WRI INDIA

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WORKING PAPER

HERE COMES THE SUN: RESIDENTIAL CONSUMERS' EXPERIENCES WITH ROOFTOP SOLAR PV IN FIVE INDIAN CITIES

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EXECUTIVE SUMMARY

Highlights

- India has set an ambitious target of achieving 40 gigawatts (GW) of rooftop solar capacity by 2022. The installed capacity of rooftop solar as of July 2018 was 1,222 megawatts (MW)—this is less than 5 percent of the 2022 target.[1] While there has been progress in the form of improvements in the performance of solar panels, availability of financing options, and favorable policy and regulatory ecosystems, rooftop solar in the residential sector is yet to gain momentum. Studies exploring reasons for poor uptake have approached the issue from the technical, institutional, and financial aspects. However, unlike traditional grid-based supply, meeting rooftop solar targets requires the active participation of the consumer; and therefore it is important to look at the sector from the consumer's perspective.[2]
- This working paper documents and analyzes the experiences of the residential electricity consumer with installing rooftop solar photovoltaic (PV) systems through household surveys in five Indian cities.
- Addressing three key challenges—lack of clear, objective, and accessible information for installation; absence of customized financing options; and lack of coordination in institutional priorities and processes—can enhance residential consumers' experience in installing rooftop solar PV.
- Consumers' experiences are contextual. Top-down approaches must be complemented by bottom-up initiatives involving multiple local stakeholders, while ensuring the rights and welfare of the consumer.

CONTENTS

Executive Summary 1
Introduction 3
Study Objectives 3
Context for the Study 3
Conceptualizing Consumer Experience 4
Understanding City Contexts 5
Methodology 9
Key Findings 10
Conclusion 17
Appendix A: Household Questionnaire Template 18
Appendix B: City-Wise Payback Calculations 30
Appendix C. City-Wise Number of Households Surveyed across Types of Residential Consumers 32
End Notes 33
Bibliography 34
Acknowledgments 36

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Context

India has announced an ambitious target of achieving 175 GW of installed renewable energy (RE) capacity by 2022. The rooftop solar PV segment has a significant role to play in achieving this target. Of the 175 GW, 20 GW is to be achieved through rooftop solar installations by residential and institutional consumers.[3] As of July 2018, 1,222 MW of rooftop solar had been installed in these segments.[4]

A concentrated national effort is required to accelerate deployment of rooftop solar to achieve the target by 2022. Unlike the traditional grid-based electricity supply, installation of rooftop solar requires the active participation of the consumer. However, analysis of experiences of consumer participation and engagement toward adoption of rooftop solar is limited. To address this limitation, we conducted a structured, evidence-based study to document consumer experiences in installing residential rooftop solar PV systems, to understand what has worked and not worked, for consumers.

Between November 2017 and January 2018, WRI India surveyed 1,808 households predominantly residing in independent dwellings, across the cities of Bengaluru, Chandigarh, Chennai, Jaipur, and Nagpur. The survey findings were validated through review of key published literature, multi-stakeholder workshops in the five cities and New Delhi, as well as semi-structured interviews with solar PV vendors, civil society organizations, and other stakeholders in the respective cities.

Key Findings

- **Lack of clear, objective, and accessible information for installation**
  Overall awareness about solar PV systems among residential consumers is limited. Drawbacks such as absence of clear information about the product, processes, and approvals required for installing the system are the key hurdles. With the lack of credible and objective sources of information, there is strong reliance on vendors as exclusive sources of information. Efforts have been made by nodal agencies at the state and national level to present information about rooftop solar PVs, but they remain elusive since there is a disconnect between the medium of dissemination (which tends to rely predominantly on online platforms and smartphone applications) and the medium of relying on references from friends, family, and neighbors who have already installed solar rooftop systems, which is preferred by consumers.

- **Absence of customized financing options**
  The local policy and regulatory context, especially with respect to tariffs and subsidies, has a significant role to play in determining how a residential consumer considers financing the installation of rooftop PV systems. In the first place, this will determine and inform the consumer decision. Considering a skewed tariff structure, there may be no incentive for a consumer to opt for rooftop PV, which will be a more cost-effective option. Therefore, instruments to finance a product like a rooftop PV system need to be customized to the nature of the product without merely presenting it as another consumer durable good. This is particularly true when it comes to determining loan collateral, which is often disproportionate to the cost of the system.

- **Lack of coordination, institutional priorities, and processes**
  The lack of coordination among the priorities of different government agencies has affected the consumer experience. While residents in Chennai encountered an electricity utility that did not support rooftop solar because it conflicted with its grid-based power supply, residents in Chandigarh faced challenges in rooftop installations due to restrictions imposed by the municipality's architectural specifications. In addition, consumers also report challenges faced during institutional processes such as delays, challenges in billing, the need for multiple visits, and the lack of capacity of officials to provide information and guidance.

Addressing these issues and enhancing the consumer experience is a significant catalyst in promoting the adoption of rooftop solar among other residential consumers. Further, consumer experiences are contextual to the cities they emerge from. Therefore, for India to achieve its ambitious rooftop solar PV targets, the current top-down approaches of the Government of India must be complemented with bottom-up initiatives that cater to the needs of the residents.

INTRODUCTION

Renewable energy plays a significant role in adding to India's electricity capacity and clean energy transition. The National Tariff Policy (2016) explicitly states "promotion of electricity from renewable sources" as a primary objective. India has set an ambitious target of achieving 175 GW of renewable energy capacity by 2022. Of this, 40 GW will be contributed by rooftop solar PV. India's rooftop solar sector has enjoyed a steady growth in recent years, reaching a cumulative installed capacity of 1,222 MW in 2018,[5] in comparison to a little over 100 MW in 2014.[6] However, solar PV still accounts for less than 5 percent of the 2022 target of 40 GW.

Within the rooftop solar segment, the contribution of the residential sector remains the lowest at around 370 MW.[7] Industrial and commercial consumers have access to external funding, diverse business models, and third-party purchase, and they enjoy economies of scale owing to larger transaction sizes. In comparison, the residential segment of consumers is characterized by individual actions with smaller transaction sizes, relatively lower tariffs, and less third-party ownership of systems. As a result, the rooftop solar experiences of residential consumers are very different when compared to other consumer categories.

In this paper, we systematically document the perceptions and experiences of urban residential consumers through household surveys in five Indian cities—Bengaluru, Chandigarh, Chennai, Jaipur, and Nagpur. This consumer-centric research studies three groups of residential consumers: those who have installed rooftop solar PV systems, those who have considered installing but have not yet installed, and those who have never considered installing. Within the specific context of each city, we also studied the nature of vendor services, the technologies available, the institutional and regulatory ecosystem in the city and state (including subsidy schemes), and the types of financing options available.

Study Objectives

Given the need for a consumer-centric approach as well as incorporating local nuances, the objective[8] of this paper is to

- document the experiences reported by residential electricity consumers and
- identify key challenges faced by them during various stages of decision-making.

Context for the Study

Previous research on rooftop solar PV has looked at barriers for adoption of this energy option from the technical, financial, and institutional angles. Technical issues include absence of standards or quality control units to monitor systems and the penetration of inferior quality products in the market. These hamper the performance of the system and create a poor reputation for PV panels and the technology (Kapoor et al. 2014). The lack of availability of standardized solar PV products is also one of the key barriers for residential consumers. Even though specifications exist for the PV panels, poor implementation processes allow noncertified products to be openly sold in the market (TERI 2014). Another major concern is the lack of adequately trained professionals to undertake post-installation operation of the system, its repair, and its maintenance (Khare et al. 2013).

The institutional barriers include absence of a research and development ecosystem for sharing information (Kapoor et al. 2014; Painuly 2001; Quitzow 2015) and uncertainty over implementation of policies (Kapoor et al. 2014). There is also limited expertise in designing consumer-centric enablers to promote adoption of rooftop solar (Khare et al. 2013). Furthermore, there is a lack of coordination among various agencies (Khare et al. 2013) and between the central and state governments (Goel 2016).

On financing, there are currently two models in use, the CAPEX (Capital Expenditure) model and RESCO (Renewable Energy Service Company) model. In the CAPEX model, consumers purchase the system up front; while in the RESCO model, they lease out their roof to a third-party vendor to install solar systems. These models are explained further in the next section. For residential consumers, the CAPEX model is challenging since the up-front cost is high. Although they require smaller systems, even with subsidy, they face longer payback periods because electricity tariffs have remained very low (BNEF 2017; CSE 2017). In the case of the RESCO model, from the developers' perspective, aggregation of smaller-sized systems to operate at scale involves huge transaction costs as it means larger numbers of customers need to be convinced to install solar PV systems (CSE 2017). Most of the installations are paid for through a combination of self-financing and subsidy, and the lack of appropriate financing products for rooftop solar limits its expansion among the smaller sized markets (BNEF 2017). The various types of techno-economic arrangements, ownership models and metering options available to the consumer are elaborated in Box 1.

Few studies focus on the consumers' perspectives and their experiences in the residential sector. Studies like Mercom (2014), Greenpeace (2013), TERI (2014), and Gambhir et al. (2012) have considered the residential sector, however, only as part of the larger solar sector. Mercom (2014) and Kappagantu et al. (2015) focus on understanding consumer perceptions. However, the experiences of residential consumers who have installed rooftop solar PV systems require further exploration. Our study focuses on residential consumers' perspectives and experiences before, during, and after installing a rooftop solar PV system.

Conceptualizing Consumer Experience

We use the term *consumer* to broadly refer to both existing and potential rooftop solar PV users and owners. Different consumers engage with rooftop solar PV as a concept (becoming aware about rooftop solar PV), intention (considering rooftop solar PV as an option), and product (experience of installing and after). Broadly, these three stages of experience have resulted in the following three categories among residential consumers:

Box 1 | **Different Techno-Economic Arrangements, Ownership, and Metering Options**

Financing

CAPEX: In the CAPEX model, consumers pay for the system up front. The owner of the roof also owns the solar panel and deals directly with the electric utility for exporting solar power. In India, three out of four rooftop solar models follow the CAPEX model (BNEF 2017).

RESCO: In this model, the RESCO installs the solar PV system at the premises of the electricity consumer and bears the up-front capital cost. The electricity consumer pays the RESCO for the electricity produced by the solar PV system. The electricity consumer has a solar net metering, solar gross metering, or solar net feed-in arrangement with the utility.

Solar System

Grid-connected:

Net feed-in: The solar PV system's output is connected to the electrical installation of the building. The solar energy is consumed by the electrical loads of the building. Surplus power, if any, is exported to the public electricity grid. When solar electricity generation is lower than the instantaneous load demand, the deficit is taken from the public electricity grid. With net metering the consumer pays for the net imported energy (import from the grid minus export to the grid). With a net feed-in mechanism, the consumer pays for the imported energy at the prevailing consumer tariff and gets paid for the exported electricity at a solar electricity tariff. The grid interface has a single bidirectional electricity meter that records and displays the imported and exported energy.

Gross feed-in: The entire electricity produced by the solar PV system is fed into the grid and paid for based on a gross feed-in solar electricity tariff. The consumer continues to pay for consumption from the grid at the prevailing consumer tariff. The grid interface has two electricity meters—the existing electricity meter that records the electricity imported from the grid and an electricity feed-in meter that records the solar electricity being fed into the grid.

Off-grid:

This system is usually deployed in areas where access to electricity from the grid is unavailable or unreliable. In addition to the solar PV panels, the solar PV system includes a charge controller, a battery bank, and an inverter that converts the DC power of the battery to AC power. In some system configurations, the DC power is used directly for DC loads. Sometimes diesel generators are part of the system if the battery storage capacity is too low to sustain through periods without adequate sunshine.

Hybrid:

These systems usually comprise solar PV panels, a hybrid inverter, and a battery bank. The system can work in both grid-interactive mode and in stand-alone mode during grid outage. Consumers opt for this system in cases where electricity supply from the grid is unreliable and/or the solar panels do not produce sufficient electricity.

Metering and Billing

Gross metering: In the instance of gross metering, all the electricity produced by the consumers' solar system is exported to the grid. Here, two bills are generated—one for the electricity that is exported to the grid (the utility will pay the consumer) and another for the electricity consumed (consumer to pay the utility for the electricity consumed).

Net metering: Here, the electricity produced is first used for self-consumption, and the remaining electricity is exported to the grid. Only one bill is generated that calculates the net of total exports and imports, keeping in mind the regulatory cap on the amount that can be exported to the grid. The consumer gets 1 kWh energy credit for every kWh exported.

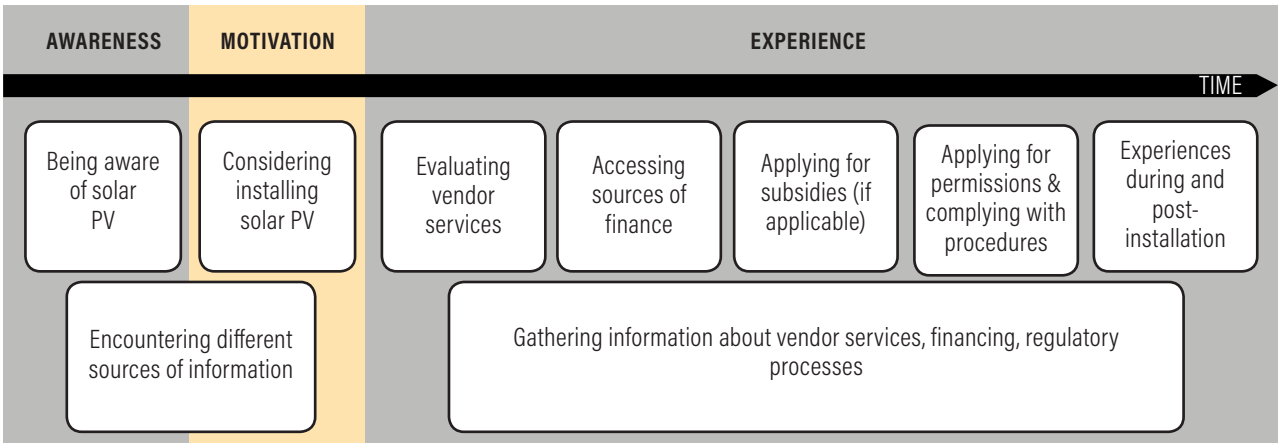
Net metering with a net feed-in tariff: The consumer pays for the imported energy and gets paid for the exported energy. The payment for the exported energy may be adjusted with the payment for the imported energy for each billing cycle. The consumer gets paid for every kWh exported at a tariff that may be different from the consumer tariff.

Source: WRI authors, in consultation with experts.

- Those who have installed rooftop solar PV
- Those who considered installing rooftop solar PV but have not installed it
- Those who have not considered rooftop solar PV as an option

Consumers who consider installing a rooftop solar PV system, might partially experience the various stages of installation up to the point at which they may decide to not pursue it further. This includes evaluating vendors, applying for financing options like subsidies and loans, and seeking permissions before deciding to install.

Figure 1 | **Stages of Consumer Experience**



Source: WRI authors.

The study captures the various stages that residential consumers experience before, during, and after installing a rooftop solar PV system (Figure 1). Over the course of these experiences, consumers encounter various stakeholders, ranging from vendors promoting the sale of rooftop solar PV systems to financial institutions. Consumers may need to obtain loans (if required) to finance the installation as well as interact with the renewable energy, state nodal agency (SNA),[9] or the electricity utility to obtain approvals for subsidy allocation and other permissions pertaining to metering and billing. Another key consideration is the after-sales services that the selected vendor provides in terms of maintaining and repairing the installed systems.

For a nascent market like residential rooftop solar PV systems, the first stage is when a consumer becomes aware of solar energy as a concept and rooftop systems as a product that generates electricity. While this awareness might be involuntary or voluntary, once this awareness translates into interest to consider rooftop solar PV as an electricity supply option, consumers might actively seek sources of information. These sources of information could either be personal references from friends, family, and neighbors or public references like newspapers, television, Internet, and social media.

Sources of information about installation processes and technological and structural requirements that are currently available through various government websites and applications become relevant at this stage. It is during this process that consumers interact with vendors, financial institutions, SNAs, and the electricity utility, and their experience is influenced by the quality of their interactions with these stakeholders.

The final stage of consumer experience includes post-installation experiences such as maintenance, repair, and periodic servicing of the installed system to ensure optimal performance.

While acknowledging the unique experiences of residential consumers, it is also observed that these experiences are further nuanced by the specific contexts that play out in different geographies.

Understanding City Contexts

Five Indian cities—Bengaluru, Chandigarh, Chennai, Jaipur, and Nagpur—were identified for this study. The cities were selected on the basis of a detailed analysis of market, policy, and regulatory conditions. The following criteria were used to shortlist the five cities:

- Installed capacity of solar PV across Indian states
- Identifying cities across tiers[10] that are solar[11] and/or smart cities[12]
- Classifying the cities into low, medium, or high electricity tariff bands

The final set of five cities was selected on the basis of the presence of suitable local partners, who are active civil society organizations that work on city-level consumer issues and can provide the local context in each city.[13]

These five cities represent different socio-economic and regulatory contexts. Bengaluru and Chennai are the only Tier 1 cities. In terms of population, Chennai has the highest population (8.69 million) followed by Bengaluru (8.5 million), Jaipur (3.07 million), Nagpur (2.49 million), and Chandigarh (1.02 million).[14] Table 1 provides a snapshot of the economic and solar characteristics of the states where the cities are located.

The policy and regulatory contexts play a significant role in the way solar PV markets are evolving in these cities. For consumers with a high daytime electricity demand, grid-connected rooftop solar systems provide substantial savings on electricity bills. Most investments in the non-residential sectors have been driven by these savings (BNEF 2017). On the other hand, for consumers with a low daytime electricity demand, such as residential consumers, grid-tied systems prove to be beneficial only when they can export power to the grid. As a result, the presence of enabling regulations and policies (such as net metering) play a key role in facilitating uptake.

Over the years, the central government, through the Ministry for New and Renewable Energy (MNRE), has made various efforts to promote rooftop solar in India. The Jawaharlal Nehru National Solar Mission Phase 1 and 2, carried out between 2010 and 2017, provided a significant thrust to the sector through the provision of subsidies,[15] introduction of channel partners,[16] and appointment of SNAs for the promotion of solar energy. During this phase, in 2015, India announced its ambitious rooftop solar target of achieving 40 GW of installed capacity by 2022. To achieve this, MNRE proposed a draft scheme called the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) in December 2017 (see Box 2 for details of the scheme).

Table 1 | **State-Level Income and Rooftop Solar Installation**

CITY	STATE/ UNION TERRITORY	STATE PER CAPITA INCOME (IN INR)[a]	TOTAL INSTALLATION CAPACITY (MW) OF GRID-CONNECTED ROOFTOP SOLAR AND SMALL SOLAR PLANTS AS OF AUGUST 2017[b]
Bengaluru	Karnataka	132,880	71.2
Chandigarh	Chandigarh	225,369	7.5
Chennai	Tamil Nadu	130,197	97.67
Jaipur	Rajasthan	76,881	42.33
Nagpur	Maharashtra	134,081	123.64

Notes: [a] http://pib.nic.in/newsite/PrintRelease.aspx?relid=169546.
[b] It is important to note that the installation capacity also includes small solar plants. At present, there is no proportional breakup of residential and small solar plant capacities. State-Wise Installed Capacity of Rooftop and Small Solar Plants, Lok Sabha Starred Question No. 269 as of August 2017. http://164.100.47.190/loksabhaquestions/annex/12/AS269.pdf; MOSPI 2017.
Source: WRI authors.

Box 2 | SRISTI: Draft Scheme by the Ministry of New and Renewable Energy to Incentivize Rooftop Solar Adoption

The SRISTI scheme was drafted by the MNRE in December 2017 to incentivize rooftop solar adoption. The scheme aims to provide much-needed impetus to the sector.

Under the SRISTI scheme, residential rooftop solar systems with a cap of 5 kW size would be eligible for a subsidy of 18,000 INR/kW. Similarly, an incentive of 5,500 INR/kW is proposed to be provided to electricity utilities for rooftop solar installations in social, institutional, and government buildings, as well as commercial and industrial establishments. The aim of these incentives is to compensate the electricity utilities for revenue loss due to reduction in electricity sales.

The scheme also moves away from previous programs by placing the electricity utility at the center of implementation, rather than creating another institutional body. This is expected to facilitate direct interactions with consumers and reduce procedural delays in approvals. The MNRE also proposes entrusting electricity utilities with empanelment of solar developers and rewarding them for adding each MW of solar during specific time frames.

However, at the city-level workshops we conducted, stakeholders were skeptical about the effectiveness of incentivizing electricity utilities, arguing that incentives will not overcome the limited implementation capacities and knowledge of rooftop solar.

Source: MNRE Concept Note 2017. https://mnre.gov.in/file-manager/UserFiles/comments-on_RTS.pdf.

In addition to the MNRE's policies and programs, some of the states also have their own policies to enhance uptake of rooftop solar. For example, in Tamil Nadu, the Chief Minister's Solar Rooftop Capital Incentive Scheme was introduced to incentivize residential consumers. It offered an additional subsidy of INR 20,000 for residential consumers installing solar plants of 1 kW capacity. State level schemes and policies are summarized in Table 2.

Table 2 | Summary of State-Level Policies

CITY	POLICY/ SCHEME	TARGETS (IF ANY)	PROVISIONS RELATED TO RESIDENTIAL ROOFTOP SOLAR PV
Bengaluru	Karnataka Solar Policy 2014–21	6,000 MW of rooftop solar PV by 2021	Introduce gross metering under rooftop solar generation across consumer categories
Chandigarh	No solar policy notified, thus far		The Science and Technology Department has made it mandatory for buildings measuring 500 square yards and above to install rooftop solar PV
Chennai	Tamil Nadu Solar Energy Policy, 2012 Chief Minister's Solar Rooftop Capital Incentive Scheme	3,000 MW of solar by 2015, of which 350 MW will be from rooftop solar	All domestic consumers encouraged to put up rooftop solar Additional subsidy of INR 20,000 for residential consumers installing 1 kW systems was provided under the Chief Minister's Solar Rooftop Capital Incentive Scheme
Jaipur	Rajasthan Solar Energy Policy, 2014	3,780 MW of solar by 2019	State will promote rooftop solar PV under the net metering scheme as per guidelines from the Rajasthan Electricity Regulatory Commission (RERC) The utilities will develop a suitable and comprehensive consumer-friendly IT application in this regard
Nagpur	Maharashtra Solar Policy, 2016	7,500 MW of solar by 2020–21	The government introduced a policy to promote solar by allowing for 100% subsidy to install systems on government buildings

Source: https://mnre.gov.in/file-manager/UserFiles/state-solar-power-policies.htm.

In keeping with the vision to promote rooftop solar, all Indian states have net- or gross-metering regulations and/or relevant tariff orders to enhance these installations. Table 3 presents a summary of the metering and consequent compensation mechanisms prevalent in the cities studied.

Table 3 | **Summary of the Regulatory Contexts in Each State**

CITY	INSTALLED CAPACITY	METERING	COMPENSATION	LOCAL LAWS MANDATING ROOFTOP SOLAR
Bengaluru[a]	Not more than 100% of the sanctioned load, subject to a maximum of 5 kW on a single-phase supply and 5–50 kW on a three-phase supply	At the time of applying for meter, consumer can choose between net or gross metering	Under net metering, if the exported energy exceeds imported energy, the excess can be carried over to the next month. For gross-metered connections, surplus is settled at the feed-in tariff (FiT). The FiT is different for those availing subsidies.	No
Chandigarh[b]	Cumulative capacity of all systems in the neighborhood should not exceed 30% of the capacity of the distribution transformer of the neighborhood	At the time of applying for meter, consumer can choose between net or gross metering	Under net metering, export surplus carried over as credit. 100% of the imports paid at the end of the financial year at FiT. Under gross metering, excess amount (if any) is paid every billing cycle at FiT. The FiT is different for those availing subsidies.	Yes
Chennai[c]	Not more than 90% of sanctioned load. Cumulative capacity of all systems in the neighborhood should not exceed 30% of the capacity of the distribution transformer of the neighborhood	Net metering	If the exported energy exceeds imported energy, the excess can be carried over. At the end of 12 months, the maximum surplus that will be credited will be 90% of the energy import.	No
Jaipur[d]	Not more than 80% of sanctioned load. Cumulative capacity of all systems in the neighborhood should not exceed 30% of the capacity of the distribution transformer of the neighborhood	Net metering	Up to 50 units of export can be carried over. Once 50 units is crossed, the excess is paid at FiT.	No
Nagpur[e]	Not more than 100% of the sanctioned load. Cumulative capacity of installed systems should not be more than 40% of neighborhood distribution transformer's capacity	Net metering	After the month-by-month rollover of credit for one year, the surplus if any, limited to 90% of demand is purchased by the electricity utility at the Average Power Procurement Cost (APPC).	No

Notes:

[a] Karnataka Electricity Regulatory Commission Tariff Order for Solar Rooftop and Small Photovoltaic Power Plants FY17–18. Both net metering and gross metering exist in Bengaluru, according to the September 19, 2016, Tariff Order. The consumer has to choose either one.

[b] Chandigarh Renewable Energy and Science and Technology Promotion Society's Approved Generic Levelized Tariff for Grid-Connected Roof Top and Ground Mounted Solar PV Projects for FY 2016–17 and FY 2017–18 for U.T. Chandigarh.

[c] Tamil Nadu Energy Development Agency's Solar Net-Metering Consumer Guide.

[d] Rajasthan Electricity Regulatory Commission Tariff Order in determination of benchmark capital cost for solar PV and solar thermal power projects applicable during FY 2017–18 and resultant generic levelized tariff.

[e] Maharashtra Electricity Regulatory Commission's Practice Direction on Net Metering for Rooftop Solar Photo Voltaic Systems, dated September 2016.

Source: WRI authors.

METHODOLOGY

To address the above objectives, we conducted household surveys covering residential consumers across the five Indian cities identified in the previous section.

Between November 2017 and January 2018, we surveyed approximately 360 households in each city that fell into one of the three categories: households that installed, households that considered installing but did not install, and households that never considered installing rooftop solar PV systems, at the time of survey. Table 4 provides a summary of the households surveyed across residential consumer categories. City-wise data on the same are provided in Appendix C.

Table 4 | **Number of Households Surveyed across Types of Residential Consumers**

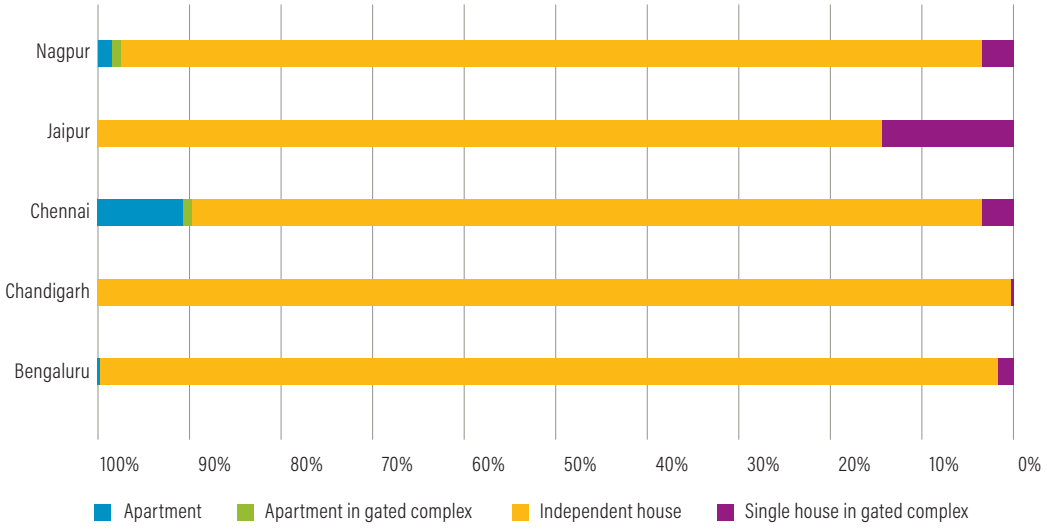
CITY	NUMBER OF HOUSEHOLDS
Households that installed solar PV	325
Households that considered installing solar PV, but did not install	223
Households that did not consider installing solar PV	1260
Total	1808

Source: WRI Survey Analysis.

Our literature review helped us identify five key areas to explore to understand further the residential electricity consumers' experience. A structured questionnaire was developed to document the respondents' levels of awareness, motivations, and experiences with respect to—status of rooftop installation, type of technological solution(s) considered, vendor selection, financing the installation, and regulatory processes and approvals. The questionnaire also captured information pertaining to the respondent's demography, description about the dwelling, electricity connection and consumption details, and recommendations that they could suggest in tackling the identified challenges. The questionnaire is provided in Appendix A.

Data on the actual numbers of residential rooftop systems at a city level are limited. Households that installed rooftop solar PV were identified on the basis of the list of consumers with grid-tied systems, obtained from the MNRE and state-level government agencies. For each installed household, we surveyed five houses in the vicinity to maximize chances of finding households that have considered installing. Independent houses constitute most of our sample size.[17]

Figure 2 | **No. of Dwellings of Each Type Surveyed**



Source: WRI Survey Analysis.

In each city, we also identified a local partner who was familiar with the local electricity context to provide overall guidance for data collection through the surveys and expert consultations.

The residential consumers were asked questions about background information, such as demography, dwelling characteristics, electricity connection and consumption details, status of installation of rooftop solar system, and their perceptions of the solar solutions, vendors, financing, and regulatory processes, on the basis of having installed, considered, or never considered rooftop solar systems.

We acknowledge that this study is not representative at a city level, as the data required to develop a comprehensive population frame from which to draw the sample were limited. Therefore, the emphasis of the research is to highlight the experiences of the consumers, rather than provide an overall representation of residential solar PV installations in each city.

KEY FINDINGS

The objective of this study was to understand the issues faced by residential consumers in their adoption of rooftop solar PV. Across the spectrum of consumer experiences, our research discovered three challenges that consumers face. Broadly, these challenges fall under access to information, financing options, and institutional priorities and processes. They can be summarized as follows:

- Lack of clear, objective, and easily accessible information
- Absence of customized financing options
- Lack of streamlined institutional priorities and processes

Lack of Clear, Objective, and Easily Accessible Information for Installation

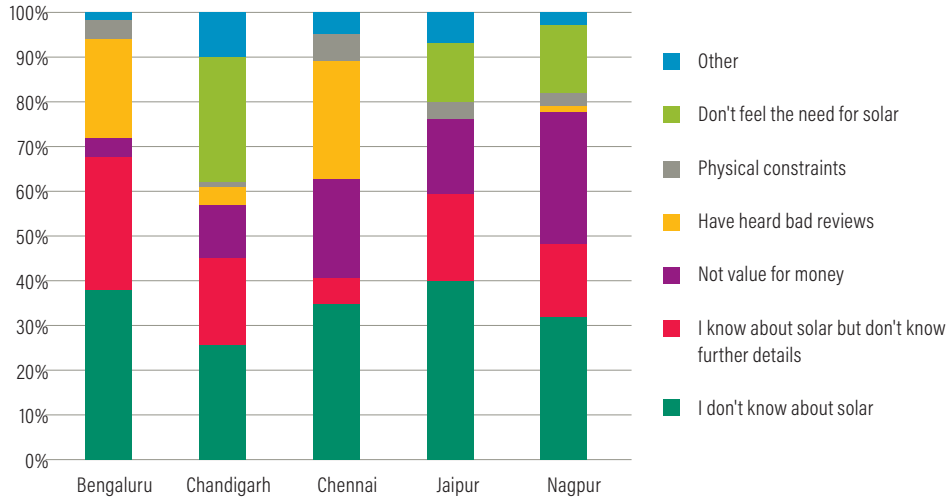
Consumers who have not installed solar PV have low overall awareness levels regarding the concept of producing electricity using solar energy or the use of solar PV as a consumer product. We sought to understand their levels of awareness by asking the following questions:

1. Do you know the difference between solar water heaters and solar rooftop PV for electricity generation?

2. Do you know how solar PV works?

On an average, only 30 percent of the consumers who considered installing and 18 percent of the consumers who did not consider installing answered yes to these questions. The remaining either answered no or said that they somewhat knew the difference. Consumers who considered solar PV were more aware than consumers who did not consider installing solar PV. When consumers who considered solar PV were asked about the barriers they faced, 46 percent responded that they faced barriers in obtaining clear information about the technology. As Figure 3 shows, 53 percent of consumers who hadn't considered solar PV said that they either did not know about solar or did not know enough details to consider solar.

Figure 3 | Top Reasons for Not Considering Rooftop Solar PV



Source: WRI Survey Analysis.

Objective sources of information

Consumers rely heavily on sources of information that are not necessarily objective and unbiased.

On an average, 45 percent of consumers who have installed a rooftop PV system relied on the vendor for obtaining all the relevant information. The vendor is often the first source of information. When asked how they got to know about the vendor, over 30 percent of consumers who had installed rooftop solar PV systems responded that the vendor approached them first. This share is highest in Bengaluru, where over 32 percent of the respondents were approached by a vendor, and lowest in Nagpur, where only 17 percent were approached directly by a vendor. Sometimes, a vendor is the only source of information. In Bengaluru, over 50 percent of respondents said that they received information about subsidies, loans, and regulations only from vendors.

Perceptions of the reliability of the information provided by the vendors are mixed. When asked about the challenges faced while dealing with vendors, 47 percent of respondents in Bengaluru and 69 percent of respondents in Chennai said that they faced problems in verifying whether the vendor was trustworthy or if the price offered was right. On the other hand, this share was less than 35 percent in the other cities, where most of the respondents said that they did not face any difficulties while dealing with the vendor.

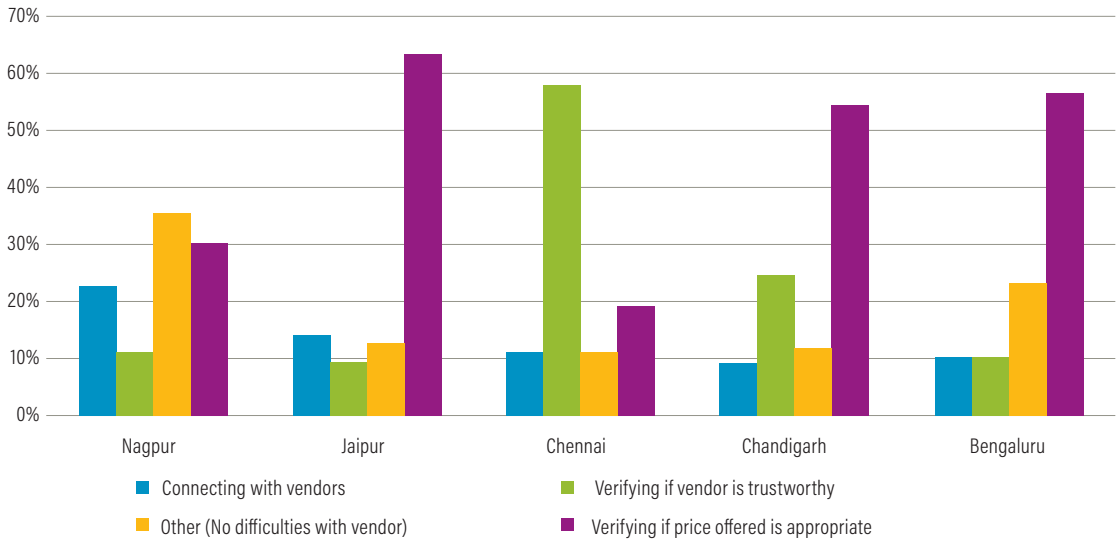
A second major source of information is anecdotal information from individual experiences. Forty-seven percent of those who have installed and 56 percent of those who considered installing solar PVs relied on information from friends, family, and neighbors. This is highest in Chennai with 61 percent for those who have installed. Furthermore, 86 percent of the consumers who have installed solar expressed their willingness to refer the vendor to their friends and acquaintances in the future.

Challenge of accessing information

In recent years, there have been efforts to make information more accessible to end users by the national government and the MNRE through mobile applications and websites. The MNRE has supported initiatives, including ARUN (Atal Rooftop Solar User Navigator), which is a web-based application that offers basic knowledge about rooftop solar and provides quick calculations on installation costs and updates on the policy and regulatory ecosystem in the country, and SPIN, an online application for Solar Photovoltaic Installation for grid-connected systems.

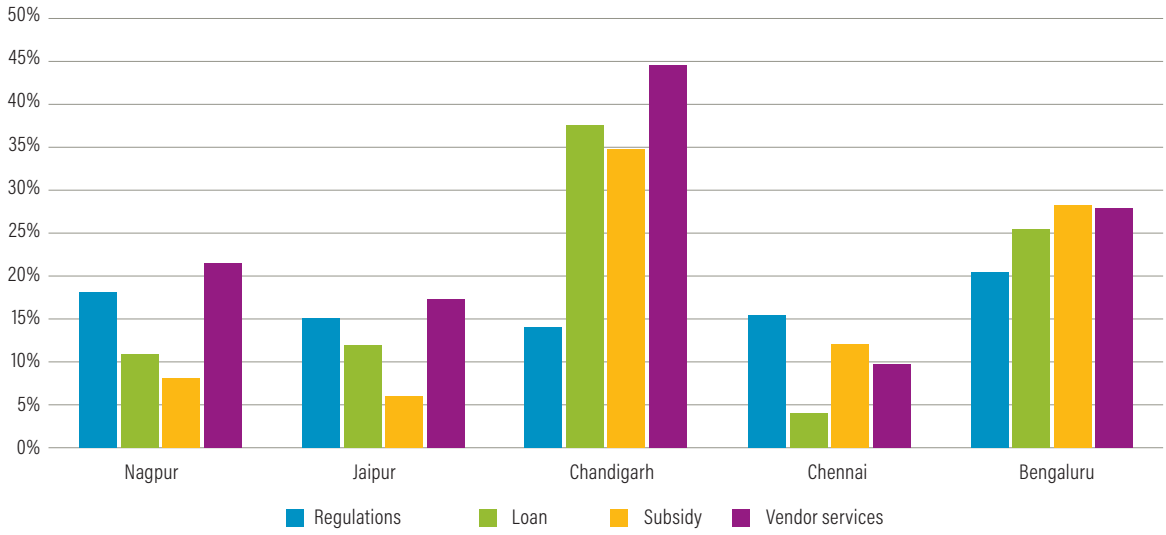
However, the survey responses suggest that the medium used to provide this information may not be what consumers are most comfortable using or accessing. Among the five cities, on an average, only 19 percent of the respondents used the Internet to obtain information.

Figure 4 | **Most Difficult Process with Vendor Services**



Source: WRI Survey Analysis.

Figure 5 | **Percentage of People Using the Internet for Information on Vendor Services, Subsidies, Loans, and Regulations**



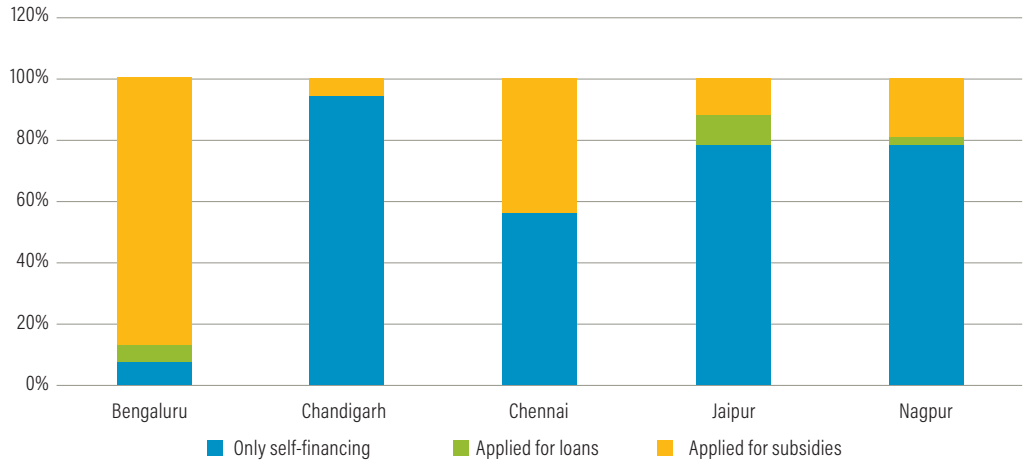
Source: WRI Survey Analysis.

Efforts by key stakeholders to ensure that the information is provided in an accurate and relevant medium is an important step toward improving awareness about the sector.

Absence of Customized Financing Options

The availability of finance is a key step in the consumer's journey toward installing a rooftop solar PV system. Figure 6 shows the type of financing used by consumers who installed rooftop solar to pay for their systems.

Figure 6 | **Types of Financing[a]**



Note: [a]These findings do not say that financing options are not required, because very few people have applied for loans so far. It could be that people who installed so far (first movers) did not need loans, i.e., they could finance the systems on their own. Many people are not even aware that there are loans for solar systems.
Source: WRI Survey Analysis.

Of all the consumers surveyed, 32 percent relied exclusively on self-financing, 63 percent applied for subsidies, and only 5 percent applied for loans. Improved access to financing options can potentially translate to increased uptake of residential rooftop solar. This presents opportunities to customize financing options at two levels:

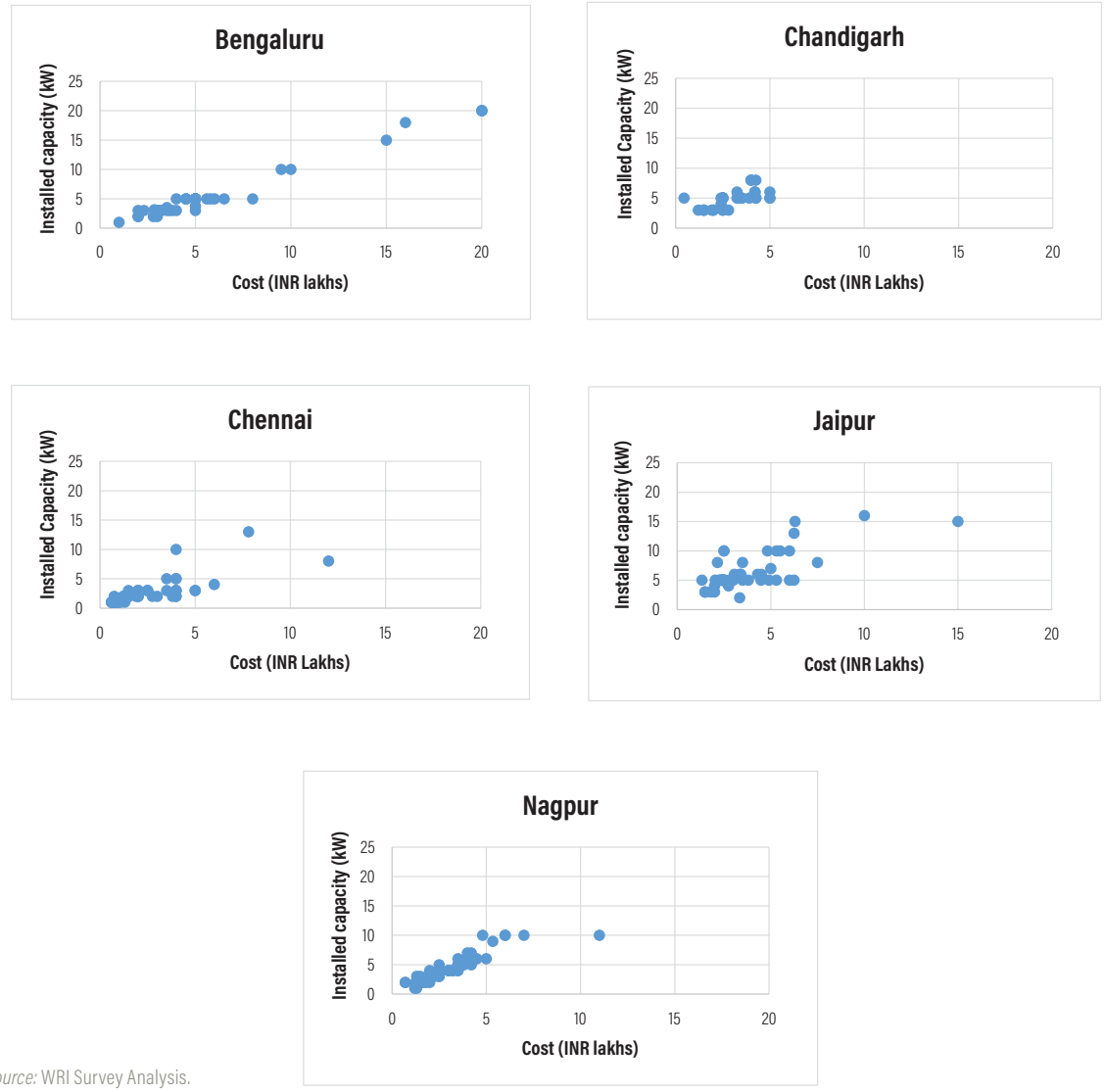
- At a city level, for financing options to better adapt to local contexts
- At a sector level, for financing options to be relevant for the residential sector

Customization to adapt to local contexts

Unlike other consumer goods, the existence of different subsidies, tariffs, metering, and financial settling mechanisms in different cities creates different cost structures and payback periods for rooftop solar systems. Moreover, as pointed out earlier, residential consumers have low daytime electricity demand, unlike other consumer segments. As a result, the recovery of their investments in solar PV is tied to the terms of their export of electricity and therefore to local policies and regulations in their city. These differences call for financial offerings that are flexible enough to adapt to local contexts.

Below are a set of scatter plots of cost versus capacity of the systems (installed across various years) from the consumers we surveyed in each of the five cities. The horizontal axis shows the cost in INR lakhs and the vertical axis shows the capacity of the systems in kW.

Figure 7 | **City-Wise Cost versus Capacity Scatter Plots**



Source: WRI Survey Analysis.

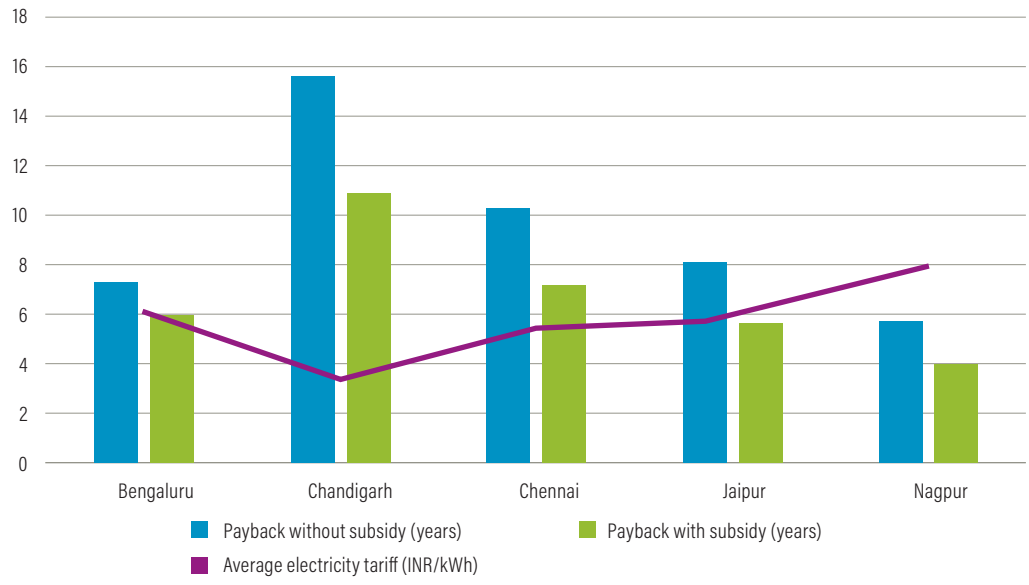
Bengaluru has the most scattered capacities, with larger numbers of people installing bigger systems. This can potentially be explained by the presence of gross-metering incentives in the city. Under the gross-metering provisions in Bengaluru, a consumer is paid for all the power exported into the grid, rather than adjusting it against the imported power. Therefore, installing a larger system means that the consumer can earn more money by exporting more power to the grid. In the short run, if the rate at which the utility pays the consumer for exported power is greater than the rate at which the consumer pays for the imported power, this arrangement is beneficial for the consumer and incentivizes larger system sizes. An additional effect of gross-metering regulations in Bengaluru is on the payback periods. According to Karnataka Electricity Regulatory Commission's Tariff Order dated May 2016, consumers who opt for subsidy are paid at a lower tariff than consumers who do not. As a result, the difference in payback periods with and without subsidy is just one year (as shown in Figure 8), leading to more consumers not opting for subsidies. As Figure 6 shows, self-financing is the highest in Bengaluru.

Chandigarh has one of the lowest electricity tariffs and therefore the highest payback periods for rooftop solar for residential consumers. In Chandigarh, a notification issued by the Chandigarh Administration[18] in May 2016 mandates rooftop solar for residential consumers and provides guidance on the kind of systems that can be installed for various house sizes.[19] This varies from 1 kW to 5 kW, depending on the size of the house, and therefore there is a cluster between 3 kW and 5 kW among the consumers surveyed in Chandigarh.

In Chennai, there is a cluster around 1 kW systems. Tamil Nadu, until recently, had the Chief Minister's Solar Rooftop Capital Incentive Scheme that provided an additional subsidy of INR 20,000 for systems under 1 kW, thus explaining the preference of consumers in Chennai to opt for 1 kW systems. Moreover, according to the net-metering regulations of the Tamil Nadu Electricity Regulatory Commission dated November 2013, any electricity export exceeding 90 percent of the consumer's electricity imports will be treated as lapsed. This disincentivizes consumers in Chennai to opt for larger systems.

In Nagpur, the electricity exported by the consumer is adjusted against the electricity imported each month. Any net export each month is carried forward to the next month till the end of the financial year, when any excess unbalanced exports are purchased from the consumer by the utility at the APPC (average power purchase cost) for that year, fixed by the Maharashtra Electricity Regulatory Commission. Because Nagpur has one of

Figure 8 | **Difference in Payback Periods with and without Subsidy (See Appendix B for Calculations and Assumptions Used)**



Source: WRI Survey Analysis.

the highest domestic electricity tariffs, it is usually higher than the APPC. This means that the consumer gains more per kW by adjusting the exports against the imports than by selling the net exports to the utility.

In Jaipur, electricity exported by net-metered consumers is adjusted against their bills until their net export reaches 50 units. If the net export crosses 50 units, the utility pays consumers at a rate higher than the average tariff, creating incentives to install bigger systems.

The mapping of the city-wise cost versus system capacity scatter plot shows how consumers' incentives and preferences are influenced by the specific regulatory characteristics of each city. Financing options that address these specificities have the potential to capture this upcoming market.

Customization to cater to the unique needs of residential consumers

Residential sector is different from other sectors in at least the following ways:

- Re-saleability: Rooftop solar PV systems, unlike other retail consumer durable goods, do not have a resale market.[20] This poses a potential risk for banks, should a consumer default or in the eventuality of failure of a system.
- Disproportionate collateral: Given the issues with re-saleability, the risk exposure that banks face, and the unique nature of rooftop PV systems (versus other products), consumers are asked to provide their houses (into which the system will be installed) as collateral. This can be a significant disincentive, given that the rooftop solar system costs only a few lakhs, while the houses cost several times over.

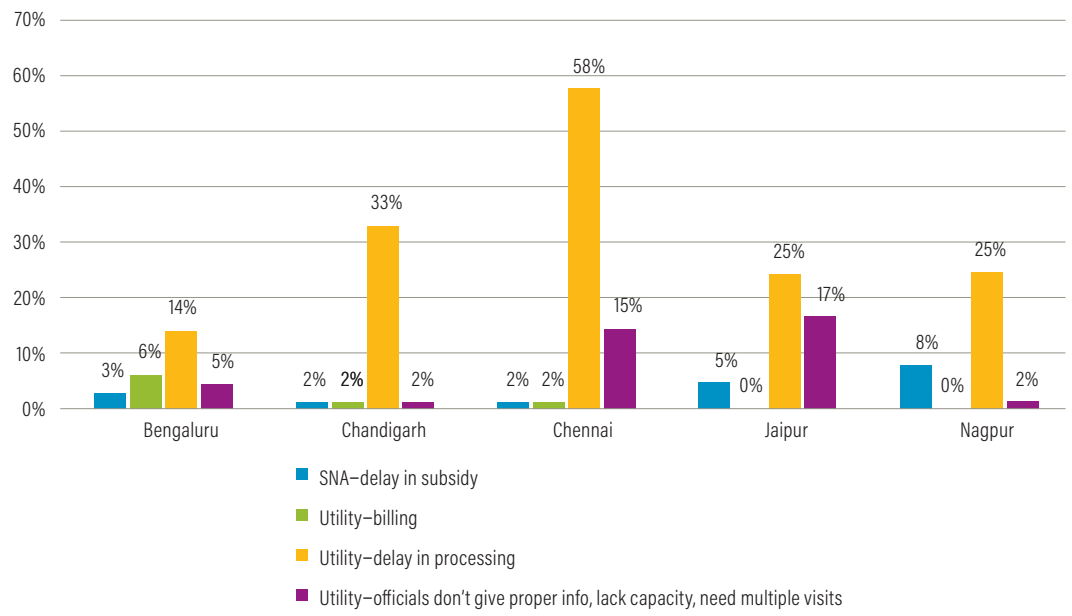
Financing options acknowledging the uniqueness of a residential consumer and catering to city-specific needs, can effectively address the monetary barriers to uptake of residential rooftop solar PV systems.

Lack of Coordination, Institutional Priorities, and Processes

The main institutional players that consumers deal with include the electricity utility and the SNA. As with other sectors, the overall vision for the rooftop solar market is set by the Energy Department of the state government. In some cities, agencies like the Urban Local Bodies (ULBs) or the Urban Planning Department also have some role to play. For example, in Nagpur, the ULB has been a key promoter of residential rooftop solar. In Chandigarh, the building regulations set by the Urban Planning Department affect the decision-making process for residential consumers regarding rooftop solar installation.

A lack of effectively managed mandates of different government agencies can result in confusion for the consumers. In Chandigarh, the mandates of the Energy Department and the Urban Planning Department are aligned, in theory, toward promoting rooftop solar. While the Energy Department has been actively pushing for the promotion of rooftop solar in Chandigarh, the architecture wing of the Department of Urban Planning stipulates building rules, for rooftop solar.[21] However, some of the latter pose difficulties for residential consumers who are considering installing rooftop solar. The rules detail specifications that have been seen to hinder the optimal functioning of the solar PV panels. The stipulations include the requirement that installations be at a maximum height of 10 feet and at least 10 feet away from the front, rear, and sidewalls and 4 feet away from common walls. There are also restrictions in the construction of permanent staircases to the panel, further hampering access to clean and maintain the systems.

Figure 9 | **Percentage of People Who Faced Challenges in Dealing with Institutions, by City**

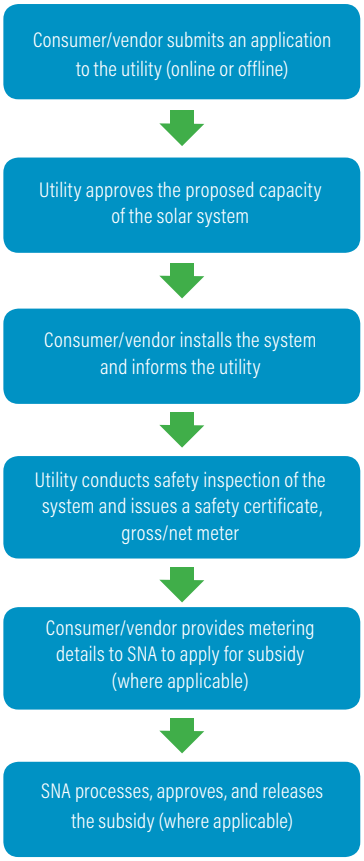


Source: WRI Survey Analysis.

Another type of inconsistency in institutional priorities is within the energy sector actors themselves, as observed in Chennai. The distribution utility perceives promotion of rooftop solar to be in conflict with the traditional grid-based power supply. This is seen in the challenges reported by consumers, as shown in Figure 9. Respondents in Chennai reported the highest instances (over 58 percent) of delays in processing by the distribution utility. Over 90 percent of them specifically mentioned delays in obtaining net meters from the electricity utility. These delays were reported to range from two to six months, despite a clear net-metering policy approved by the State Electricity Regulatory Commission. This points to a mismatch in the priorities of the electricity utility with the solar ambitions of the state.

In addition to the lack of streamlined mandates, respondents spoke of several delays in the process for solar rooftop installation. The decision to install rooftop solar involves a consumer having to obtain permission from multiple agencies and departments. This also increases the transaction costs of the individual consumers. Across all cities, the broad processes that consumers go through to obtain the necessary approvals are shown in Figure 10.

Figure 10 | **Steps in the Approval Process for Residential Rooftop Solar**



Source: WRI authors.

Although the processes to be followed are clearly laid out in all the cities, consumers report challenges, such as delays in processing subsidy and net-metering applications, challenges in billing, the need for multiple visits, and the lack of capacity of the officials to provide sufficient information and guidance. This insufficient capacity of officials to deal with paperwork points to a mismatch in how institutions state what their priorities are and how they strengthen their capacities to deliver on them. Addressing these issues will be crucial to enhancing the consumer experience.

CONCLUSION

India has established ambitious goals for solar deployment. Early data and the results of this survey may indicate that more work needs to be done to satisfy the requirements for achieving 20 GW of residential rooftop solar. Outreach to consumers is one of the major needs. Our study finds that 49 percent of respondents remained unaware of the technologies or how they could apply them to their households. While diverse market conditions in Indian cities and states mean that the economics and rules vary, the information needed by consumers regarding product specifications, pricing, reliability, and the economics of these technologies could be provided via a standardized information sheet, per market.

Our study made three key observations:

- There is low awareness among consumers about the use of solar PV as a technology to produce electricity. The sources of information that they rely on tend to lack objectivity and clarity. Efforts to improve awareness need to be undertaken by relevant stakeholders, including the government and civil society organizations, to ensure that information is made available in an accurate manner across relevant media.
- Where available, consumers indicate a tendency to seek subsidy. Our survey also discovered that many of the installations were financed by the consumers themselves, thus indicating an interest in uptake of solar PV among a certain class of residential electricity consumers. These decisions, as well as those pertaining to the size of systems, are also informed by the local regulatory contexts prevailing in the cities. Developing financial products that acknowledge the unique characteristics of rooftop solar PV and that are sensitive to the city contexts in terms of subsidies and approvals can assist consumers in addressing the financial barriers limiting their decision to install rooftop solar.
- Consumers experience confusion over procedures and delays in approvals due to institutional inconsistencies and lack of coordination in the priorities and processes set by these institutional bodies. One of the first steps to mitigate these challenges is to enhance the capacities of the relevant officials, especially those tasked with interacting with the consumers during the stage of applying and seeking approvals to install rooftop solar.

Given the need for proactive engagement on the part of the consumer, addressing the issues of consumers is crucial to catalyze the uptake of rooftop solar PVs. This requires effective dissemination of objective information about solar PV in an easy-to-understand format that is accessible to consumers. Such information could be better supported through information campaigns locally or third-party experts or trusted community partners like civil society groups and resident welfare associations.

Customized offerings, competitive rates, and convenient processes for financing rooftop solar can facilitate faster deployment of systems. Loans to finance the installation of solar PVs need to be rethought, keeping in mind the unique characteristics of the product and the risks associated with it. This will also require awareness-building among members of the financial community.

Prioritizing the provision of easy-to-understand, hassle-free processes for billing and approvals can go a long way toward enhancing the consumer experience of installing solar PV. This can involve everything from equipping local utility officials with adequate capacity and training in processing paperwork to investing in technology for automation of bills so that consumers' requests can be processed in a timely manner.

Our study indicates that consumer experiences and issues are context-specific. Therefore, any top-down approach to facilitate deployment of residential rooftop solar must be complemented by bottom-up initiatives by multiple stakeholders—including local government structures, utilities, resident welfare associations, vendors, and civil society—while keeping the rights and welfare of the consumer in mind.

Appendix A | Household Questionnaire Template

	QUESTIONS	RESPONSES	COMMENTS
1	Interviewer Details		
1.1	Name of the Interviewer		
1.2	Accompanied by		WRI, local partner
1.3	City		
1.4	Date of the Interview		
2	Details of the Dwelling – Section 2 Onward to Be Filled Based on Responses		
2.1	Ownership	a. Owned b. Rented	(If rented, please end the interview here)
2.2	Which of the following categories is applicable to you?	a. I have installed solar PV in my house b. I am in the process of installing solar PV in my house c. I have considered solar PV but have not yet decided d. I have never considered solar PV	
2.3	How many years old is the dwelling?		(Mention 999 for don't know)
2.4	For how many years have you been living here?		
2.5	Is this an independent house with a personal roof?	a. Yes b. No	If no, skip to 2.6
2.5a	Is it in a gated complex?	a. Yes b. No	If, no skip to 2.5h
2.5b	How many plots are there in the community?		(Mention 999 if the answer is don't know)
2.5c	How many built houses are there in the community?		(Mention 999 if the answer is don't know)
2.5d	Does the community have common areas like a clubhouse with flat roof space that can be used for solar for electricity generation?	a. Yes b. No	If no, skip to 2.5h
2.5e	Does the community already have a solar rooftop system for electricity generation on the common area roof?	a. Yes b. No	
2.5f	Who would be the right person to contact to understand about the solar system for electricity generation on the common area roof?		(Mention 999 if the answer is don't know, 888 if the question is not applicable)
2.5g	Does the community have an electricity backup for the houses and common areas?	a. Yes, it has diesel genset b. No power backup for the community c. Other (specify)	
2.5h	In your house, there are how many floors including basement?		

	QUESTIONS	RESPONSES	COMMENTS
2.5i	Is this house occupied only by your family, or have you rented out one or more floors to someone?	a. No rental b. Yes, we have rented to one or more families	
2.5j	Roof type	a. Sloping b. Flat c. Other	
2.5k	Total flat roof space	a. Specify in square feet b. Don't know c. Not applicable, do not have flat roof space	(In a, if response is not in sq.ft, specify the unit) Move to Section 3 after this question
2.6	Is this a flat in an apartment building?	a. Yes b. No	
2.6a	Is it in a gated complex?	a. Yes b. No	If no skip to 2.6 g
2.6b	How many buildings are there in the complex?		
2.6c	Does the complex have common areas like a clubhouse with flat roof space that can be used for solar for electricity generation?	a. Yes b. No	
2.6d	Does the complex already have a solar rooftop system for electricity generation on the common area roof?	a. Yes b. No	
2.6e	Who would be the right person to contact to understand about that solar system on the common area?		(Mention 999 if the answer is don't know, 888 if the question is not applicable)
2.6f	Does the complex have an electricity backup for the houses and common areas?	a. Yes, it has diesel genset b. No power backup for the complex c. Other (specify)	
2.6g	On which floor is your flat?		
2.6h	How many floors are there in the building?		
2.6i	Roof space ownership in your building	a. Commonly owned by all property owners b. Each owner has designated roof space c. Other (specify) d. Don't know	
2.6j	Roof type of your building	a. Sloping b. Flat c. Other (Specify)	
2.6k	Total flat roof space on your building	a. Specify in square feet b. Don't know c. Not applicable, do not have flat roof space	(In a, if response is not in sq.ft, specify the unit)
3	Electricity Connection and Consumption Details		
3.1	Total electricity connection load for your house/flat (kW or kV) (sanctioned load by utility)		(Mention 999 if the answer is don't know)

	QUESTIONS	RESPONSES	COMMENTS
3.1 a	What is the tariff category you fall into (LT or HT)?		(Mention 999 if the answer is don't know)
3.2	When is the electricity consumption highest in the day	a. 7–10 a.m. b. 10 a.m.–1 p.m. c. 1–4 p.m. d. 4–7 p.m. e. 7–10 p.m.	
3.3	What appliances are responsible for this high electricity consumption?	a. Geyser b. AC c. Other (specify)	Select all applicable options
3.4	Do you have a personal backup power for your house/flat? If so what backup do you use?	a. Diesel generation set (DG set) b. UPS c. Other (specify) d. I don't have power backup	If a is selected, then go to 3.4a else skip to 3.5
3.4 a	If you use a DG set, how much do you spend per month on it?	a. Specify in Rupees b. Don't know c. Not applicable, do not use DG set	
3.5	Do you face power cuts?	a. Yes b. No	If no, skip to 3.6
3.5 a	How many hours of power outage do you witness on an average?	a. Less than 2 hours/day b. Between 2–5 hours/day c. More d. Other (if outage is not on a daily basis) (specify)	
3.6	Do you have a solar water heater installed?	a. Yes b. No	If yes, ask 3.6a Otherwise skip to section 4
3.6 a	How much area does the solar water heater occupy on your roof?	a. Specify in square feet b. One-third of flat roof space c. Half of flat roof space d. Don't know	(In a, if response is not in sq.ft, specify the unit)
4	Status of Solar Rooftop PV Installation for Electricity Generation		
4.1	Have you Installed solar PV for electricity generation?	a. Yes b. No	If yes, go to section 5
4.2	Are you in the process of installing solar PV?	a. Yes b. No	If yes, answer 4.2a and then go to section 5. If no, go to section 6
4.2 a	If you are in the process, at what stage are you in?	a. Speaking to vendors a. Placed the order with vendor, but not yet installed b. Waiting for approvals c. Waiting for commissioning of the system d. Other	
5	Customers Who Have Installed – Or Are in the Process of Installing		
	Background		
5.1	When did you install solar PV for electricity generation (year)?		Mention 888 if the question is not applicable

	QUESTIONS	RESPONSES	COMMENTS
5.2	Why did you consider solar PV?	a. Cleaner way to produce power that is good for the environment b. For generating own power c. Solar is cheaper d. Solar is more reliable e. Someone I know has gone for solar f. Other (specify)	Select all applicable options
5.3	How did you get to know of solar PV for houses?	a. References from friends, neighbors, family b. Vendor approached me c. Ads/news in media d. Other (specify)	Select all applicable options
5.4	Was there anyone in family or outside who encouraged you to make the decision?	a. Yes (specify who, if there is anything else to add) b. No (specify if there is anything else to add)	Space given is to capture qualitative responses to this question
5.5	What was the time taken to make the decision to install solar?	_____months	
5.6	What was the time taken from decision-making to completion of installation?	_____months	Mention 888 if not applicable
5.7	Has the solar rooftop system affected any activity that you conducted on the roof before you had solar? What activity has been affected?	a. Drying b. Gardening c. Other (specify) d. Nothing in particular	Select all applicable options
	Type of Solution		
5.8	Have you installed or are you in the process of installing a hybrid solar system?	a. Yes b. No	If no, skip to 5.9
5.8a	What is the capacity of the system in kW?		(Mention 999 if the answer is don't know)
5.8b	What is the name of the hybrid inverter company?		(Mention 999 if the answer is don't know)
5.8 c	What is the battery capacity?		(Mention 999 if the answer is don't know)
5.8 d	What appliances are connected to the battery?		(Mention 999 if the answer is don't know)
5.8 e	What was your average electricity bill amount before you installed the hybrid system?	I paid_____to the utility against each bill	
5.8 f	What is your average electricity bill amount after you installed the hybrid system?	a. I pay_____to the utility against each bill b. I get_____from the utility against each bill c. I get paid _____at the end of the financial year from the utility d. Other (specify)	(Mention 999 if the answer is don't know, 888 if the question is not applicable)

	QUESTIONS	RESPONSES	COMMENTS
5.8 g	How many units of electricity do you export to the grid each month?		(Mention 999 if the answer is don't know, 888 if the question is not applicable)
5.8 h	What is the rate per unit that the utility gives you for the power you supply to grid?	a. _____Rs/units b. Don't know	(Mention 999 if the answer is don't know, 888 if the question is not applicable)
5.8 i	How much roof area does it occupy?	a. Specify in square feet b. One-third the roof space c. Half the roof space d. Don't know	(In a, if response is not in sq.ft, specify unit) After this, move to section 5.11
5.9	Have you installed or are you in the process of installing an off-grid system?	a. Yes b. No	If no, skip to 5.10
5.9 a	What is the capacity of the system in kW?		(Mention 999 if the answer is don't know)
5.9 b	What is the capacity of the battery?		(Mention 999 if the answer is don't know)
5.9 c	What appliances are connected to the battery?		(Mention 999 if the answer is don't know)
5.9 d	What was your average electricity bill amount before you installed the off-grid system?	I paid _____to the utility every billing cycle	
5.9 e	What is your average electricity bill amount after you installed the off-grid system?	I now pay _____to the utility every billing cycle	(Mention 888 if the question is not applicable)
5.9 f	How much roof area does it occupy?	a. Specify in square feet b. One-third the roof space c. Half the roof space d. Don't know	(In a, if response is not in sq.ft, specify unit) After this, move to section 5.11
5.10	Have you installed or are you in the process of installing a grid connected solar system?	a. Yes b. No	
5.10 a	What is the capacity of the system in kW?		(Mention 999 if the answer is don't know)
5.10 b	On an average, how many hours per day are you not able to export power into the grid?		(Mention 999 if the answer is don't know)

	QUESTIONS	RESPONSES	COMMENTS
5.10 c	What was your average electricity bill amount before on-grid solar?	I paid _____to the utility against each bill	
5.10 d	What is your average electricity bill amount after on-grid solar?	a. I pay _____to the utility against each bill b. I get _____ from the utility against each bill c. I get paid _____ at the end of the financial year from the utility d. Others (specify)	(Mention 999 if the answer is don't know, 888 if the question is not applicable)
5.10 e	How many units of electricity do you export to the grid per month?		(Mention 999 if the answer is don't know, 888 if the question is not applicable)
5.10 f	What is the rate per unit that the utility gives you for the power you supply to the grid?	a. _____Rs/units b. Don't know	(Mention 999 if the answer is don't know)
5.10 g	How much roof area does it occupy?	a. Specify in square feet b. One-third the roof space c. Half the roof space d. Don't know	In a, if the answer is not in sq.ft, specify unit
Experience During Selection Phase of Vendors			
5.11	What channels did you use to connect with vendors?	a. Vendor approached us b. Word of mouth c. Internet search d. News from TV, newspapers, and social media e. Through tender notice in newspapers f. Others (specify)	Select all applicable options
5.12	How many vendors did you talk to?		
5.12 a	Name the vendor who finally provided the services		
5.13	What was the basis for filtering out and deciding the vendor for installation?	a. Offered the best price b. Vendor came with good recommendations. c. Vendor shared all details about the technology, cost, and installation process d. Vendor committing to post sales services. e. Other (specify)	Select all applicable options
5.14	Among the options given, which do you feel was the most difficult?	a. Connecting with the vendors b. Verifying if vendor is trustworthy c. Verifying if the price offered by the vendor is appropriate d. Other (specify)	
5.15	Who else in the installation supply chain did you have to engage with for installation? What was the purpose of the engagement?	a. Electrical utility _____ b. Financial institutions _____ c. Others (specify)	Select all applicable options. Mention purpose of engagement against each

	QUESTIONS	RESPONSES	COMMENTS
Technology Experience			
5.16	Among the options given, which do you feel was the most difficult?	a. Identification of the right solution _____ b. Installation of the system _____ c. Operation and maintenance of the system _____ d. Others (specify)	
5.17	Mention challenges (if any) faced in identifying the right solution, installation, maintenance, operation, or anything else		Mention 888 if question is not applicable
Financing Experience			
5.18	Total cost of the system in Rupees		
5.19	Did you know of subsidies for solar PV?	a. Yes b. No	if No, skip to question 5.20
5.19 a	Source of information for subsidies	a. Vendor b. Internet search c. News/ads in media d. Others (specify)	
5.19 b	Did you apply for subsidies?	a. Yes b. No	If no, skip to 5.20
5.19 c	How much subsidy did you get (in %)?		
5.20	Did you know of loans for solar PV?	a. Yes b. No	if No, skip to question 5.21
5.20 a	Source of information on loans	a. Vendor b. Internet search c. News/ads in media d. Inquiring with financial institutions e. Others	
5.20 b	Did you apply for loans?	a. Yes b. No	
5.20 c	Did you get the loan?	a. Yes b. No	If no, skip to 5.23
5.20 d	How much loan did you get?		
5.20 e	Name the institutions you approached for the loan		
5.20 f	Name the institution that gave you the loan		
5.20 g	What is the interest rate (in %)?		Skip to 5.23
5.21	Did you end up self-financing it after considering loan and subsidy?	a. Yes b. No	
5.22	Did you know that you would self-finance it from the beginning?	a. Yes b. No	

	QUESTIONS	RESPONSES	COMMENTS
5.23	What kind of help did the vendor provide for financing?	a. Vendor did not help in financing at all b. Vendor provided various financing options but did not explain everything c. Vendor provided various financing options and explained everything d. Other (specify)	
5.24	Has your system recovered the costs?	a. Yes b. No c. Don't know	Mention 888 if the question is not applicable
5.25	Among these options given, which do you believe was the most difficult, based on what option you tried?	a. Availing subsidy b. Availing bank loan c. Availing NBFC loan d. Arranging for self-financing e. Others (specify)	
5.26	Challenges (if any) faced in getting subsidy, loan, or anything else on financing		If respondent says he took subsidy or tried for it, specifically ask him about issues with subsidy. If respondent says if he took loan or tried for loan, specifically ask him about issues with loan. Mention 888 if question is not applicable
Regulatory Experience			
5.27	Are you aware of the rooftop solar regulations or policies for the residential sector?	a. Yes b. No	Details on tariff, net-metering etc. If no, skip to 5.28
5.27 a	What was your source of information?	a. Vendor b. Internet search c. News/ads in media d. Others (specify)	
5.28	What permissions did you have to seek?	a. Net metering b. Building permit to get solar rooftop installed c. Others (specify) d. Don't know, vendor took care of everything	Select all applicable options
5.29	How many months did it take to get the permissions?	a. Net-metering _____ b. Building permit to get solar rooftop installed _____ c. Others (specify) d. Don't know, vendor took care of everything	Select all applicable options
5.30	Which govt. agencies/departments did you have to visit? Please mention purpose of engagement against each	a. Electrical utility, purpose of engagement _____ b. Others and purpose (specify) c. Don't know, vendor took care of everything	Select all applicable options

	QUESTIONS	RESPONSES	COMMENTS
5.31	Challenges (if any) in engaging with electrical utility	a. Had to make multiple visits b. Officials were not properly trained to handle solar PV issues c. Officials were properly trained but were not helpful d. Delays in processing documents e. Delays in arranging inspection visits f. I do not get my new bill on time g. Other (specify) _____ h. Don't know, vendor took care of everything	Select all applicable options
5.32	Positive aspects of engaging with electrical utility	a. Didn't have to make multiple visits b. Officials were properly trained to handle solar PV issues c. Officials were not properly trained but were helpful d. There was no delay in processing documents e. There was no delay in arranging site visits f. Billing process is smooth g. Other (specify) _____ h. Don't know, vendor took care of everything	
5.33	Any other challenges faced with regulations or government agencies or if you want to add details to the issues covered above		Ask respondent about the experience with the utility and billing experience so far Mention 888 for not applicable
5.34	Mention challenges related to the awareness levels and perceptions about solar		Mention 888 for not applicable
Recommendations and Referrals			
5.35	Among the options given, which do you feel was the most difficult? Why was it so?	a. Unsatisfactory vendor services_____ b. Technology, operations, maintenance issues _____ c. Getting financing_____ d. Dealing with electrical utility _____ e. Dealing with any other government agency _____ f. Other_____	
5.36	Can you recommend what can be done to improve each of these processes?	a. Vendor services _____ b. Technology, operations, maintenance issues _____ c. Getting financing _____ d. Dealing with electrical utility _____ e. Dealing with any other government agency _____ f. Other _____	Mention 888 if not applicable
5.37	Have you recommended solar to anyone?	a. Yes b. No	
5.38	Will you recommend solar to anyone in the future?	a. Yes b. No	
5.39	Has anyone adopted solar based on your recommendation?	a. Yes b. No	

	QUESTIONS	RESPONSES	COMMENTS
5.40	Can you name people in your community who have decided not to install solar or who have installed solar? May we interview them?	a. Yes, please share name, phone number and address _____ b. No, I cannot name anyone	Skip to section 7
Customers Who Have Not Installed – Decided Not to After Considering, Not Considered at All			
6.1	Do you know the difference between solar water heater and solar rooftop PV for electricity generation?	a. Yes b. No c. Somewhat, not very clear about the difference	
6.2	Do you know how solar rooftop PV works?	a. Yes, I know exactly how it works b. Yes, I know a little c. No, I don't know how it works	
6.3	What do you use the roof space for?	1. Drying 2. Gardening 3. Nothing in particular 4. Other (specify) _____	Select all applicable options
6.3 a	Would you be willing to use roof space for installing a solar PV system in the future?	a. Yes b. No	
6.4	What is your monthly electricity bill in Rupees?		
6.5	Have you considered solar at all?	a. Yes b. No	If no, skip to 6.6
6.5 a	Why did you consider solar?	a. Cleaner way to produce power, which is good for the environment b. For generating own power c. Solar is cheaper d. Solar is more reliable e. Someone I know has gone for solar f. Other (specify) _____	Select all applicable options
6.5 b	How did you get to know of solar PV for houses?	a. References from friends, neighbors, family b. Vendor approached me c. Ads/news in media d. I took the initiative to find out more e. Other (specify) _____	Select all applicable options
6.5 c	Was there anyone within the family or outside who encouraged you to make the decision?	a. Yes, (specify who, anything else you want to add) _____ b. No, (specify anything else you want to add) _____	
6.5 d	Have you made a decision not to install solar PV?	a. Yes (Specify reason) _____ b. No, I am still considering it and may install in the future	
6.5 e	Based on the stage at which you decided to not install or paused the process, what barriers did you face?	a. Lack of trustworthy vendor/lack of knowledgeable vendor b. Lack of awareness about technology c. Lack of financing knowledge and options d. Complicated policy and regulations e. Physical constraints like no space on the roof f. Other (specify) _____	Select all applicable options
6.5 f	Name the vendors you had interacted with		Mention 888 if the question is not applicable

	QUESTIONS	RESPONSES	COMMENTS
6.5 g	Please mention any challenges specific to the vendor or vendor services	a. Connecting with the vendors (elaborate) _____ b. Evaluating costs (elaborate) _____ c. Evaluating vendor support and services (elaborate) _____ d. Selecting vendor (elaborate) _____ e. Others (specify) _____ f. I haven't gone through any of these processes	Select all applicable challenges.
6.5 h	Please mention any challenges specific to the technology	a. Identification of the right solution (elaborate) _____ b. Installation of the system (elaborate) _____ c. Operation of the system (elaborate) _____ d. Maintenance of the system (elaborate) _____ e. Others (specify) _____ f. I haven't gone through any of these processes	Select all applicable challenges.
6.5 i	Please mention any challenges specific to financing	a. Availing subsidy (elaborate) _____ b. Availing bank loan (elaborate) _____ c. Availing NBFC loan (elaborate) _____ d. Arranging for self-financing (elaborate) _____ e. Others (specify) _____ f. I haven't gone through any of these processes	Select all applicable challenges.
6.5 j	Please mention any challenges specific to regulatory practices	a. Net metering (elaborate) _____ b. Building permit to get solar rooftop installed (elaborate) _____ c. Others (specify) _____ d. I haven't gone through any of these processes	Select all applicable challenges.
6.5 k	Please mention any challenges specific to physical constraints	a. Roof being used for other purposes (elaborate) _____ b. Lack of space, small roof, tiled or sheeted roof (elaborate) _____ c. Inability to divide the roof space (in case of flat in apartment complex) (elaborate) _____ d. Inability to get buy-in of other roof owners (elaborate) _____ e. Others (specify) _____ f. I don't have any physical constraints	Select all applicable challenges.
6.5 l	What are the challenges related to the awareness levels and perceptions about solar?		(Mention 888 if question is not applicable)
6.5 m	Other challenges		(Mention 888 if question is not applicable)
6.5 n	Which processes were the most difficult for you?	a. Lack of trustworthy vendor/lack of knowledgeable vendor b. Lack of awareness about technology c. Lack of financing knowledge and options d. Complicated policy and regulations e. Physical constraints like no space on the roof f. Other (specify) _____	
6.5 o	Based on your decision not to install solar after considering it, can you give specific recommendations for the following:	a. Improving awareness b. Vendors c. Financial institutions d. Regulators and policymakers e. Others (specify) _____	Skip to section 7

	QUESTIONS	RESPONSES	COMMENTS
6.6	Why have you not considered solar yet?	a. I don't know about solar b. I know about solar, but I don't know further details c. Not value for money d. Have heard bad reviews e. Physical constraints like lack of roof space f. Others (specify) _____	Select all applicable options.
6.7	Do you have any other concerns or worries about installing a rooftop solar PV system?		Please capture general perception of the person being interviewed
6.8	Under what circumstances will you consider solar in the future?	a. When I renovate the house (elaborate) _____ b. When more favorable subsidy, loan becomes available (elaborate) _____ c. I need more information to make a decision (elaborate) _____ d. Others (specify) (elaborate) _____	
7	Details of the respondent		
7.1	Name of the respondent		
7.2	Phone number		Numerical only
7.3	Email id		
7.4	Age		
7.5	Gender	a. Male b. Female	
7.6	Occupation		
7.7	Address		
7.8	Any other comments or feedback		

Appendix B | City-Wise Payback Calculations

CITY AND METERING		SYSTEM CAPACITY AND ELECTRICITY CONSUMPTION					NET- OR GROSS-METERING TARIFF		
CITY	METERING TYPE (NET OR GROSS)	ENERGY CONSUMED (KWH)	AVERAGE TARIFF RATE (INR/ KWH)	SYSTEM CAPACITY (KW)	ENERGY GENERATED PER MONTH (KWH)	MONTHLY ELECTRICITY BILL BEFORE (INR)	WITHOUT SUBSIDY (INR PER KWH)	WITH SUBSIDY (KWH)	SOURCE
Bengaluru	Gross-Metering	300	5.5	3	360	1661	7.08	6.03	KERC tariff order for solar rooftop and small solar PV power plants dated May 2016[a]
Bengaluru	Gross-Metering	500	6.1	3	360	3050	7.08	6.03	
Bengaluru	Gross-Metering	1000	6.5	3	360	6500	7.08	6.03	
Bengaluru	Gross-Metering	1500	6.6	3	360	9900	7.08	6.03	
Chandigarh	Net-Metering	300	3.2	3	360	953	8.51	6.14	JERC net-metering regulations dated March 2015
Chandigarh	Net-Metering	500	3.5	3	360	1750	8.51	6.14	
Chandigarh	Net-Metering	1000	3.7	3	360	3700	8.51	6.14	
Chandigarh	Net-Metering	1500	3.7	3	360	5550	8.51	6.14	
Chennai	Net-Metering	300	4.4	3	360	1313	0	0	
Chennai	Net-Metering	500	5.3	3	360	2650	0	0	
Chennai	Net-Metering	1000	5.9	3	360	5900	0	0	
Chennai	Net-Metering	1500	6.2	3	360	9300	0	0	
Jaipur	Net-Metering	300	5.8	3	360	1750	6.74	6.74	RERC tariff order dated June 2015
Jaipur	Net-Metering	500	6.2	3	360	3100	6.74	6.74	
Jaipur	Net-Metering	1000	6.7	3	360	6700	6.74	6.74	
Jaipur	Net-Metering	1500	6.8	3	360	10200	6.74	6.74	
Nagpur	Net-Metering	300	5.5	3	360	1637	3.75	3.75	2014-15 APPC approved by MERC
Nagpur	Net-Metering	500	7.1	3	360	3550	3.75	3.75	
Nagpur	Net-Metering	1000	9.1	3	360	9100	3.75	3.75	
Nagpur	Net-Metering	1500	10.2	3	360	15300	3.75	3.75	

Appendix B | City-Wise Payback Calculations (Cont.)

NET-METERING					INSTALLATION COST				APPROX. PAYBACK PERIOD (IN YEARS)			
NET BILLED UNITS AFTER SOLAR (KWH)	MONTHLY ELCTRICITY BILL AFTER SOLAR (INR)	SAVING PER MONTH (INR)	EARNINGS PER MONTH (INR) WITHOUT SUBSIDY	EARNINGS PER MONTH (INR) WITH SUBSIDY	BENCH-MARK COST (INR/KW)	TOTAL COST WITHOUT SUBSIDY	CENTRAL SUBSIDY	COST WITH SUBSIDY (INR/KW)	PAYBACK WITHOUT SUBSIDY	PAYBACK WITH SUBSIDY	DIFFER-ENCE IN PAY BACK PERIOD	AVERAGE DIFFER-ENCE IN PAYBACK PERIOD
-60	1660.8	0	2549	2171	75000	225000	67500	157500	7	6	1	1
140	3050	0	2549	2171	75000	225000	67500	157500	7	6	1	
640	6500	0	2549	2171	75000	225000	67500	157500	7	6	1	
1140	9900	0	2549	2171	75000	225000	67500	157500	7	6	1	
-60	0	953	0	0	75000	225000	67500	157500	20	14	6	5
140	490	1260	0	0	75000	225000	67500	157500	15	10	4	
640	2368	1332	0	0	75000	225000	67500	157500	14	10	4	
1140	4218	1332	0	0	75000	225000	67500	157500	14	10	4	
-60	0	1313	0	0	75000	225000	67500	157500	14	10	4	3
140	742	1908	0	0	75000	225000	67500	157500	10	7	3	
640	3776	2124	0	0	75000	225000	67500	157500	9	6	3	
1140	7068	2232	0	0	75000	225000	67500	157500	8	6	3	
-60	0	1750	404	404	75000	225000	67500	157500	9	6	3	2
140	868	2232	0	0	75000	225000	67500	157500	8	6	3	
640	4288	2412	0	0	75000	225000	67500	157500	8	5	2	
1140	7752	2448	0	0	75000	225000	67500	157500	8	5	2	
-60	0	1637	225	225	61000	183000	54900	128100	8	6	2	2
140	994	2556	0	0	61000	183000	54900	128100	6	4	2	
640	5824	3276	0	0	61000	183000	54900	128100	5	3	1	
1140	11628	3672	0	0	61000	183000	54900	128100	4	3	1	

Note: [a]The latest notification in this regard is the Official Memorandum on Determination of Tariff and Other Norms in Respect of Grid-Connected SRTPV in BESCOM, dated June 21, 2018. However, all the installations we surveyed were installed before this date. Hence, we have used the previous KERC Tariff Order for SRTPV FY17–18, dated May 2, 2016.

Appendix C | City-Wise Number of Households Surveyed across Types of Residential Consumers

CITIES	INSTALLED	CONSIDERED	NOT CONSIDERED	TOTAL
Bengaluru	63	5	298	366
Chandigarh	63	31	267	361
Chennai	62	97	201	360
Jaipur	77	34	250	361
Nagpur	60	56	244	360
Total	325	223	1,260	1,808

ENDNOTES

1. MNRE Programme/Scheme-wise Physical Progress in 2018—19 & Cumulative up to July 2018. https://mnre.gov.in/physical-progress-achievements.
2. Under a traditional grid connection, where the transmission and distribution infrastructure already exists, a consumer only needs to get a wire connected to the grid to access electricity. However, under rooftop solar, since the generation will happen on the consumer's premises, s/he is expected to take the initiative in understanding the system, how it is installed, and maintaining the system.
3. New directives from the draft SRISTI (Sustainable Rooftop Implementation for Solar Transfiguration of India) scheme that has proposed the residential sector's target at 5 GW.
4. MNRE Programme/ Scheme-wise Physical Progress in 2018—19 & Cumulative up to July 2018. https://mnre.gov.in/physical-progress-achievements.
5. MNRE's current Grid Connected Rooftop and Small Solar Power Plants program provides Central Financial Assistance for 2100 MW of rooftop solar in these segments. Numbers taken from MNRE Programme/ Scheme-wise Physical Progress in 2018—19 & Cumulative up to July 2018. https://mnre.gov.in/physical-progress-achievements.
6. India Solar Handbook, Bridge to India, 2014. http://www.bridgetoindia.com/wp-content/uploads/2014/06/BRIDGE-TO-INDIA_THE-INDIA-SOLAR-HANDBOOK_June-2014-Edition.pdf.
7. India Solar Rooftop Map, Bridge to India, 2017. http://www.bridgetoindia.com/wp-content/uploads/2017/12/India-Solar-rooftop-Map-Dec.pdf.
8. The study is not to suggest how the increase in uptake could take place based on the mappings and characteristics of the consumers analyzed as part of the survey.
9. State Nodal Agencies (SNAs) were mandated by the MNRE (the central ministry responsible for the promotion of renewable energy) to plan and implement RE programs at the state level.
10. Tiers are a form of classification of cities that are based on their population based on the most recent census conducted by the Government of India. For our study, we selected two Tier 1 cities, namely Bengaluru and Chennai, and three Tier 2 cities—Chandigarh, Jaipur, and Nagpur—to enhance coverage and representation of different city categories.
11. Solar Cities is a program of the MNRE that aims to promote renewable energy and energy-efficiency measures at the city level.
12. Smart City Mission is an initiative of the Government of India's Ministry of Urban Development focusing on urban renewal and retrofitting of 100 Indian cities.
13. Twelve cities—Ajmer, Aurangabad, Bengaluru, Chandigarh, Gandhinagar, Jaipur, Kalyan-Dombivali, Nagpur, Nasik, Rajkot, Surat, and Thane—were shortlisted based on the above-mentioned criteria.
14. Given the rapid growth and expansion of cities, urban agglomeration data from Census 2011 is used as reference. http://censusindia.gov.in/2011-prov-results/paper2/data_files/India2/Table_3_PR_UA_Citiees_1Lakh_and_Above.pdf.
15. The subsidy scheme under the Jawaharlal Nehru National Solar Mission seeks to assist with the capital costs. The scheme provides a 40 percent subsidy on capital costs of solar PV systems in urban and rural areas across India.
16. These are solar developers who are enlisted by the SNA and/or by the MNRE based on the L1 price offered to install a rooftop solar system of 1 Kw and also the services they need to provide on a mandatory basis.
17. Thus far, the market penetration has mostly been in independent houses because they have sufficient roof space and the independence to decide how to use it, and in apartment complexes, these are common areas and hence require consensus (from the builder as well) in terms of how to use this space. We did, however, engage with RWAs during our city consultation workshops. There is interest, but only a few have implemented it thus far.
18. May 2016 Notification by Chandigarh Union Territory Administration. http://www.crestchd.org.in/Building.pdf.
19. Chandigarh Finance Department Draft Notification. http://chandigarh.gov.in/pdf/finance2017-dbr2017.pdf.
20. This could be attributed to several factors, such as the lack of a mature market for solar panels, to begin with, or absence of overall standards to manage this market.
21. Chandigarh Building Rules (Urban) 2017.

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We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

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