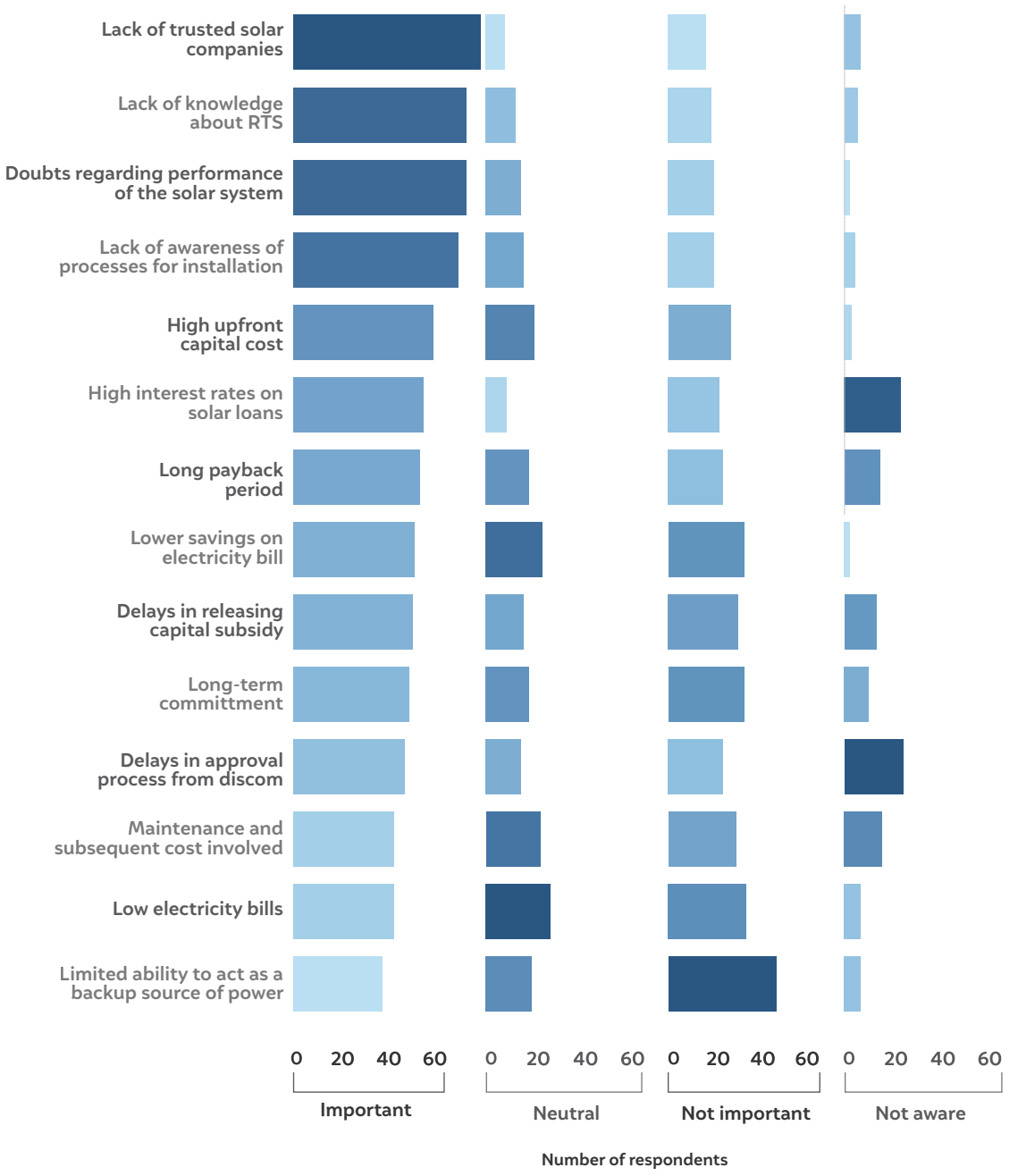


FIGURE 16:
Barriers for adoption among high-paying consumers

Source:
Authors' analysis

Number of respondents

Lowest Highest

Access to an exclusive roof area is a major challenge for urban residential consumers.

Image: Josh Sorenson/Pexels

6. Room for innovation

Consumer acceptance of innovative business models

Key findings

- Consumers are open to innovative business approaches such as shared systems, on-bill financing, third-party ownership, and subscription payment models.
- Developing models around such approaches can help address current market challenges and increase the adoption of rooftop solar in the residential sector.

RTS has achieved grid parity for residential consumers in the higher energy-consumption slabs in Delhi.[19] Despite this, there has been minimal adoption of RTS even among this consumer segment, due to the market challenges faced by consumers as well as by the other stakeholders operating in the residential sector. Table 1 summarises the challenges faced by the different stakeholders in Delhi.

Consumers	Discoms	Developers	Financiers
• Lack of awareness • High capital cost • Lack of access to finance • Issues with roof ownership and access • Quality of installations- lack of reliable developers • Need for regular operation and maintenance	• Loss of revenue from RTS system owners (primarily high-paying consumer categories) • Higher variability at distribution transformer level • Grid integration, load management, unscheduled request for commissioned capacity for peak load	• Lack of access to finance • Fragmented distribution of installations • Ownership of rooftop • Availability of shadow-free areas • Cap on transformer capacity • Creditworthiness of consumers	• Creditworthiness of consumers • Small size of rooftop projects • Lack of legal enforceability • Transaction cost • Access to consumers

TABLE 1:
Market challenges for stakeholders in Delhi

Source:
Neeraj Kuldeep et al. (2019)[20]

19 Authors' analysis.

20 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs, New Delhi: CEEW.

The existing business model in the residential sector—the capital expenditure (CAPEX) model —does not address these challenges. The Renewable Energy Service Company (RESCO) model, which is being implemented in the commercial and industrial sectors, is not currently being offered to residential consumers because of the unique challenges that exist in the residential sector. These challenges include high payment default risk, high transactional costs, small and distributed systems, and difficulty in getting regular roof access from a residential consumer. Hence, there is a need to adopt new business models with innovative features in order to address market challenges.

Some of the innovative features that can address the challenges in the residential sector are shared/community systems, on-bill financing, third-party owned systems and solar subscription models. CEEW, in partnership with BYPL, has conducted a detailed study of the feasibility of these business models for BYPL consumers.[21] The survey examined the consumers' acceptance of such innovative measures and their willingness to adopt them. This section captures these findings.

Some of the innovative features that can address the challenges in the residential sector are shared/ community systems, on-bill financing, third-party owned systems and solar subscription models

6.1. Shared systems

Yes to community solar

Shared systems, referred to as community solar systems, are a good fit for urban residential consumers. Ever-expanding Indian cities are also witnessing an increasing rate of vertical development. At the time of the 2011 Census, around half of Delhi's population lived in apartment buildings, and this will have grown significantly in the last eight years.[22] This means that about half of the city's residents do not have exclusive access to rooftops, thus excluding them from the RTS market. Hence, arrangements where a group of consumers share the rights to a solar system that is installed either in their community or elsewhere would be an ideal way to extend the technology to these segments.

Of the people surveyed, 76 per cent were willing to own a share of a larger solar system and avail solar electricity (Figure 17). Around 73 per cent of these respondents preferred that the system be located within their community while around 17 per cent preferred that the system be located elsewhere but at an accessible site (Figure 18). The remaining respondentsdid not feel it was important where the system was located. Around 72 per cent of the total respondents said they were satisfied with occasionally or never visiting the site of the solar system, and the remaining 28 per cent wished to visit the shared systems frequently (Figure 19). It can thus be inferred that a community solar model, with the shared system installed within the community, would be welcomed by a majority of consumers.

21 Ibid.

22 Government of NCT of Delhi, Housing Conditions in Delhi: Based on NSS 69th Round Survey (New Delhi: Directorate of Economics and Statistics, 2012).

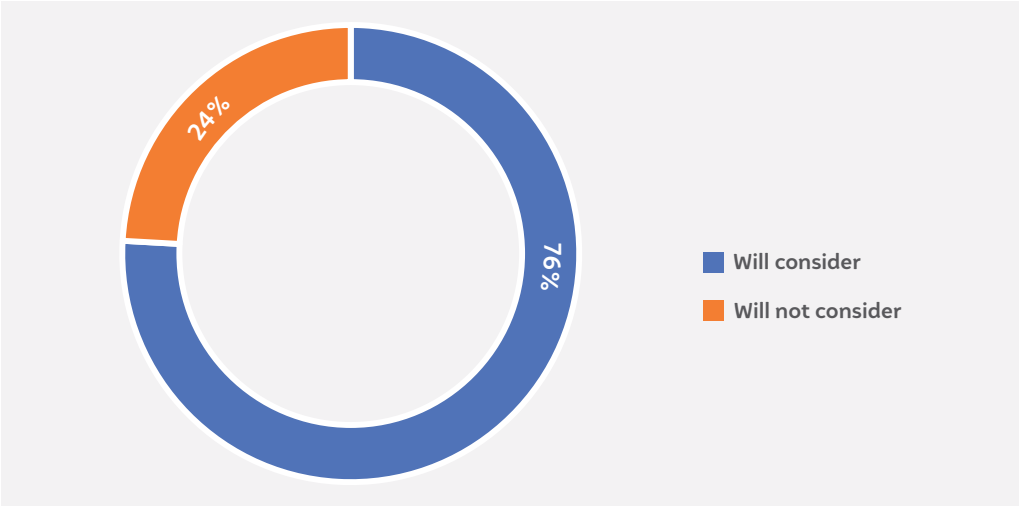


FIGURE 17:
Consumers who will consider owning a shared system

Source:
Authors' analysis

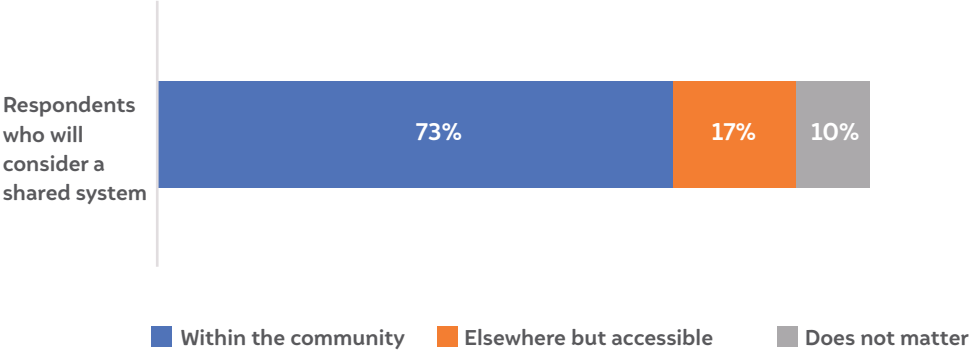


FIGURE 18:
Consumers' preferred location of shared systems

Source:
Authors' analysis

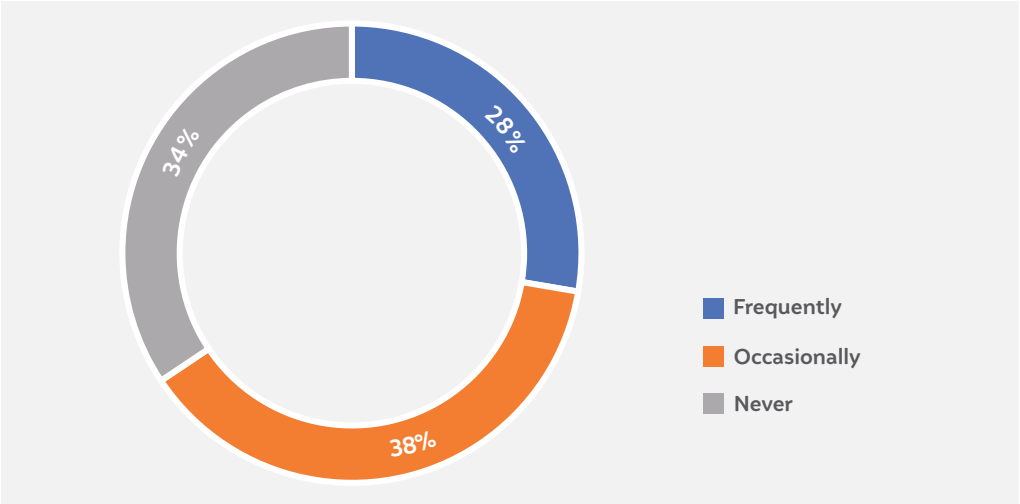


FIGURE 19:
Preference for frequency of visits to shared system

Source:
Authors' analysis

6.2 Innovation in financing

Bill financing, lower rates

A typical household would have an RTS system of 4 to 5 kW. The current market price for installing such a system would be about INR 1.5 to 3.5 lakhs, which is a huge investment for many households and indicates a need for innovation in financing.

One possibility would be to finance it through the consumer's electricity bill. The capital required for the system could be extended to the consumer as a loan by a financier or by the developer, and the consumer could then pay back that amountin equated monthly instalments (EMIs) collected as part of the electricity bill. The discom would then pass on the EMI to the financier. The involvement of a discom in payment collection would reduce the risk and the associated transaction costs. Hence, loans could be extended at better terms. Figure 20 illustrates the on-bill financing model.

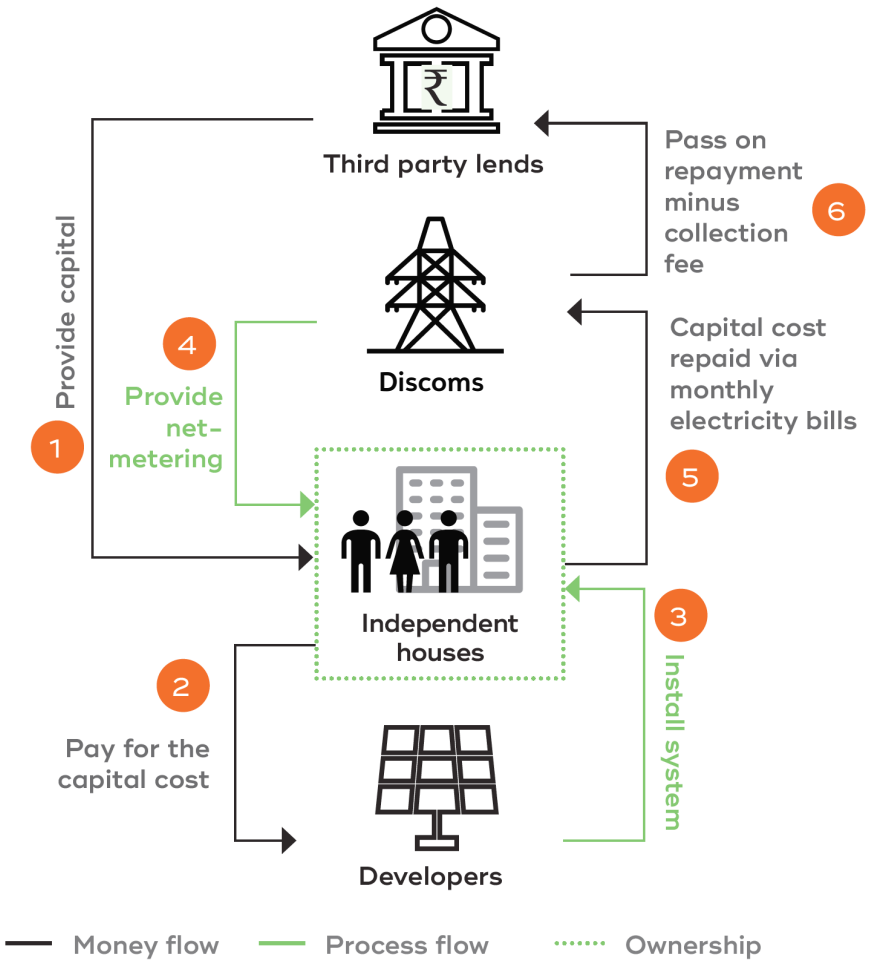


FIGURE 20: On-bill financing model

Source: *Neeraj Kuldeep et al. (2019)*[23]

The survey investigated the consumers' willingness to finance an RTS system on their electricity bill. A total of 83 per cent of respondents said they would consider installing systems with an on-bill financing mechanism (Figure 21).

23 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) *Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs*, New Delhi: CEEW

On further probing of their financing preferences, out of the consumers surveyed, 66 per cent said that, rather than utilising their own capital, they would prefer to obtain the partial or full amount as a loan with direct or on-bill repayments (Figure 22). However, the expected interest rates were not market reflective for most of the respondents, with more than 77 per cent wishing for rates lower than 8 per cent.

Given the high proportion of consumers expressing interest in an on-bill financing model for installing RTS systems, discoms should consider developing such a programme for their licence area. One of the most important criteria for the uptake of an on-bill programme will be the interest rate at which the financing is offered. The discom could therefore partner with a financial institution to obtain an aggregated loan which they could then disburse, reducing the risks and transaction costs for the bank and in return for which the discom would be able to obtain the loan at a lower interest rate. The discom would first have to get approval from the regulatory commission to undertake such activities. However, given that this kind of undertaking would place no financial burden on the discom, the commission should have no reservations.

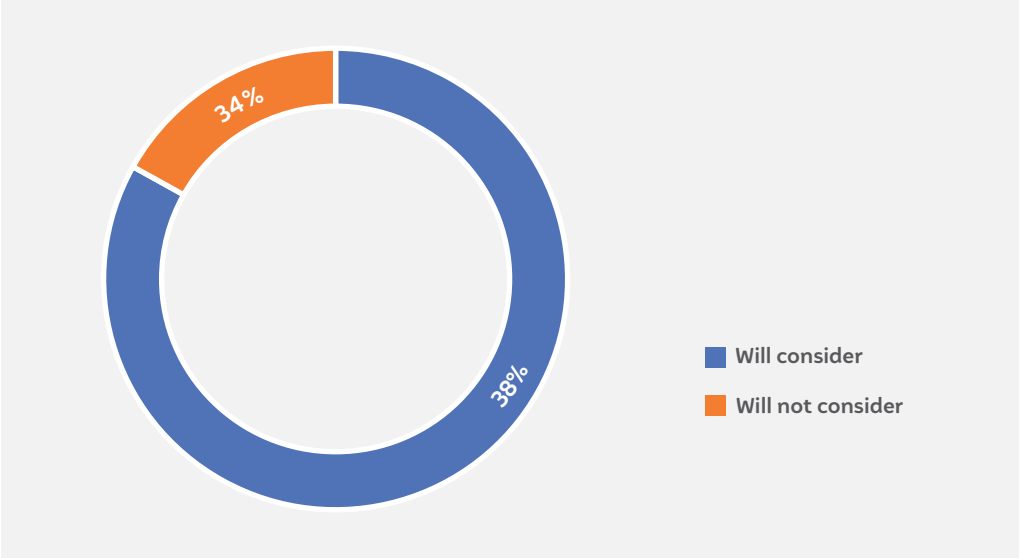


FIGURE 21:
Consumers who will consider installing RTS through an on-bill financing mechanism

Source:
Authors' analysis

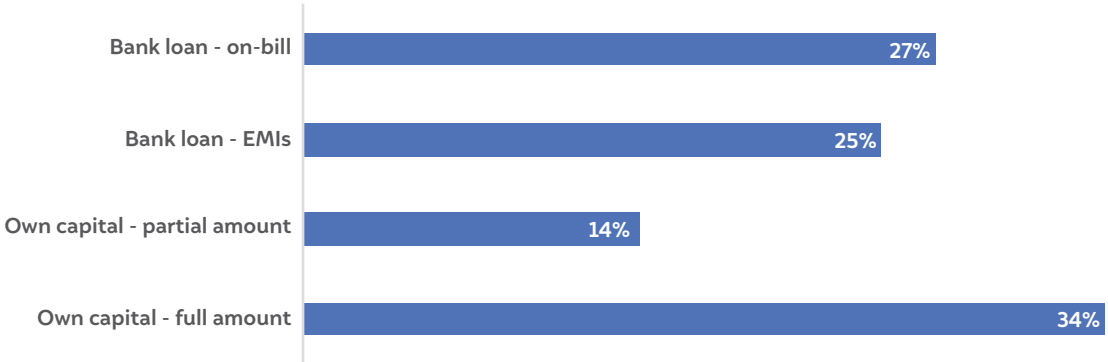


FIGURE 22:
Consumers' financing preferences

Source:
Authors' analysis

6.3 Third-party ownership

Third-party owned RTS systems, or the RESCO model, are quite prevalent in the commercial and industrial sectors. However, developers are usually reluctant to offer this model in the residential sector citing reasons such as the poor creditworthiness of residential consumers, difficulties in accessing the system for O&M, and the higher transaction costs involved in billing, payment collection, etc. However, these challenges can be addressed by bringing a few additional features into the business model such as an on-bill payment mechanism.

When probing consumers about their perspective on third-party ownership of the systems, 84 per cent mentioned that they would allow a third party to install a system on their rooftop (Figure 23). Despite the issue of trustworthiness of solar developers, 66 per cent preferred the third-party owner to be a solar developer, while about 32 per cent said they would choose the discom over the developer. Surprisingly, less than 2 per cent preferred that their resident welfare association (RWA) own the system (Figure 24). However, households expressed some reluctance to giving a third party regular access to the roof for maintenance: 10 per cent were not willing to give access, another 32 per cent were not sure about giving access, and 57 per cent responded that they were willing to give regular access (Figure 25). However, around 55 per cent of respondents said they would seek roof rent if they were not otherwise benefitting from the system (Figure 26).

Thus, residential consumers were open to hosting third-party owned systems on their rooftops, and more than half of them were willing to provide regular access for maintenance. With additional mechanisms such as on-bill payment collection and the use of electricity bills as a measure for credit checks, it should be possible to extend third-party owned RTS models to the residential sector.

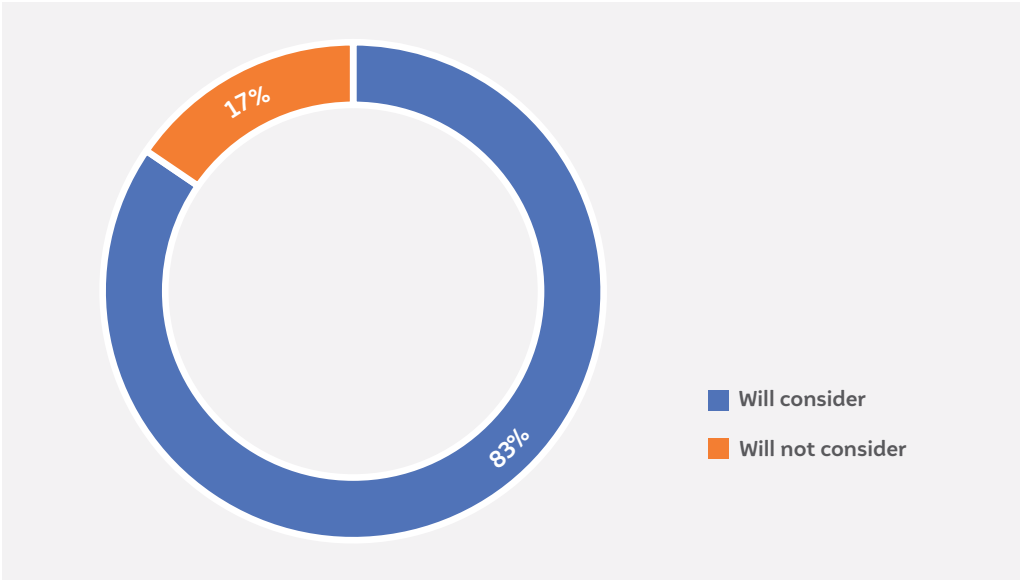


FIGURE 23:
Consumers who will consider third-party owned installations on their roofs free of cost

Source:
Authors' analysis

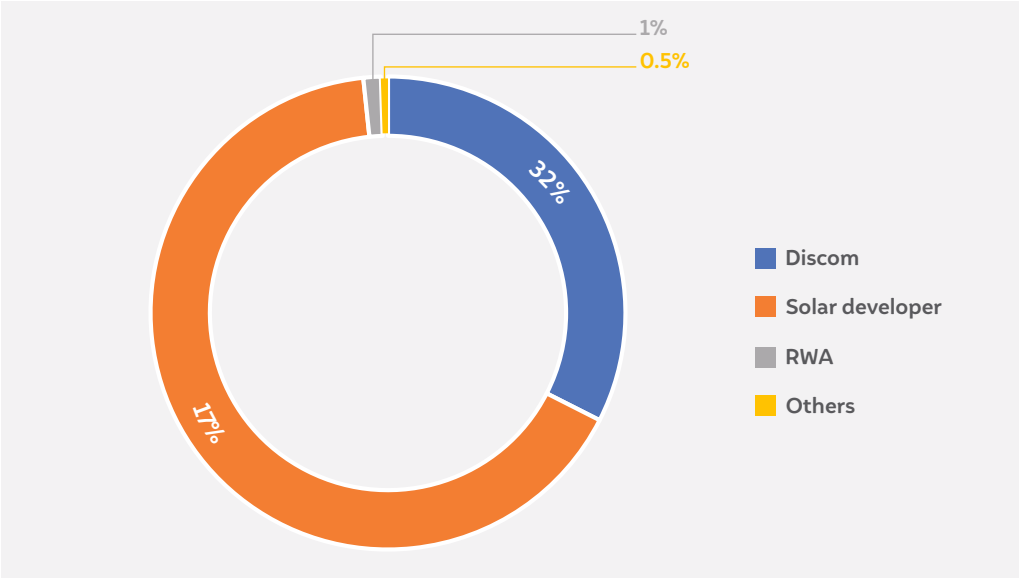


FIGURE 24:
Ownership preferences for third-party owned systems

Source:
Authors' analysis

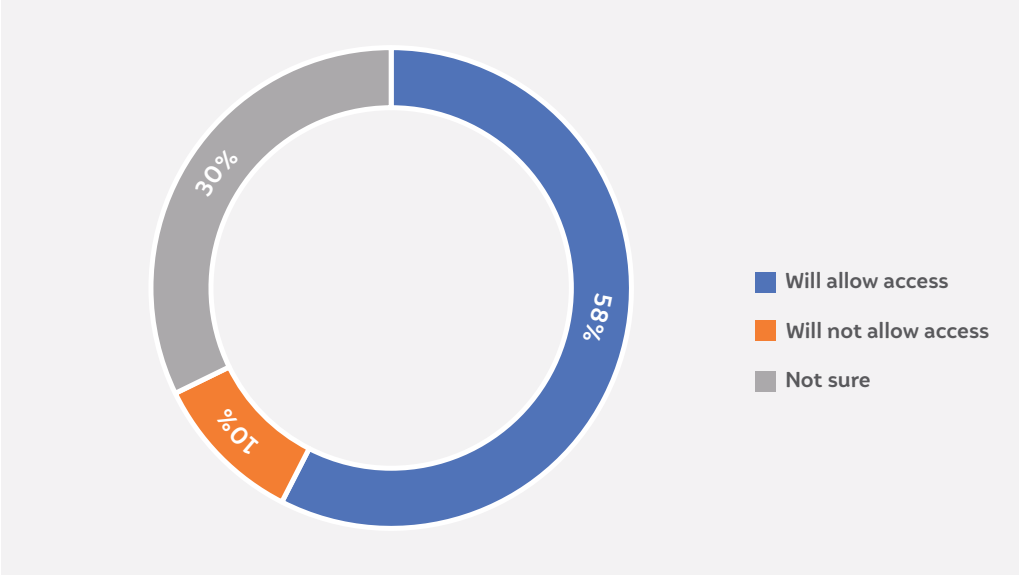


FIGURE 25:
Consumers on allowing regular access to a third-party

Source:
Authors' analysis

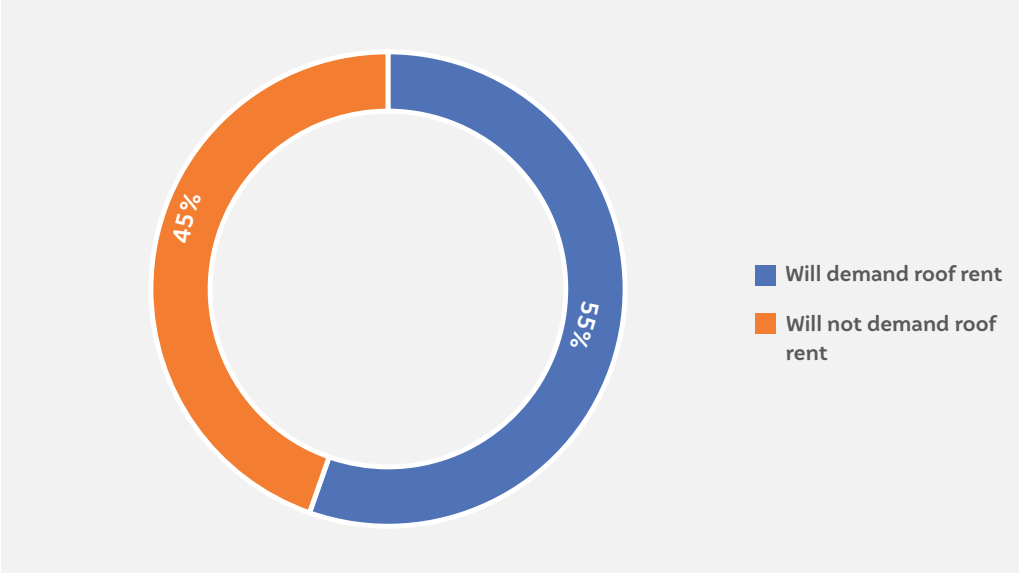
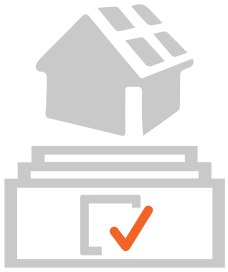


FIGURE 26:
Consumers on seeking roof rent

Source:
Authors' analysis

6.4 Solar subscription

Solar subscription is one way to finance a residential RTS system, whereby consumers can subscribe for solar electricity and pay for the electricity generated every month. The subscription model can be employed for systems located within the consumer's property, for shared systems, as well as for systems located elsewhere. This is very advantageous as it eliminates the need for upfront capital from consumers. Off-site systems with subscription models can also make the technology accessible to consumers who do not have suitable roof space but wish to gain the benefits of RTS energy.



Consumers, irrespective of the availability of a suitable roof area on their property, do not have any reservations in subscribing for solar electricity

However, the main concern with such a model is timely billing and payment collection. Developers have expressed concerns regarding the creditworthiness of the consumer and hence are reluctant to offer a RESCO-based model where they must earn the revenue by collecting tariffs from consumers for the lifetime of the system. In this context, the discom can take up billing and collection of payments, which will increase payment security and reduce the risk for developers.

Open to solar subscription

Subscribing for solar electricity generated from a system located elsewhere is a new concept for the Indian consumer. The BYPL consumers were asked about their preferences with regard to such a subscription model. The findings suggest that consumers, irrespective of the availability of a suitable roof area on their property, do not have any reservations in subscribing for solar electricity. Around 83 per cent of consumers said they will consider availing solar electricity from BYPL if they do not have suitable roof access (Figure 27). Approximately the same proportion said that they would avail solar electricity if there was a suitable area within their property (Figure 28).

Figure 29 also shows the expectations for electricity bill savings by consumers. Around 36 per cent of the respondents expect more than 50 per cent savings on their monthly electricity bill with a solar subscription. Of these, only 22 per cent of the respondents who have a monthly electricity consumption of more than 400 units expect more than 50 per cent savings on their electricity bill, while around 40 per cent of the respondents with a monthly consumption of less than 400 units expect the same (Figure 30). In reality, however, as per our analysis, consumers who are in the higher energy slabs (greater than 800 units a month) can save 20 to 25 per cent with a solar subscription, while consumers in the lower consumption categories will not find it feasible to subscribe to solar energy at the current market rates.[24,25]

Subscription-based RTS programmes could be an effective way to address the high upfront cost and the availability of suitable roof areas, and could thus provide consumers with the benefits of RTS systems installed on larger areas such as warehouses or public buildings. To meet the savings expectationsof most consumers, however, there need to be additional mechanisms such as differential tariff rates.

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24 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) *Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs*, New Delhi: CEEW.

25 This is assuming that 50 per cent of regular consumption is replaced by solar subscription. Further assumptions are listed in Kuldeep et al., "Scaling Rooftop Solar" (see previous footnote).

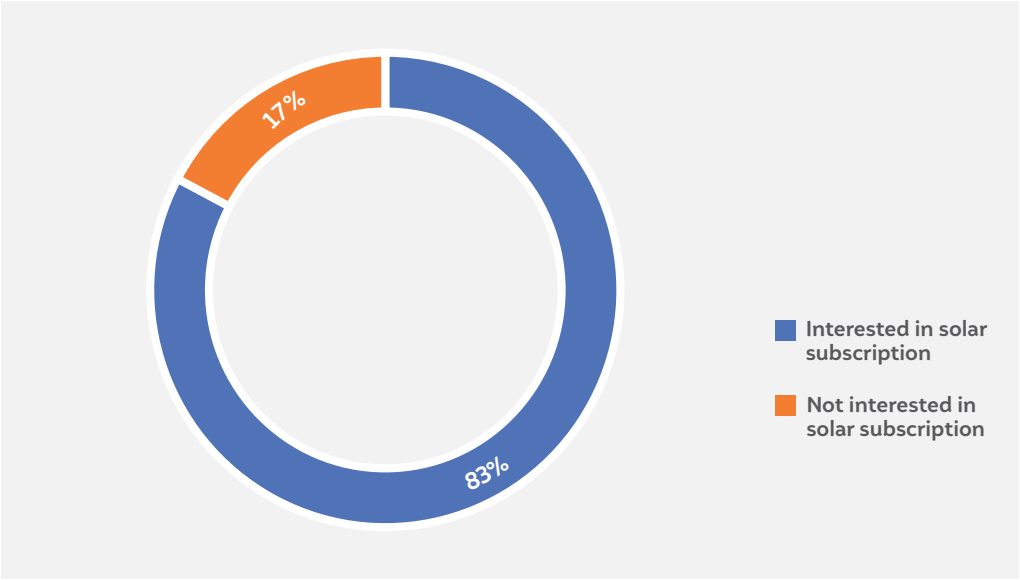

FIGURE 27:
Consumers' interest in solar subscription if they do not have access to their own suitable roof area

Source:
Authors' analysis

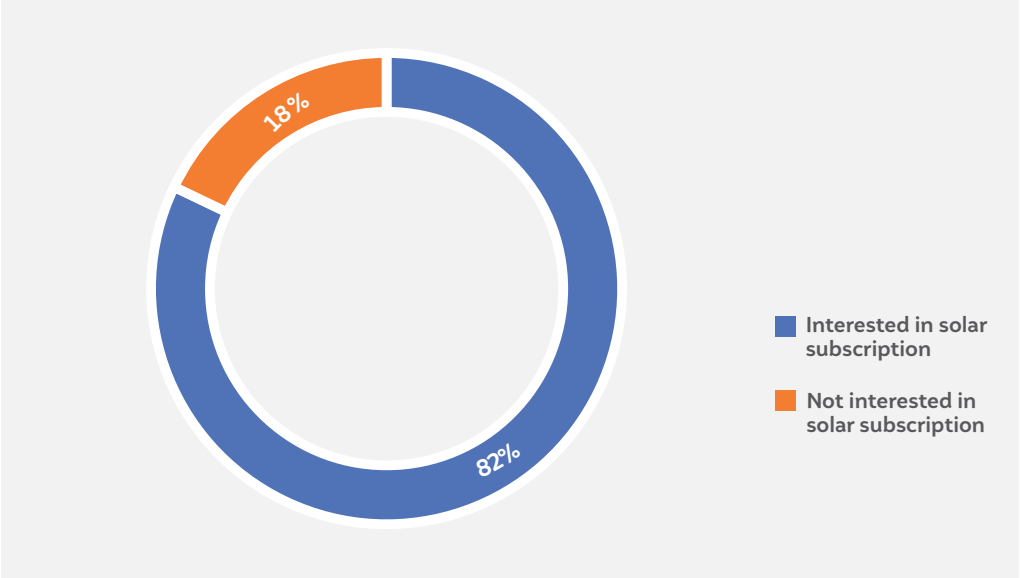

FIGURE 28:
Consumers' interest in solar subscription even if they have access to a suitable roof area

Source:
Authors' analysis

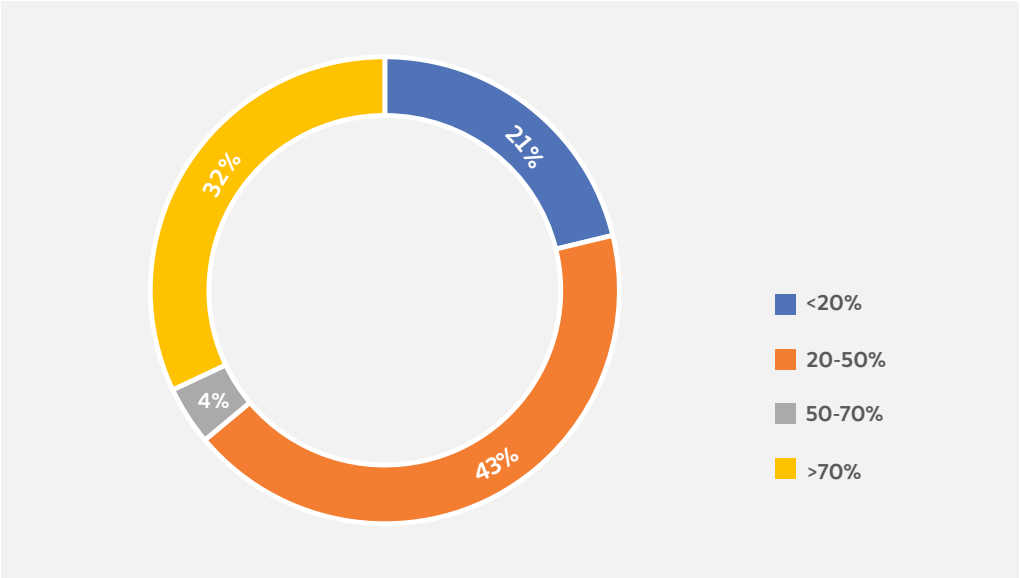

FIGURE 29:
Consumers' expectations of a reduction in electricity bill with solar subscription

Source:
Authors' analysis

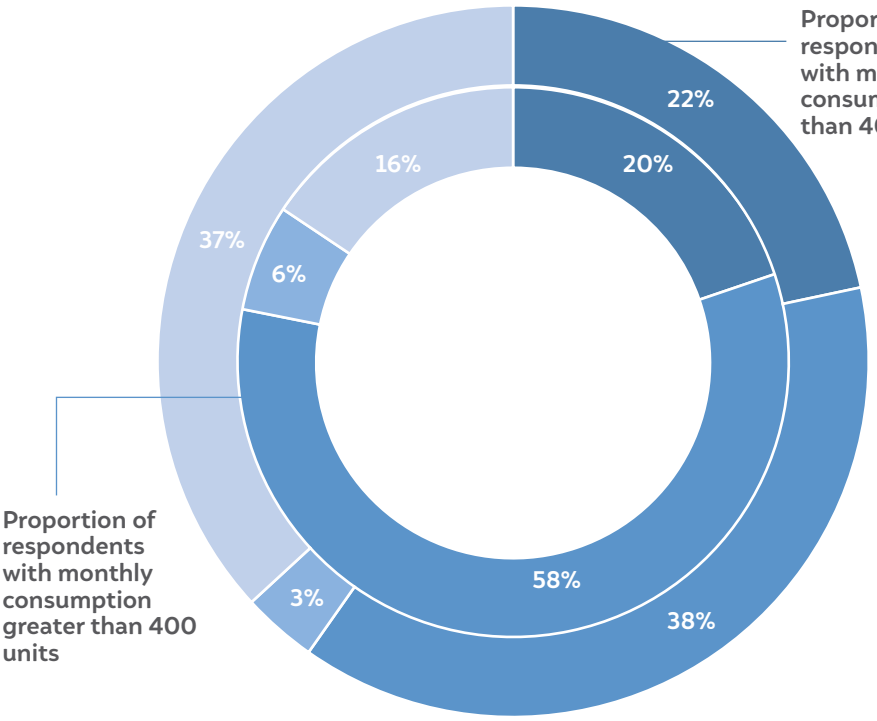

FIGURE 30: Consumers' expectations for reduction in electricity bill with solar subscription: Proportion of subsidised and non-subsidised consumers

Source:
Authors' analysis

Differential solar tariff mechanism[26]

CEEW has proposed an innovative solar subscription design with a differential tariff mechanism to make solar affordable for residential consumers. Currently, a solar tariff above INR 2/kWh (current solar tariffs are INR 5–6/kWh for residential consumers) will not be economically feasible for around 84 per cent of the consumers in BYPL. The differential tariff mechanism is an affordable slab-based solar subscription for consumers in different consumption slabs. Under a single solar subscription programme, there would be consumers from multiple consumption slabs. By designing slab-based subscription rates, all the consumers across the consumption slabs would find it economically feasible to subscribe to solar power.

26 Neeraj Kuldeep, Selna Saji, and Kanika Chawla (2019) *Scaling Rooftop Solar: Powering India's Renewable Energy Transition with Households and DISCOMs*, New Delhi: CEEW.

7. Conclusion and recommendations

In recent years, the cost of setting up RTS photovoltaic (PV) systems has decreased significantly, and it is anticipated that this trend will continue. Improving cost competitiveness as compared to grid electricity is expected to result in steady yearly increases in the adoption of RTS. Commercial and industrial categories have witnessed accelerated adoption with improved cost competitiveness; however, installations in the residential sector account for a far smaller share in terms of capacity compared to the other two sectors. Unlike in commercial and industrial sectors where the key driving factors of solar are cost savings (compared to grid electricity) and the provision of the RESCO model, decision-making in the residential category is a complex function which requires careful consideration of all aspects.

As part of this report, we have tried to understand consumers' decision-making processes in the adoption of RTS. It was found that most of the respondents were aware of RTS PV; however, they lacked an in-depth understanding of its multiple benefits, processes, subsidies, and other aspects. Those who were considering the installation of an RTS system reached out to solar companies, discoms, their social circle, the internet, etc., in order to get answers to their questions, as there is a lack of any single reliable source of information on this topic. Consumers rely on information and opinions from their social circles to make decisions regarding the installation of RTS systems. It was also found that the roof lock-in period of 25 years, which was thought to be a key deterrent to the adoption of RTS systems in the residential category, was not a significant barrier.

BYPL engaging with residents on rooftop solar

Images: BYPL

Given the high upfront cost of RTS systems, financing options are also an important consideration in decision-making. Consumers sought cheaper interest rates and expressed their interest in more innovative mechanisms such as on-bill financing.

Based on the findings from the survey, the following considerations will support decision-making in the residential category and thus support the adoption of RTS.

The existing residents' welfare associations network can thus be tapped to create more social events where RTS technology can be demonstrated and promoted

- **Consumer awareness:** The analysis suggests a significant gap in consumer awareness about the technology and the various government schemes that have been launched to promote RTS. In the absence of such awareness, supportive policies such as capital subsidy, GBI schemes, and net-metering will fail to create demand for RTS in the residential category. Discoms, with their widespread on-ground presence, should take the initiative in building consumer awareness about these favourable policy schemes. Financial assistance under the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme could be utilised to create more localised consumer awareness campaigns. A customer care office in each division could be the nodal centre for the promotion of such campaigns on an ongoing basis.

- **Creating social influence:** It has been observed that members of households considering the installation of an RTS system consider their social circle—including those who have already installed rooftop systems—as the most trustworthy source of information. The existing residents' welfare associations (RWA) network can thus be tapped to create more social events where RTS technology can be demonstrated and promoted. Such gatherings could use actual demonstration kits or mobile solar vans to disseminate reliable and consistent information about the technology and the available schemes.

  In addition, referral programmes could be developed whereby a large number of solar influencers could build momentum for RTS in the residential category.

- **Affordable financing:** Residential consumers who are considering, or have considered, installing RTS systems are looking for alternative financing options to beat the high upfront capital requirement. Provisions such as on-bill financing from discoms would encourage such residential consumers. In the on-bill financing scheme, discoms or developers could provide upfront capital at cheaper interest rate (sourced from financial institutions) to consumers. The repayment from consumers would then be collected along with the electricity bill through fixed EMIs.

- **New business models:** Residential consumers from different socio-economic strata face different sets of challenges in the adoption of RTS. While households in high-rise buildings lack exclusive access to rooftops, high upfront costs and the lack of easy financing cause individual homeowners with exclusive roof access to defer the decision to install RTS. A large proportion of people also live in rented properties and thus do not control the decision to adopt RTS. Initiatives designed to overcome such challenges and create demand in the residential category include the innovative business models proposed by CEEW such as community solar, on-bill financing, and solar partners programmes.

Annexure A.

Discom-led rooftop solar business models for the residential sector

A. Utility-led community solar model:

Community solar is ideal for consumers who wish to benefit from solar power but do not have access to suitable roof spaces, such as households in high-rises and multistorey buildings. Through this model, a group of consumers could either own the solar PV system jointly or buy the solar electricity from community solar PV plants at a predetermined tariff. Individual consumers could subscribe to a share of the system through one of the two subscription options—upfront payment or subscription fee.

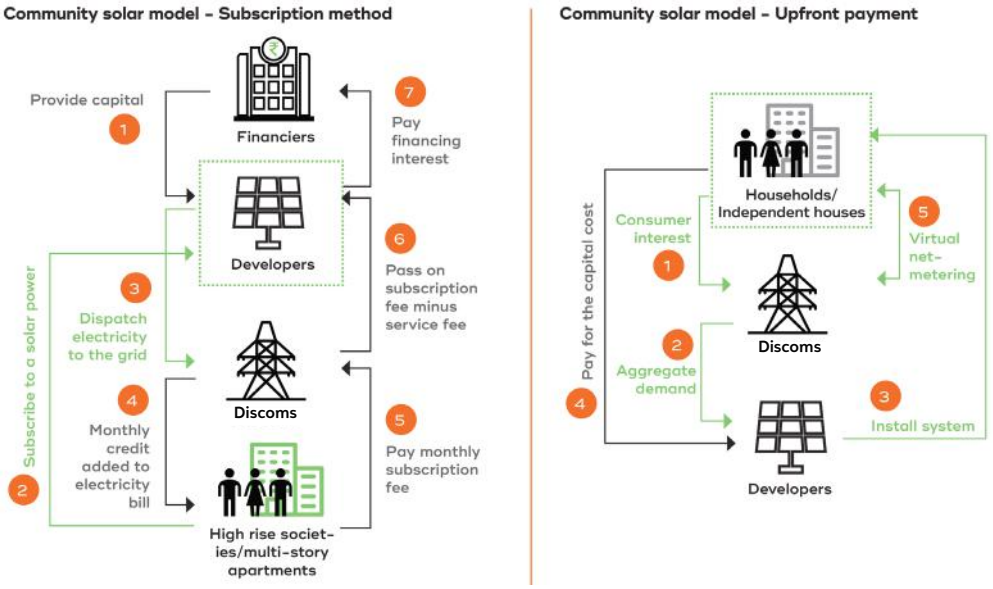

FIGURE 31: Community solar model

Source:
Neeraj Kuldeep et al. (2019)

B. Solar partners model

The solar partners model mimics the reverse auction model deployed for utility-scale large solar plants. Discoms play the role of a demand and supply aggregator. At the supply end, Discoms aggregate rooftop owners in their licence area, tender the capacity through reverse auction, and sign power purchase agreements (PPAs) with developers who would then install systems on the aggregated rooftop space. Solar electricity from these rooftop solar plants would be made available to residential consumers through an electricity exchange platform. This model allows tenants as well as flat owners (without roof access) to avail solar electricity by paying an annual subscription fee.

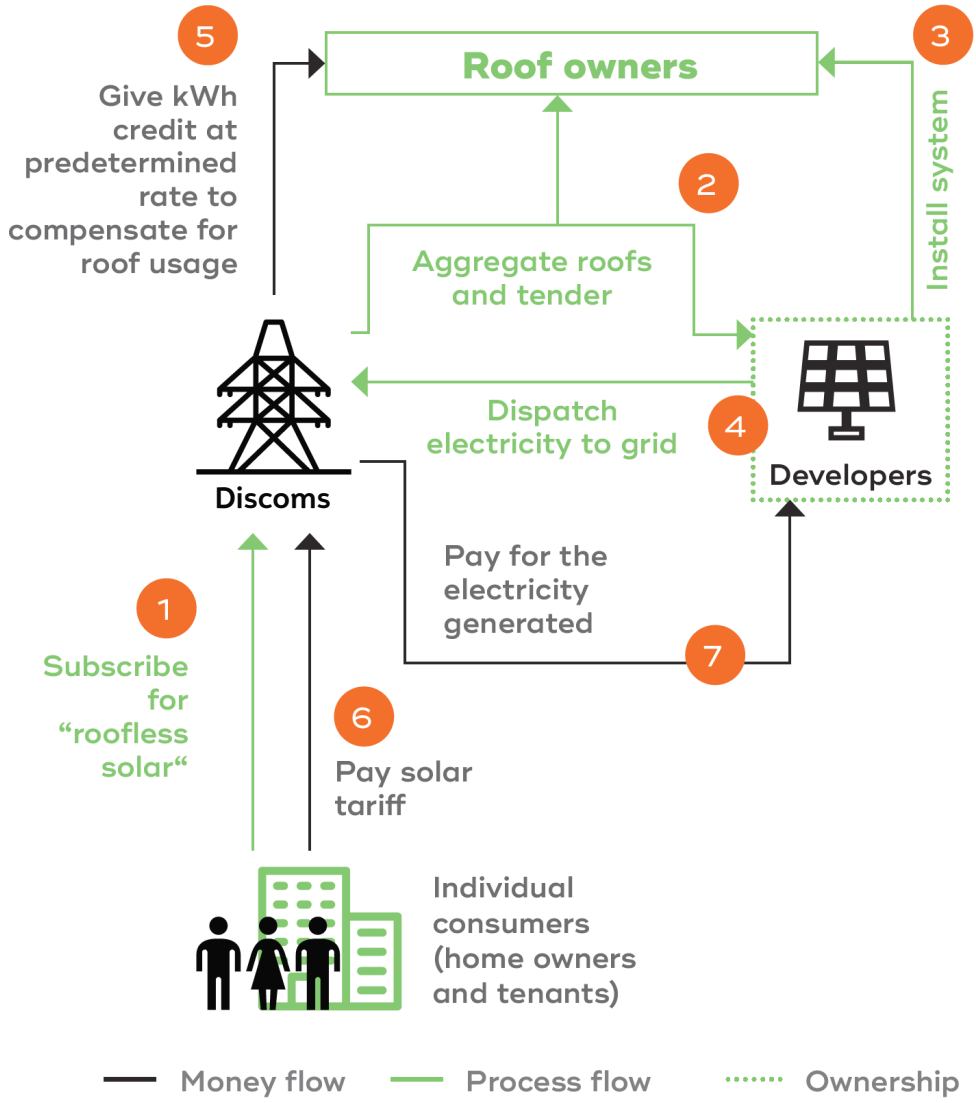

FIGURE 32:
Solar partners model schematic

Source:
Neeraj Kuldeep et al. (2019)

C. On-bill financing model:

The on-bill financing model allows individual consumers with roof ownership to install rooftop solar systems while not having to pay a huge upfront amount. This is made possible by offering the capital cost as a loan which the consumer repays through their monthly electricity bill. The average savings achieved through reduced grid-electricity consumption (or a proportion of those savings) would then be used to make the monthly loan repayment. On-bill repayment, with a threat of disconnection in case of non-payment, reduces the risk of loan default.

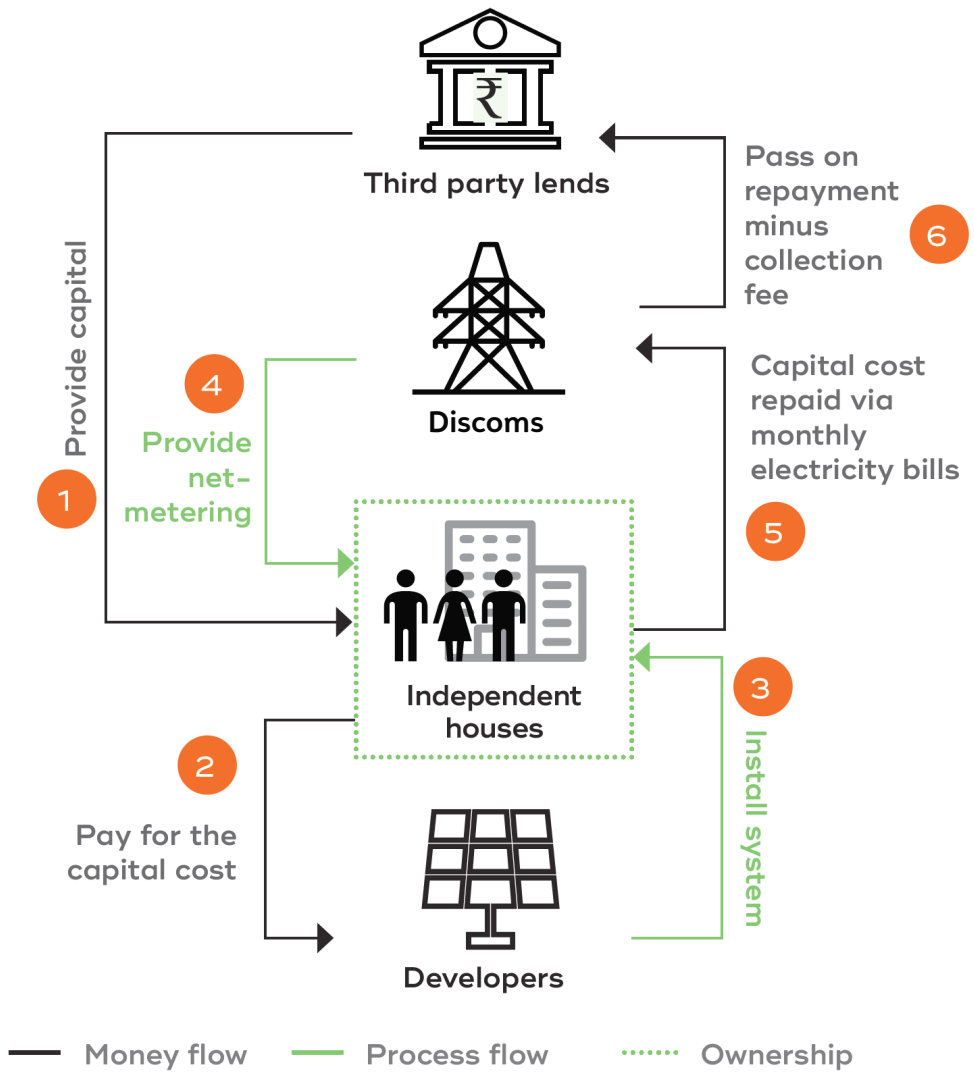

FIGURE 33:
On-bill financing schematic

Source:
Neeraj Kuldeep et al. (2019)

	Utility-led community solar (on-site) model	Utility-led community solar (off-site) model	On-bill financing model	Solar partners model
Target consumer segments	Residents in high-rises and multi-unit buildings with shared roofs, consumers with no access to suitable roof spaces	Residents in high-rises and multi-unit buildings with shared roofs, consumers with no access to suitable roof spaces	Individual consumers with exclusive roof ownership but who cannot finance upfront	Renters and owners without roof access, consumers sceptical of installing and owning a rooftop solar system
Location	Common areas and rooftops within a society's premises	Government buildings, commercial buildings, institutions	Consumers' rooftops	Public, commercial, and industrial buildings; community spaces; and other available roof spaces
Ownership	Community (society or group of consumers), if payment is upfront; third party, if payment is through a monthly subscription fee	Community (society or group of consumers), if payment is upfront; third party, if payment is through a monthly subscription fee	Ownership transferred to consumers after loan repayment	Developers, discoms, municipalities
Metering arrangement	Virtual net-metering	Virtual net-metering	Net-metering	Virtual net-metering

TABLE 2:
Business models at a glance

Source:
Neeraj Kuldeep et al. (2019)

Annexure B.

Survey questionnaire

CEEW – BYPL Consumer Survey for Residential Rooftop Solar

Introduction:

Sir/Ma'am,
BSES Yamuna Discom which supplies electricity in this region,together with the Council on Energy, Environment, and Water (CEEW), is conducting a research project to support the installation of rooftop solar PV systems. BYPL Discom is conducting a small survey to better understand consumers' opinions on rooftop solar. This survey requires a response from a senior family member or the head of the household. I am here to conduct the survey; it would take about 10 to 15 minutes to answer all the questions.

We have an authorisation letter from the BSES Yamuna Discom, here it is for your perusal.
(Show the letter of support.)

Sir/Ma'am, are you the head of the family?

If yes: would you like to share your inputs?
(or)
If no: may I kindly request that you invite the head of the family.

Next Page:
Thank you, Sir/Ma'am, for agreeing to participate in the survey. We are now going to start.
Would you prefer the survey in English or Hindi?

Next Page:
This survey has six different sections. I will explain each section at the start of it.

Section 1: Consumer Information

We are now starting the first section.

1. Name of the respondent: .....
2. Location/area (colony): .....
3. Type of residence (read the options):
   - ☐ Independent house
   - ☐ Flat/apartment
   - ☐ Other
4. Total number of floors in the building: .....
5. How many people live in the house? .....
6. Ownership of the building?
   - ☐ Rented
   - ☐ Owned

7. Do you receive a separate electricity bill from BSES Yamuna?

- ☐ Yes
- ☐ No

(Sir/Ma'am, may I please see the electricity bill.)

8. What is your customer number for your electricity connection? .....

(Copy it from the electricity bill or request the respondent to share the electricity bill and take a photo.)

9. On average, how much is your monthly electricity bill? .....

- ☐ Summer months: .....
- ☐ Winter months: .....
- ☐ Do not know: .....

10. On average, what is the monthly household expenditure on electricity? .....

11. Do you use power backup systems during power cuts?

- ☐ Yes
- ☐ No

(If answer to Q11 is no, skip Q12 and go to Q13.)

12. What type of power backup system do you have? (Read the options.)

- ☐ Inverter batteries
- ☐ Generator (diesel/petrol/gas)

Section 2: Roof Details

13. What is the total flat/roof area? .....

(Mention the unit as well, whether sq. ft. or sq. yd. etc.)

14. On which floor do you live?

- ☐ Ground/first floor
- ☐ Top floor
- ☐ Other .....

15. In your building, who has the roof right/ownership? (Read the options.)

- ☐ Self-owned
- ☐ Used/owned by top floor occupant
- ☐ Shared by building occupants
- ☐ Builder-owned
- ☐ Society-owned
- ☐ Other .....

16. How frequently and for what purpose does your family use the roof? (Read the options.)

- ☐ Frequently
- ☐ Rarely/not at all
- ☐ During the winter

- ☐ For family functions
- ☐ For storage purposes
- ☐ Don't have roof access
- ☐ Other .....

(If answer to Q15 is "Self-owned", skip Q17 and move directly to Q18.)

17. In case of a shared roof, how frequently and for what purpose do other occupants use the roof? (Read the options.)

- ☐ Frequently
- ☐ Rarely/not at all
- ☐ During the winter
- ☐ For family functions
- ☐ For storage purposes
- ☐ Don't have roof access
- ☐ Other .....

Section 3: Consumer Interest

18. Are you aware that people are installing solar systems on their rooftops to save on their electricity bills?

- ☐ Yes
- ☐ No

[About rooftop solar systems:
Solar plates are installed on the rooftop which generate electricity from light (the sun's energy). Solar electricity is now cheaper than coal electricity. Solar electricity is also environmentally friendly and pollution free.]

19. Have you ever considered installing a rooftop solar system on your rooftop?

- ☐ Yes
- ☐ No

20. How did you get to know about rooftop solar systems? (Read the options.)

- ☐ Not aware of rooftop solar systems
- ☐ People you know
- ☐ Discom (BSES Yamuna)
- ☐ Solar companies
- ☐ RWAs
- ☐ Newspaper advertisement
- ☐ Television
- ☐ Radio
- ☐ Other .....

21. Has anyone in your neighbourhood or social circle, or among your relatives, installed a rooftop solar system?

- ☐ Yes
- ☐ No

(If answer to Q21 is no, move on to Q23.)

22. What feedback did you get from them?

Describe: .....

23. Did you try to get more information about the rooftop solar system after you got to know about it?

- ☐ Yes
- ☐ No

(If answer to Q23 is no, move on to Section 4, Q25.)

24. To whom did you reach out to get more details about rooftop solar? (Read the options.)

- ☐ No one
- ☐ Existing consumers
- ☐ Solar companies
- ☐ DISCOMs
- ☐ RWAs
- ☐ Internet
- ☐ Other .....

Section 4: Consumers' Perceptions

25. What do you think is the life of a rooftop solar system? (Read the options.)

- ☐ Less than 10 years
- ☐ 10 to 15 years
- ☐ 15 to 25 years
- ☐ More than 25 years

26. Are you aware of the maintenance requirements of a rooftop solar system? *(Read the options.)*

- ☐ Yes
- ☐ Doesn't require maintenance
- ☐ Not aware

27. What do you think is the price of solar electricity per unit? (Read the options.)

- ☐ Less than INR 3
- ☐ Between INR 3 andINR 5
- ☐ Between INR 5 and INR 8
- ☐ Between INR 8 and INR 12
- ☐ More than INR 12
- ☐ Do not know

28. Do you think the solar tariff will increase or decrease in the coming years? *(Read the options.)*

- ☐ Increase
- ☐ Decrease
- ☐ Not sure

29. Do the uncertainties regarding solar tariffs stop you from installing it in the current year? *(Read the options.)*

- ☐ Yes
- ☐ No
- ☐ Do not care

.....

30. How many units of electricity do you think a 1 kW solar system can generate in a year? *(Read the options.)*

    - ☐ Less than 500 units
    - ☐ Between 500 and 1000
    - ☐ Between 1000 and 1500 units
    - ☐ More than 1500 units
    - ☐ Do not know

31. What do you think is the cost of a rooftop solar system of 1kW capacity? *(Read the options.)*

(A1 kW system will generate 100 to 120 units of electricity in a month.)

    - ☐ INR 30,000 to INR 50,000
    - ☐ INR 50,000 to INR 70,000
    - ☐ INR 70,000 to INR 90,000
    - ☐ More than INR 90,000
    - ☐ Do not know

32. How much would you be willing to spend for a 1kW rooftop solar system?

33. How much do you think you will save annually from a 1kW solar system? *(Read the options.)*

    - ☐ Less than INR 5000
    - ☐ Between INR 5000 and INR 8000
    - ☐ Between INR 8000 and INR 12000
    - ☐ More than INR 12000
    - ☐ Do not know

34. What do you think is the payback period for a rooftop solar system? (Explain payback period and read the options.)

    - ☐ 2 to 5 years
    - ☐ 5 to 8 years
    - ☐ More than 8 years
    - ☐ Do not know

35. What returns (in percentage) would you expect for your investment in solar? (Explain based on investment in FD and mutual funds.) .....

New page

Rooftop solar system techno-economic parameters:

For 1 kW system:

System price: INR 65,000 to INR 70,000

Electricity generation: 1,200 to 1,500 units annually

Lifespan: More than 25 years

Payback period: 5 to 7 years

Area required: 100 sq. ft.

Number of modules: 3 to 4 plates

Section 5: Consumer Acceptance—New Business Models

36. If a solar system on your rooftop functioned for 25 years, would you consider installing one?

    ☐ Yes
    ☐ No

(Ask Q37 and Q38 only if answer to Q36 is no, otherwise jump to Q39.)

37. Would you consider installing a solar system on a small part of your rooftop? (Read the options.)

    ☐ Yes, on one-quarter of the roof
    ☐ Yes, on half of the roof
    ☐ Yes, on three-quarters of the roof
    ☐ No

38. What is an acceptable lock-in period, in number of years? .....

39. Would you prefer to buy solar electricity from BSES Yamuna without having to own or install a solar system, even if you own your own roof?

    ☐ Yes
    ☐ No

40. Even if you don't have roof access or ownership, would you still be interested in buying solar electricity?

    ☐ Yes
    ☐ No

41. Would you be willing to own a share of a large solar system and avail solar electricity?

    ☐ Yes
    ☐ No

42. How much reduction do you expect in your electricity bill after availing solar electricity? (Read the options.)

    ☐ Less than 20 per cent
    ☐ Between 20 and 50 per cent
    ☐ Between 50 and 70 per cent
    ☐ More than 70 per cent

43. If you owned a share of a large solar system, where would you prefer it to be located? (Read the options.)

    ☐ On your community/housing society rooftop
    ☐ Elsewhere but at an accessible site
    ☐ Doesn't matter

44. If you owned a share of a larger solar system, would you like to be able to visit it? (Read the options.)

    ☐ Yes, frequently
    ☐ Yes, occasionally
    ☐ No

45. Would you consider getting a solar rooftop system installed without having to pay upfront, but instead paying EMIs based onthe savings on your monthly electricity bill?
    (The savings on the electricity bill fromusing solar will be used to pay for the system cost over a certain period.)
    - ☐ Yes
    - ☐ No
46. Which of the following would you prefer for financing your rooftop solar system? (Read the options.)
    - ☐ Own capital—full amount
    - ☐ Own capital—partial amount
    - ☐ Bank loan—full amount (repayment through EMIs)
    - ☐ Bank loan—full amount (repayment with electricity bill)
47. What do you think is an acceptable interest rate on a solar loan? .....
48. Given the opportunity, would you allow a third party to install your solar system free of cost?
    (Consumer would then have to pay for their consumption of solar electricity at a fixed rate which would be lower than thediscom rate.)
    - ☐ Yes
    - ☐ No
49. In case of third-party installation, who should own the system? (Read the options.)
    - ☐ Discom
    - ☐ Solar company
    - ☐ RWA
    - ☐ Other .....
50. In case of third-party ownership, would you allow them access to the roof to operate and maintain the solar system? (Read the options.)
    - ☐ Yes
    - ☐ No
    - ☐ Not sure
51. In case of third-party ownership, would you demand roof rent from the solar system owner?
    - ☐ Yes
    - ☐ No

(Ask Q52 and Q53 only if the answer to Q51 is yes. Otherwise, jump to Q54.)

52. How much rent would you expect for your rooftop annually? .....
53. Would you prefer to get subsidised solar electricity to offset the rent amount?
    - ☐ Yes
    - ☐ No

Section 6: Market Drivers and Barriers

54. Which of the following parametersmake you interested in installing a rooftop solar system?
(Please rate between 1 [lowest]and 5 [highest]. Mark "zero" if you are not aware of a certain parameter.)

Parameter	0	1	2	3	4	5
Monthly savings on electricity bill						
Solar subsidy (30%)						
Net-metering benefits						
Exemption from electricity tax (5%) on solar power						
Relief from powercuts						
Environmentally friendly						
Generation-based incentive						
Other (please specify)						

55. Which of the following parameters stop you from installing a rooftop solar system?
(Please rate between 1 [lowest] and 5 [highest]. Mark "zero" if you are not aware of a certain parameter.)

Parameter	0	1	2	3	4	5
Don't know much about solar						
High system cost						
High interest rate on solar loans						
Long-term commitment (>25years)						
Maintenance and subsequent costs involved						
Cannot use it during power outages						
Long payback period						
Lack of trusted solar companies						
Performance of solar system						
Not aware of processes						
Lower savings on electricity bill						
Delays in releasing capital subsidy						
Delays in approval process because ofthe discom						
Electricity bill is not too much						
Other (please specify)						

56. Address: .....

57. May I request you to kindly share your contact number: .....

58. Would you be interested in engaging further with BSES Yamuna Discom, and contributing more to developing rooftop solar programmes?

    ☐ Yes
    ☐ No

Section 7: Metadata

59. Name of the Interviewer: .....

60. BSES Yamuna region: .....

61. Date of interview: .....

62. Interview duration:Start time ..... End time .....

63. GPS location:Latitude ..... Longitude .....

Scale model of a multi storey house with proposed roof top solar panels.

Image: Envato


TAXI

Council on Energy, Environment and Water (CEEW)

Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India
T: +91 (0) 11 4073 3300
info@ceew.in | ceew.in | @CEEWIndia