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PROSUMERS IN BENGALURU: LESSONS FOR SCALING ROOFTOP SOLAR PV

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EXECUTIVE SUMMARY

Like many cities in developing countries with rapidly growing urban centers, Bengaluru, in the Indian state of Karnataka, is struggling to meet its electricity demands. In September 2015, the city's electricity utility, BESCOM, fell short of peak demand—roughly 3,400 megawatts (MW)—by almost 900 MW. Heavily dependent on hydro, the state is increasingly vulnerable to erratic monsoon rainfall. Given the recent shortfalls and its dependence on diminishing hydro reserves, the city is looking to expand and diversify its electricity supply.

Rooftop solar photovoltaic (PV) systems that allow consumers to generate electricity at the point of consumption, and send any excess to the grid, have emerged as an attractive option. The Government of India has demonstrated its commitment to rooftop solar PV by setting ambitious targets: by 2022, India aims to hit a solar capacity of 100 gigawatts (GW), 40 GW of which is to come from rooftop systems. The state of Karnataka has set an ambitious goal of its own: 400 MW of grid-connected rooftop solar PV by 2018.[1]

Electricity consumers who produce their own electricity at the point of consumption and export their excess to the grid are known as "prosumers." Globally, residential prosumers account for a significant share of global PV capacity. The International Energy Agency estimated that, in 2013, between 25 percent and 35 percent of the global cumulative installed capacity of PV was owned by residential entities. Reasons for growth in the prosumer

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

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market are varied and include increasing retail electricity rates, as well as technology performance improvements and innovations that allow for greater consumer choice, such as cost reductions and availability of subsidies.

Net-metering is an arrangement through which solar PV system owners are credited for electricity that they export to the grid. In November 2014, BESCOM introduced a net-metering program after the Government of Karnataka's Solar Policy 2014–2021, and the Karnataka State Regulatory Commission's 2013 tariff order (BESCOM 2015b). As of March 2016, over 5.6 MW of grid-connected rooftop solar PV systems on 262 rooftops had been connected (BESCOM 2016). But, while Bengaluru is making progress in capacity addition, the pace of rooftop solar PV system adoption will need to accelerate if Karnataka is to meet its solar goals.

To better understand the current barriers to BESCOM's net-metering program, we interviewed a small set of local industry experts, project developers,[2] and customers who have installed or want to install a rooftop solar PV system. The interviews shed light on what may or may not be working successfully to date with BESCOM's net-metering program, and what may or may not be discouraging potential prosumers from participating in the future.

Based on the interviews, we identify six barriers that appear to be preventing a wider scale-up of rooftop solar PV in Bengaluru:

- Poor understanding of PV performance, cost, and payback
- Confusion on net-metering specifications
- Uncertainty in project developer selection and interaction
- Limited reach and appeal of the net-metering program
- Limited effect of the promotional net-metering rate
- Limited institutional capacity of the program administrator

Drawing on insights and suggestions from local industry experts, project developers, and customers, as well as the literature we reviewed, we offer initial recommendations for how program administrators and others can address these barriers:

- **To address limited understanding among prosumers**, program administrators can increase publicity and frequency of newspaper advertisements, and provide more detail on rooftop solar PV technology through lengthier articles or television reports. They can also facilitate information exchange through open knowledge-sharing platforms, and provide detailed information about realistic system costs and payback periods.
- **To address a lack of clarity on net-metering program specifications and processes,** program administrators can facilitate information exchange about net-metering program application, installation, and interconnection processes and specifications through online platforms or frequent prosumer gatherings. They can also develop concise program guidelines that specify each process in a step-by-step, easy-to-follow format, as well as expected timelines. These guidelines should include clear, up-to-date information about what is and is not allowed under the net-metering program.
- **To improve prosumer trust in project developers,** program administrators can offer an open certification process for developers, and an accessible and up-to-date list of certified developers to prosumers. Furthermore, program administrators can offer training and education programs for project developers, specifically about BESCOM's net-metering program specifications. These trainings will be useful for ensuring that project developers pass along the correct information to customers.
- **To expand the limited reach and appeal of the net-metering program,** program administrators can undertake market research to understand why the program appeals to some population segments more than others, and to identify how the program can be redesigned to reach a larger share of the population. Administrators can better promote the benefits of solar PV by highlighting community champions and stories of successful systems. Government agencies can also better promote current subsidy and loan programs, and create stronger and simpler financial incentives to lower the upfront cost of rooftop solar PV systems and attract interest from a broader range of residential customers.

- **To maximize the effectiveness of current incentives provided under the net-metering program,** program administrators should research the effectiveness of the promotional rate in attracting program adoption among the current prosumer demographic and large potential prosumer demographics. If the promotional rate is found to be effective, program administrators should more clearly and explicitly promote its economic benefits. If the rate is found ineffective, the funds supporting it can be redirected elsewhere.
- **To strengthen institutional capacity,** program administrators can introduce short-term solutions, such as streamlining approval procedures, as well as longer-term solutions, such as creating a "one window" unit that manages the entire net-metering process and provide specialized training sessions for employees.

INTRODUCTION

With over 9.6 million inhabitants, Bengaluru, in the state of Karnataka, is India's fourth largest city (India Ministry of Home Affairs 2011). BESCOM, Bengaluru's electricity utility, serves 8.9 million customers, 76 percent of whom are residential (KERC 2015).

Like many utilities serving rapidly growing urban centers in developing countries, BESCOM is struggling to supply sufficient power to meet demand. Bengaluru depends largely on hydro to meet its energy needs. However, because of technical challenges and dropping hydro reserves, BESCOM has recently fallen short of meeting peak demand—roughly 3,400 Megawatts (MW)—by as much as 900 MW (The Times of India 2015). To meet demand and minimize the risks associated with droughts and erratic monsoons, BESCOM will need to diversify its electricity supply.

Rooftop solar photovoltaic (PV) systems can help reduce the pressure to meet demand by providing electricity supply at the point of demand. Like other large developing cities, Bengaluru is promoting rooftop solar PV largely because of this benefit. A growing number of "prosumers"—energy consumers who produce their own energy at the point of consumption and export their excess to the grid—are installing rooftop solar PV systems in the city (See Box 1). In November 2014, BESCOM introduced a net-metering program that allows consumers who generate electricity from solar power to transfer their surplus to the grid (See Box 2). As of March 2016, the program had resulted in over 5.6 MW of grid-connected rooftop solar PV systems on 262 rooftops. However, the rate of new connections will need to accelerate if Karnataka is to meet its solar goal of 400 MW of grid-connected rooftop solar PV by 2018 (Government of Karnataka 2014)[3] (see Figure 1).

Box 1 | What Are Prosumers?

Prosumers are end-use consumers of electricity who also produce their own electricity at the point of consumption to meet their own electricity needs, to export electricity to "the grid" (the electricity system), or some combination of both. Simply, prosumers are electricity consumers interacting with the grid by generating some amount of electricity.

The increasing number of prosumers could transform the electricity system and the way in which all electricity consumers interact with it. In addition to the ability of prosumers to self-generate and connect with the grid, prosumers have the potential to help mitigate the growth of energy supply-demand gaps and electricity system losses. These potential benefits are particularly important at the city level, where almost two-thirds of the world's energy is consumed and where consumption is set to rise with rapid rates of urbanization globally (IPCC 2014).

Prosumers use a variety of renewable energy technologies and applications such as solar photovoltaic (PV), small wind turbines, and stationary fuel cells. The types of systems that prosumers install are categorized according to several different but related terms:

- Distributed systems: Power generation system connected to the distribution network (as defined by the voltage level) of the grid. This term can also refer to the geographically distributed nature or small capacity (typically under 1 MW) of the power generation system.
- Grid-connected: Any power generation system connected to the centralized electricity system can be referred to as "grid-connected."
- Rooftop solar PV (RTSPV): Solar PV systems that are installed on residential, commercial, or other rooftops. These systems can be either grid-connected or not grid-connected, but if they are grid-connected they are typically connected to the distribution network (i.e. a distributed system).

Box 2 | What Is Net-Metering?

Net-metering "allows residential and commercial [and other] customers who generate their own electricity from solar power to feed electricity they do not use back into the grid" (SEIA 2015b). Net-metering acts as "a billing mechanism that credits [electricity customers that are] solar energy system owners for the electricity they add to the grid." For example, if residential customers have a solar PV system on their rooftop, it may generate more or less electricity than it uses. At the end of a billing cycle, customers are presented with a single financial transaction and are only billed for their net energy use (energy consumed minus energy generated) (SEIA 2015b). Practically, net-metering policies are implemented and administered through programs run by local electricity utilities.

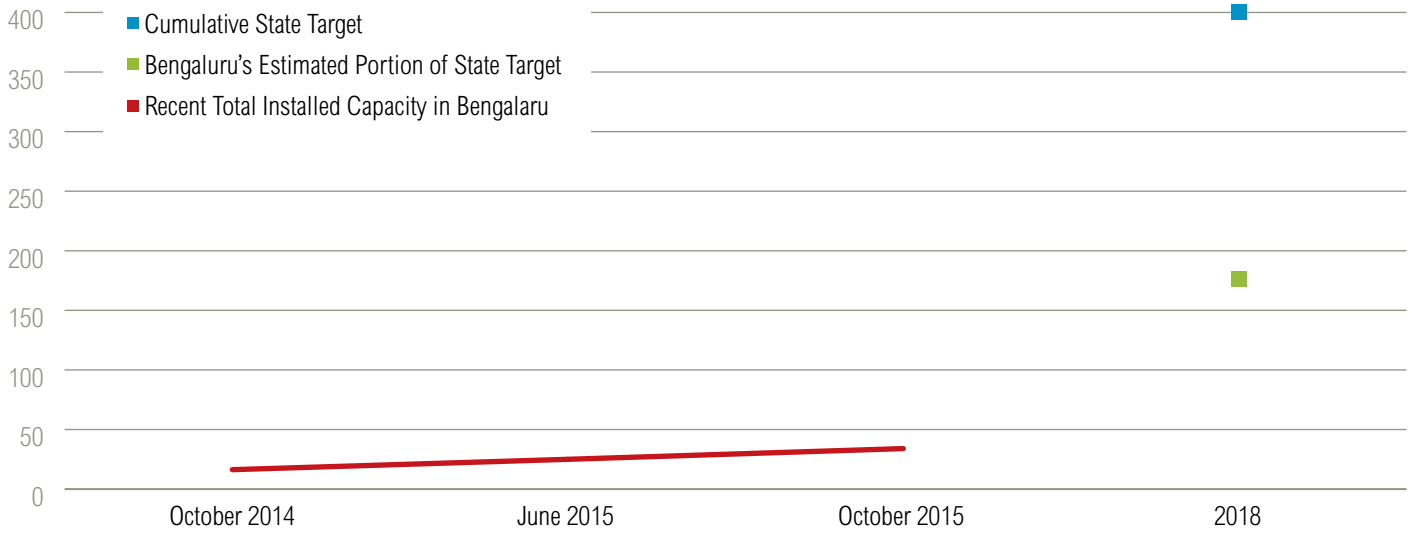
In order to participate in a net-metering program, rooftop solar PV systems need to be connected to the grid (i.e. grid-connected) on the customer side of the meter (i.e. behind-the-meter). Net-metering customers are by definition prosumers because their rooftop solar PV system is grid-connected; this paper focuses on these systems. Other policy and billing mechanisms that allow rooftop solar PV systems to interact with the grid include feed-in tariffs and gross metering. For more information see Box 4.

Other states with net-metering policies show similar trends in capacity addition. In 2012, the Government of Tamil Nadu set a target of 3,000 MW of solar power by 2015 (TEDA 2015). Total installed rooftop solar PV reached 76 MW in October 2015, 19 MW of which came from the residential sector (Bridge To India 2015c). In 2013, the Government of Uttar Pradesh set a 500 MW target by 2017 (Government of Uttar Pradesh 2013), and by October 2015 reached a total installed rooftop solar PV capacity of 36 MW, 16 of which came from the residential sector (Bridge To India 2015c).

This working paper provides insight into how Bengaluru can encourage an increasing number of prosumers to install rooftop solar PV systems, specifically through BESCOM's net-metering program. It offers initial recommendations for actions that will enable program administrators to strengthen BESCOM's net-metering program and increase prosumer interest and adoption of rooftop solar PV. It assesses current prosumers' motivations and experiences with the program, and identifies barriers from the prosumers' perspective.

The insights into BESCOM's net-metering program are derived from the experiences of project developers and customers who have already installed net-metered rooftop solar PV systems in Bengaluru. We focus on residential systems because we were able to collect

Figure 1 | Karnataka Rooftop Solar PV Targets and Capacity



Source: Government of Karnataka (2014).

the most information from this customer segment. We do not suggest that the interviews are statistically representative of the population of Bengaluru, or of the subgroup interviewed. Instead, we present this information to offer insight into the experiences of some prosumers and experts.

We begin by considering the global and national context for prosumer adoption of rooftop solar PV, before turning to the local context in the state of Karnataka and, more specifically, in the city of Bengaluru. We then identify six barriers that emerged in our interviews with prosumers and project developers. We offer initial recommendations for how BESCOM could improve the net-metering program and scale rooftop solar PV in Bengaluru.

This paper is unique in that it analyzes the uptake of rooftop solar PV under a net-metering program from the perspective of those participating in it: primarily prosumers, and secondarily project developers. Most existing analyses investigate the economic and technical drivers and barriers influencing prosumer adoption of rooftop solar PV from the perspective of program administrators or policymakers.[4] With our approach, we hope that the barriers and solutions identified in this paper will be helpful in informing policymakers, utilities, and program administrators in Bengaluru and possibly beyond.

METHODOLOGY

Our findings are based on a small set of interviews with local industry experts, project developers,[5] and customers who have installed or want to install a rooftop solar PV system. In total, we interviewed seven project developers currently operating and providing services related to rooftop solar PV installations in Bengaluru, 12 residential prosumers, two commercial/industrial prosumers, and two public institution prosumers. Most of our interviewees were identified through a publicly available list of customers participating in BESCOM's net-metering program (BESCOM 2016). However, some prosumer interviewees were referred to us by project developers.

By interviewing people familiar with the market in Bengaluru and prosumers themselves, we sought to answer four questions:

- What is motivating prosumers in Bengaluru to install rooftop solar PV systems?
- What have been prosumer experiences while participating in the program?
- What barriers currently inhibit wider adoption?
- What actions could potentially help increase interest in rooftop solar PV in Bengaluru?

Because of the relatively small sample size and because the majority of responses came from residential prosumers, our findings target the residential sector. Our findings are not based on a fully representative sample of the residential population in Bengaluru or the subgroup of prosumers interviewed. Nonetheless, they offer some insights into prosumers' experiences with the net-metering program and the challenges impeding the growth of the program. A more comprehensive analysis would require further research. For more information on methodologies used, please see Appendix B.

GLOBAL CONTEXT

In many countries, the number of prosumers installing rooftop solar PV systems is rising (Rickerson 2014). Supportive policies are emerging, such as net-metering for rooftop solar PV systems, to promote prosumer involvement with the electricity system (the grid).[6] As of 2015, 48 countries, both developed and developing, had implemented net-metering policies (REN21 2015). In the United States, net-metering helped 1.2 Gigawatts (GW) of residential solar to come online in 2014 (SEIA 2015c) and is projected to bring another 5 GW per year online by 2020 (Litvak 2015).

In several other countries, rooftop solar PV is emerging as a popular choice for electricity customers. Over 70 percent of solar PV capacity in Germany is classified as residential, commercial, or industrial. In the Belgium, Czech Republic, Denmark, and the Netherlands, over half of solar PV capacity is classified as residential (SolarPower Europe 2015). The Chinese National Energy Administration set a goal of 7 GW in distributed solar PV capacity[7] for 2015, with at least 3.15 GW coming from rooftop solar PV (Ayre 2015).

Globally, distributed solar PV[8] is growing rapidly, with projected installation of 346 GW between 2015 and 2024 (Labastida and Gauntlett 2015).[9] This represents an increase from a total installed capacity of roughly 12 GW in 2008 and just over 100 GW in 2014 (BNEF 2015a).[10] Much of this growth is expected to come from the

residential sector, where solar PV capacity is likely to almost double from approximately 45 GW in 2014 to roughly 80 GW by the end of 2017 (BNEF 2015a).

Box 3 | **India's Goals in Context**

India's national targets of 100 MW of grid-connected solar PV and 40 GW of rooftop solar PV by 2022 are particularly ambitious in light of the fact that:

- India's total installed power capacity from all energy sources was 276 GW as of July 31, 2015 (Ministry of Power 2015)
- India's total installed grid-connected solar PV capacity was 4.1 GW as of July 13, 2015 (MNRE 2015b)[a]
- Over 3.5 GW of rooftop solar PV needs to be installed per year in order to reach 40 GW by 2022. Only 240 MW was installed last year (see Figure 2).

a. Another source claims a total capacity closer to 4.4 GW as of May 2015 with capacity from commissioned utility-scale solar projects at 4.1 GW and capacity from rooftop solar installations at 350 MW (Bridge To India 2015b).

SOLAR PV IN INDIA

The Government of India has set an ambitious national target of 100 GW of grid-connected solar power capacity by 2022 (see Box 3). For more on India's renewable energy goals and annual targets, see Appendix C. This national target has direct and significant implications for the residential sector because 40 GW is expected to come from rooftop solar PV systems (Government of India 2015).

India has enough rooftop space and market potential to meet its targets. The estimated technical potential of rooftop solar PV in urban settlements is around 352 GW and the estimated market potential is roughly 124 GW.[11] This is enough to meet India's current target three times over, meaning that the goals are technically and economically viable (Sundaray et al. 2014). However, for India to meet its rooftop solar PV goals, a significant increase in the adoption rate of rooftop solar PV among residential and other customers will be required.

The economics of rooftop solar PV systems are becoming more attractive to customers across India as system costs come down and electricity tariffs continue to rise. Solar energy prices have dropped significantly in the last five years, from 17.90 INR per unit in 2010 (Government of India 2015) to bids as low as 5.05 INR per unit as of July 2015 (Jai 2015). Rooftop solar PV has already reached "grid parity"[12] in 12 states for industrial and commercial electricity customers under certain policy conditions[13] (Bridge To India 2015b).[14] Electricity tariffs vary widely from state to state but, on average, between FY2009–10 and FY2013–14, residential tariffs increased by 15 percent and commercial tariffs rose by 16 percent (Table 1). This represents an annual increase of roughly 5 percent (Planning Commission 2014).

Table 1 | **Average Indian Customer Tariff by Customer Type, 2011–2012 and 2013–2014 (INR/kWh)**

CUSTOMER	2011–2012	2013–2014
Residential	3.14	4.08
Commercial	6.9	7.64
Agricultural	1.44	1.83
Industrial	5.14	6.26
Railway	5.54	6.64

Source: Planning Commission (2014).

Recent Progress

As of October 31, 2015, total installed rooftop solar PV capacity in India was 525 MW with 143 MW in residential installations (Bridge To India 2015c), up from 285 MW in October 2014 (Bridge To India 2014) and 350 MW in June 2015 (Bridge To India 2015b). See Figure 2.

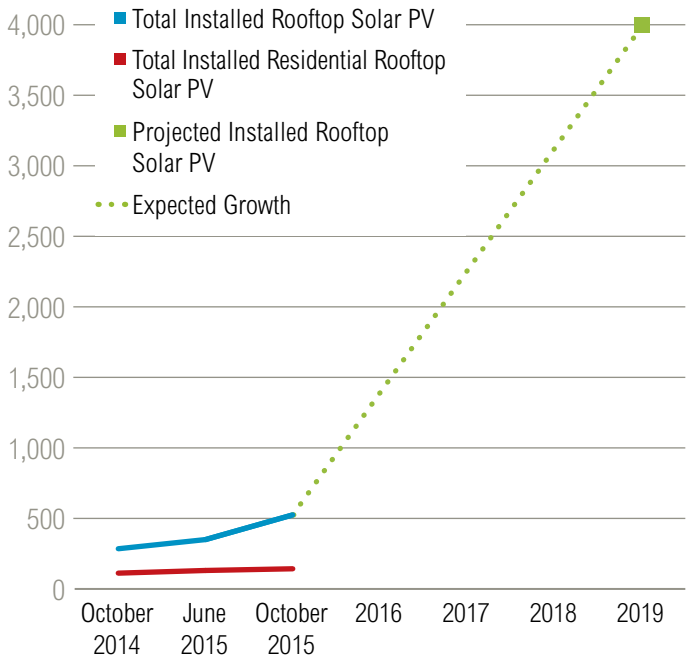
Rooftop solar PV capacity is projected to continue growing rapidly at a compound annual growth rate around 60 percent, reaching 4 GW by 2019 (Bridge To India 2015b). For comparison, from 2007 through 2014, renewable energy generation capacity in India grew at a compound annual growth rate of 18.4 percent (PwC 2015) and total solar PV capacity grew at a compound annual growth rate of over 90 percent (BNEF 2015a).

Government Support

Many Indian states are introducing their own solar policies, including capacity targets and net-metering schemes. As of May 2015, 19 states had either introduced or drafted a solar policy. The cumulative target for solar power capacity in these 19 state policies is 50 GW. While this falls significantly short of 100 GW, 10 of the 19 targets are to be reached by 2019—three years before the date of India's national target (Bridge To India 2015b).

The number of states with net-metering schemes has increased dramatically over the last year. By October 31, 2014, nine states and union-territories had developed at least a draft net-metering scheme (Bridge To India 2014). By April 2015, the number had grown to 12 (Kohli 2015) and, by the end of May 2015, 25 states reportedly had proposed policies (Bridge To India 2015b).[15] For more on supportive national and state policies, see Box 4.

Figure 2 | **India's Rooftop Solar PV Capacity (MW)**



Box 4 | **Government Support Mechanisms**

Policymakers use a number of support mechanisms to encourage the spread of renewable electricity technologies. Most commonly, these policies include renewable purchase obligations, feed-in tariffs, reverse auctions, public benefit funds, and net-metering programs. These mechanisms have been well documented and their merits and drawbacks have been evaluated and compared at length. For governments choosing among policy mechanisms, their particular needs and objectives will determine the most effective policy combination (Couture et al. 2015).

In India, governments have implemented several support mechanisms in addition to net-metering policies:

Renewable Energy Certificates. Regulated by the Central Electricity Regulatory Commission, renewable energy certificates seek to create a national market for renewable energy-based generation, where renewable energy generators can sell renewable energy generation at a preferential tariff (Renewable Energy Certificate Registry of India 2015).

National Capital Subsidy Scheme. A subsidy for rooftop solar systems between 1 kilowatt (kW) and 500 kW is available from the Ministry of New and Renewable Energy's Grid-Connected Rooftop and Small Solar Power Plants Programme. The subsidy provides "15 percent of the benchmark cost"[a] to qualifying residential, institutional, government, and social sector buildings[b] (MNRE 2015e).

Accelerated Depreciation Benefit. Commercial and industrial buildings that are not eligible for the national subsidy are eligible for an accelerated depreciation[c] benefit of 80 percent of the capital cost of the rooftop solar PV system applied in the first year of operation (Khurana 2014). This provides a value of approximately 26 percent of the system's capital cost when fully realized.

Gross Metering. An arrangement where the entirety of electricity generated from a renewable energy system (in most cases rooftop solar PV) is directly fed into the grid and the customer receives electricity supply from the utility grid. Separate meters read energy generated and energy consumed, and customers are billed separately for what they consume from the grid and what they export to the grid (Urja 2014).

a See MNRE (2014) for full details on the program, including the previous subsidy rate of 30 percent, and "benchmark cost."
b "The subsidy mechanism is expected to be replaced by an interest rate subvention scheme although it may take some time before that is finalized. As part of the interest rate subvention scheme, the MNRE is planning to reduce the effective interest rate for rooftop solar projects to around 8.5 percent per year, helping to reduce the levelized cost by around 10 percent" (Bridge to India 2015d).
c "Accelerated depreciation is a policy [that] allows the developer to write off the asset value of a renewable energy project in its initial years, thereby reducing tax liability. However, after the value of the asset has completely depreciated, taxes are higher in later years, which would lead to partial government recovery of the cost of support" (Shrimali et al. 2015).

SOLAR PV IN KARNATAKA

BESCOM introduced its net-metering program in Bengaluru in November 2014. The program came after the Government of Karnataka's Solar Policy 2014–2021 and the Karnataka State Regulatory Commission's 2013 tariff order, which approves the net-metering tariff for rooftop solar PV systems at Rs. 9.56/kWh[16] (BESCOM 2015b). Karnataka's solar policy aims to promote green sources of energy as an alternative to current sources to promote energy security and sustainability in the state. It sets a state target of installing 2 GW of new solar power capacity by 2021. Of this capacity, 1.6 GW is to come from utility-scale systems and 400 MW from grid-connected rooftop solar PV (Government of Karnataka 2014). The state government also proposed to reach its rooftop solar PV goal by 2018, setting annual targets of 100 MW per year between FY2014–15 and FY2017–18 (see Table 2).

Karnataka is well positioned to reach its rooftop solar PV goals. Its solar resources are significant, estimated at between 20 GW (Government of Karnataka 2014) and 24.7 GW (Kumar 2014).[17] Furthermore, household structures in Bengaluru, Karnataka's most populous city, are generally well suited to support rooftop solar PV systems: 67.8 percent of rooftops are made from concrete and 22.3 percent are made from metal or asbestos—materials that can support the weight of rooftop systems.

It is worth noting, however, that only 38.4 percent of households in Bengaluru are owner occupied, while 58.7 percent are rented. The International Energy Agency has reported that home ownership is an important condition influencing prosumer growth (Rickerson 2014). See Appendix A for more census data on Bengaluru.

Rooftop solar PV has become more economically feasible for commercial and industrial customers in Karnataka in recent years (Bridge To India 2015b) and has become feasible for residential customers with the introduction of net-metering (see Appendix D for more information). The increasing average cost of electricity tariffs in the state has made rooftop solar PV systems more attractive to consumers. The average residential tariff rose from 3.38 INR per kWh in FY2009–10 to 4.23 INR per kWh in FY2013–14 (see Table 3). This represents an average annual increase of 5.7 percent (Planning Commission 2014).

BESCOM's Net-Metering Policy

On October 10, 2013, the Karnataka Electricity Regulatory Commission set a net-metering tariff for grid-connected rooftop solar PV systems (KERC 2013). The tariff order also provided general and technical specifications for rooftop solar PV systems for all customers. On November 7, 2014, BESCOM announced specifications for net-metering in its service territory (BESCOM 2014).[18]

Table 2 | **Annual Solar PV Targets in Karnataka, 2014–2021**

CATEGORY	ANNUAL TARGETS (IN MW)						
	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21
Utility-Scale Projects	350	150	150	150	200	200	200
Rooftop PV Projects (grid-connected and off-grid)	100	100	100	100	N/A	N/A	N/A
Total	450	250	250	250	200	200	200

Source: Government of Karnataka (2014).

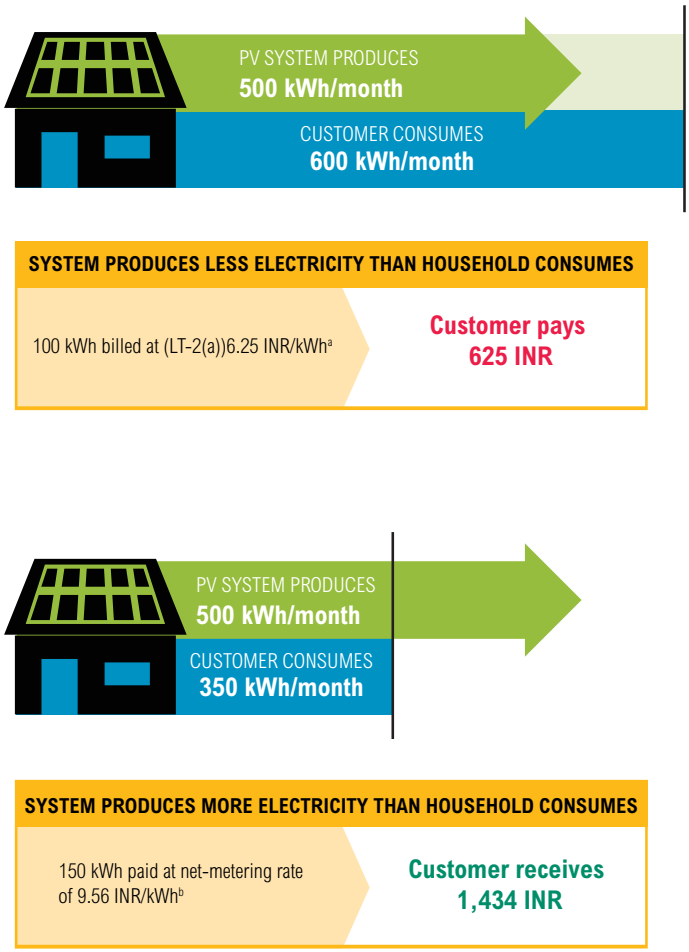
Table 3 | **Average Residential Tariff Prices, Karnataka**

FINANCIAL YEAR	2009–10	2010–11	2011–12	2012–13	2013–14
Cost (INR/kWh)	3.38	3.54	3.83	4.01	4.23

Source: Planning Commission (2014).

Under BESCOM's net-metering tariff, owners of rooftop solar PV systems are paid a promotional rate of 9.56 INR per kWh for net excess generation provided to the grid on a monthly basis.[19] This rate is only applicable to systems that do not receive a capital subsidy from the Ministry of New and Renewable Energy. For systems that receive the subsidy, the rate is 7.20 INR per kWh. Net-metering customers with rooftop solar PV systems that do not provide net excess generation to the grid on a monthly basis are billed at the per kWh rate of their normal tariff for their electricity consumption minus any generation from their rooftop solar system. (See Figure 3 and Box 5 for further details of BESCOM's net-metering policy).

Figure 3 | **Examples of How BESCOM's Net-Metering Program Works**



Note: a) LT-2(a) refers to a domestic customer under BESCOM's retail tariff categories. The tariff rate represented is based on the Karnataka Electricity Regulatory Commission's 2015 Tariff Order.
b) The 9.56 INR/kWh net-metering rate is based on KERC's 2013 tariff order, and is applicable to those who have not received an MNRE subsidy. This rate has changed since May 2016 (KERC 2016). The new 2016 rate of 7.08 INR/kWh for systems smaller than 10kW changes the economics of rooftop solar PV in Bengaluru significantly.

Box 5 | **Details of BESCOM's Net-Metering Program**

- Fixed and demand charges are billed to net-metering customers at their normal tariff rate
- To be eligible, a rooftop solar PV system must be below 1MW, but is not limited by any restrictions relating to consumption or sanctioned load[a]
- Customers bear the whole cost of the net-metering arrangement, including accessories
- When the proposed installed capacity of the rooftop solar PV system exceeds the sanctioned load and requires upgrades to the current infrastructure (service line, meter, transformer), consumers have to upgrade at their own expense

BESCOM charges the following registration fees for systems of different sizes:

- <5kW — 500 INR
- >5kW, <50kwp — 1,000 INR
- >50kW, <1MW — 2,000 INR

Two details in BESCOM's written net-metering guidelines appear to be at odds with BESCOM's actual practice as described by BESCOM officials:

- BESCOM guidelines state that this policy is "only for the solar rooftop facility owned, operated, and maintained by the consumer(s)"[b]
- Hybrid rooftop solar PV systems (or systems with battery backup) are now allowed as of mid-2015[c]

BESCOM could strengthen the net-metering program by clarifying these details.

a Clarified and validated with BESCOM at July 24, 2015 meeting
b In a meeting with the BESCOM Managing Director on July 24, 2015, the authors were told that customers could actually participate in any financial transaction outside BESCOM regarding their rooftop solar PV system that they wished.
c This is not explicitly stated in any policy or guideline document, but was confirmed by BESCOM officials. At least one hybrid system has already been allowed to connect.

Sources: BESCOM (2014, 2015c).

Status of Rooftop Solar PV in Bengaluru

As of October 31, 2014, the total installed rooftop solar PV capacity in Karnataka was 16.3 MW, with 5.7 MW in residential installations (Bridge To India 2014).[20] While BESCOM's net-metering policy is essential to allowing grid-connected systems,[21] at the time, it spurred less interest than hoped. There were just 80 applications to the program, representing a capacity of 0.5 MW, after the first two weeks—a disappointing number "when the government was hoping to generate at least 200 MW" in Bengaluru by 2018 (Kaggere 2014) (see Box 6).

The rooftop solar PV market in Bengaluru has steadily gained traction since the introduction and slow start of the net-metering program. By March 2016, over 5.6 MW of grid-connected rooftop solar PV systems had been connected since the program's implementation in November 2014.[22] Of the 262 systems connected under the net-metering program, 71 percent were systems under 7 kW, suggesting that roughly 70% of these systems were located on residential or small commercial buildings (BESCOM 2016).

Bengaluru consumes one-third of the state's electricity (Elavarthi 2014) and BESCOM customers represent 44 percent of Karnataka's annual energy consumption (Government of Karnataka 2014). Thus, BESCOM will likely need to have an installed capacity of between 33 and 44 percent of Karnataka's 400 MW rooftop solar PV target —that is, between 133 and 176 MW—by 2018 if Karnataka is to meet its goals. This indicates that, although the city is making progress in terms of capacity addition, the pace at which the program is progressing will need to be accelerated in order to drive enough rooftop solar PV capacity for the state of Karnataka to meet its 400 MW goal.

Box 6 | Stakeholder Engagement in Karnataka's Solar Targets and BESCOM's Net-Metering Program

How were Karnataka's solar targets set, how was the net-metering policy designed, and what stakeholder participation methods were used in those processes? These questions are relevant because comprehensive, multi-stakeholder engagement in policy design makes it more likely that specific needs and concerns of different groups are taken into consideration, and aids in the success of a policy program.

Inclusive approaches to policymaking often lead to faster program uptake or early program buy-in, and result in more successful programs, desirable outcomes, and overall program acceptance and understanding (Jairaj et al. 2013).

A draft of Karnataka's solar policy, which defines the state's solar targets, was made publicly available by the government of Karnataka on government websites, as well as in the Karnataka Gazette. Stakeholders and the general public were encouraged to provide comments on the draft, which were received, examined, and considered. Beyond that, it is unclear how these views were accounted for (Government of Karnataka 2011). Similarly, it is unclear what kind of engagement processes were undertaken by BESCOM in the development and design of the net-metering program beyond an initial citizen meeting (Praja 2012).

BARRIERS TO SCALING ROOFTOP SOLAR PV

Current research on barriers to and drivers of rooftop solar PV adoption focuses on financial, technical, and policy factors (Bridge To India 2015b; Pillai 2014; Rickerson 2014; Sundaray et al. 2014; Magal et al. 2014).

Sundaray et al. (2014) surveyed residential customers to identify real and perceived barriers that prevent consumers from installing rooftop solar PV systems. Of 177 residential respondents, 83 percent replied that they "had heard about…solar PV systems but had never used [them]," with 8 percent having already installed a system. These findings suggest significant barriers in India beyond basic awareness of rooftop solar PV systems. The specific barriers to rooftop solar PV in India, particularly in cities, are well documented and include:

- technology and market maturity;
- commercial viability;
- grid interconnection challenges;
- impacts on incumbents (such as utilities and power sector operators);
- system financing; and
- public awareness.

Largely because of these barriers, residential grid-connected RTSPV systems have been greatly under-explored in India to date (Pillai 2014) and few studies concentrate on the impacts that rooftop solar PV systems and net-metering programs have on the people they are meant to serve: the prosumers. Understanding how programs are being implemented, how consumers are being engaged, their level of awareness, and their experience with the program is all-important in creating and maintaining a successful rooftop solar PV program that can meet state and national goals. To shed light on the barriers to rooftop solar PV adoption in Bengaluru, this section reviews responses from prosumers to questions related to motivations, concerns, and barriers surrounding their rooftop solar PV system and BESCOM's net-metering program (see Appendix B for research methodology).

Although the responses do not represent a fully representative sample of the residential population in Bengaluru, they do provide insights into what may or may not be working successfully to date in Bengaluru, and what may or may not be discouraging customers from participating in the future.

Overall, our analysis finds that there are six principal barriers to the successful scale-up of rooftop solar PV in Bengaluru:

1. Poor understanding of PV performance, cost, and payback
2. Confusion on net-metering specifications
3. Uncertainty in project developer selection and interaction
4. Limited reach and appeal of the net-metering program
5. Limited effect of the promotional net-metering rate
6. Limited institutional capacity of the program administrator

1. Poor Understanding of PV Performance, Cost, and Payback

The interview responses suggest that consumers in Bengaluru lack a basic understanding of solar PV technologies, including how they perform and their costs. It also appears that consumers do not understand how they can receive payments through the net-metering program. This lack of understanding threatens the potential growth of rooftop solar PV and the net-metering program in Bengaluru.

Technology and Performance

According to the project developers interviewed, many electricity consumers in Bengaluru are unfamiliar with how solar PV works and how it can interact with the grid. Even some current prosumers with rooftop solar PV systems lack an overall understanding of their system and PV technology. For example, 3 out of 12 residential prosumers interviewed did not know how much energy their rooftop solar PV system should produce annually (in kWh) and two more were unsure.

Solar PV Cost

Consumers and current prosumers are also uncertain about the cost of solar PV technology. Current residential prosumers without battery backup quoted a wide range of prices, from 70 to 135 INR per watt, depending on the installer and system requirements. While actual quotes from project developers varied less significantly, they still varied by roughly 20 percent, from 83 to 120 INR per watt (see Table 6).

Table 6 | **Quotes for Rooftop Solar PV Systems Without Batteries**

		QUOTES FROM PROSUMERS, <10KW	QUOTES FROM DEVELOPERS, ~5KW
COST (INR PER W)	**Total Range**	70–135	83–120
	Average Total	93.5	101.3
	(+/-) (number of respondents)	+44%–25% (8)	18% (5)

It is unclear why the costs vary as much as they do, especially when the financial models used by project developers are similar.[23] Possible explanations include the following:

- There is a range of quality in products and services (noted by one developer who has researched this issue across India)
- Developers are not explaining costs properly
- Developers have given customers different quotes
- Customers do not understand the costs quoted to them

Payback Period

Residential prosumers' answers also varied significantly when asked for the payback period of their system. The payback period quoted by customers ranged from 2 to 10 years. Developers citing payback on residential systems quoted 5 to 10 years with most focusing on 8 to 10 years[24] (Table 7).

Table 7 | **Knowledge Among Prosumers and Developers Regarding Payback Periods for PV Systems Without Batteries**

	RESIDENTIAL PROSUMERS	PROJECT DEVELOPERS
Number with knowledge of payback or return investment	11 out of 12 know payback or return on investment	5 out of 6 working with residential customers responded with payback for residential systems
Positive payback	9 out of 11 claimed positive payback	4 out of 5 claimed positive payback
Positive range given	2–10 years	5–10 years (three claimed 9–10 years)

This variance suggests poor developer communication and customer misunderstanding. Both explanations have implications for the customer-developer relationship, which we consider below when we discuss uncertainty in project developer selection and interaction.

Impact and Recommendations

Lack of public understanding could limit the growth of rooftop solar PV and the net-metering program in Bengaluru because it creates uncertainty among potential prosumers. To address this lack of understanding, program administrators can:

- Increase the frequency of radio and newspaper advertisements, and provide more details on rooftop solar PV technology through lengthier articles or television reports. Some of the prosumers interviewed mentioned seeing or hearing BESCOM's promotional materials about the net-metering program; one noted that he applied for the program immediately after hearing an advertisement. Both prosumers and developers noted that it would be helpful if BESCOM were to provide more details about the technologies, including how they operate and their costs.
- Help facilitate prosumer interaction and information exchange through formal online platforms or frequent formal prosumer gatherings. Prosumers noted that self-organized online groups were helpful for evaluating and understanding technology, performance, and cost. Program administrators could make discussions from these forums publicly available so that individuals who are not yet prosumers could also learn from this exchange of information.
- Provide detailed guidelines and information about realistic costs for rooftop solar PV systems, their components, and payback periods. The broad range of cost and payback periods quoted by the prosumers interviewed demonstrates a clear need for reliable price information. This information can be provided through online portals or brochures disseminated through media campaigns or at community events.

2. Confusion on Net-Metering Specifications

Both prosumers and developers are uncertain about some of the specifications of the net-metering program. This includes confusion about specifications outlined in online net-metering program documents.

Multiple prosumers and developers cited confusion about several program specifications, but most notably whether a hybrid rooftop solar PV system—a grid-connected system with battery backup—is allowed.[25] Hybrid rooftop solar PV systems are attractive to prosumers because they allow prosumers to store excess generation for when the system and the grid cannot provide power, for example at night and during power cuts. During power cuts, net-metered rooftop solar PV systems that are not hybrid systems are required to disconnect from the grid and stop generating. This means that net-metered systems without battery backup do not improve the reliability of a consumer's electricity supply.

Despite the benefits of hybrid systems, none of the project developers interviewed uses hybrid inverters,[26] which are needed for rooftop solar PV systems with batteries to provide backup. Similarly, none of the 12 residential prosumers interviewed had hybrid rooftop solar PV systems. Four of 12 prosumers interviewed did have some sort of battery backup, but all four of these systems were installed in 2014 before the net-metering program was in place (Table 8). Further, three more prosumers had a separate source of backup, including one prosumer with a backup battery connected to the grid separately. The latter is a technically viable option for potential prosumers looking both to install a rooftop solar PV system and to increase the reliability of their electricity supply.

Table 8 | **Prosumers with Battery Backup**

NUMBER WITH BATTERY BACKUP	4 out of 12
NUMBER INSTALLED UNDER NET-METERING POLICY	0 out of 4
NUMBER WITH SOME FORM OF BACKUP	7 out of 12

Other points of confusion include:

- Whether a power purchase agreement (PPA) between a customer and a developer is allowed in addition to the agreement between BESCOM and the customer
- The maximum installed rooftop solar PV system size, in absolute terms and compared to load
- The rate at which a prosumer's consumption is charged
- The length of contract signed with BESCOM[27]

Impact and Recommendations

Confusion about the specifications of the net-metering program could impair adoption by future prosumers who may already have a limited understanding of rooftop solar PV, or who may have reservations about installing a system. Specifically, uncertainty about whether hybrid systems are allowed could deter potential prosumers who are looking to make their electricity supply more reliable. To address this lack of clarity, program administrators can:

- Facilitate information exchange about net-metering program application, installation, and interconnection processes and specifications through formal online platforms or frequent formal prosumer gatherings. Prosumers mentioned that self-organized online groups were helpful for understanding the application, interconnection, and operation processes.
- Develop clear and concise program description documents. BESCOM and the Karnataka Electricity Regulatory Commission do provide guidelines online, but these guidelines are often complicated or not clear to the user. Prosumers noted the need for a checklist that specified the steps and estimated time for the net-metering application, installation, and interconnection processes. This list would reduce uncertainty by clarifying what is required of customers if they are to participate in this program. Guidelines should also include clear, up-to-date information about what is and what is not allowed under the net-metering program, clearly identifying the relevant documents and specifications online.

3. Uncertainty in Project Developer Selection and Interaction

Potential prosumers are often reliant on project developers for information about the net-metering program. However, the information that project developers provide is not always correct, and no mechanisms are in place to monitor the accuracy or quality of their services. Misinformation and the high number of project developers may undermine consumer trust and hinder current and future program adoption.

Misinformation

Several project developers across Bengaluru are offering information and services that are sometimes incorrect. For example, three residential prosumers quoted the payback figures that project developers provided them. Two of these quotes were unrealistic (two to three years). Currently, there are no mechanisms in place to monitor or determine the accuracy or quality of information and services provided by project developers.

Number of Developers

As of August 15, 2015, when interviews for this paper were being completed, more than 51 developers had been involved in installing more than 100 rooftop solar PV systems under BESCOM's net-metering program. Of the 12 residential prosumers interviewed, two installed their own systems and the other 10 used, in total, nine developers (Table 9).

Ultimately, the number of developers points to a lack of market maturity, and creates uncertainty for customers when choosing and trusting one developer over another. Prosumers cited several different research processes for choosing a project developer, including Google searches, BESCOM suggestions, and word of mouth, in addition to a variety of different selection criteria.

Table 9 | **Project Developers Used by Residential Prosumers**

NUMBER OF SELF-INSTALLED SYSTEMS	2
NUMBER OF DEVELOPERS USED	9 out of 10
NUMBER OF DEVELOPERS USED BY TWO SEPARATE PROSUMERS	1 out of 12

Recommended Developers

In some cases, BESCOM has recommended project developers to customers who applied to the net-metering program. In other cases, BESCOM shared customer information with only certain developers, so that the developers could reach out to participating prosumers. These arrangements may lead customers to believe that the developers are pre-approved or accredited by BESCOM, which, in turn, may create a false impression that these developers are in some way the most desirable to work with. When asked how they found a developer, three residential prosumers reported that they were contacted by or put in touch with developers via BESCOM.

This may create a false impression that these developers are the most trustworthy or most competent and that customers must choose from a set list.

Impact and Recommendations

The misinformation and uncertainty noted above can undermine potential prosumers' confidence in buying a rooftop solar PV system and participating in the net-metering program, particularly in the case of customers with limited understanding of solar PV technology and cost. These customers rely heavily on project developers for information, and they put a significant amount of trust in the information that developers provide. To ensure that consumer trust in project developers is well founded, program administrators can:

- Offer a free and open certification process to developers who want to provide rooftop solar PV services and products under BESCOM's net-metering program. An accessible list of certified project developers could be made available to the public, along with certification criteria and processes. Local experts noted that, until the market for rooftop solar PV has had time to mature, such a certification process could provide clear, transparent guidance on the quality of project developers.
- Offer training and education programs for project developers, specifically about BESCOM net-metering program specifications. These trainings should be offered when major program updates occur to help ensure that project developers pass along correct information to customers.

4. Limited Reach and Appeal of the Net-Metering Program

BESCOM's net-metering program is attractive and attainable to only a small, relatively wealthy, and motivated segment of the population, limiting its potential reach and growth.

Prosumer Demographic

All developers noted that the demographic of the residential customers they or others work with is "low middle class to upper class," with three out of seven explicitly stating that their current focus is only the "upper" class. Recent estimates put the "upper class" population of urban India at 0.23 percent (Meyer and Birdsall 2012).[28] This is roughly equivalent to 5,500 households in Bengaluru—many times larger than the number of residential rooftop solar PV systems currently installed.

Prosumer Motivations

Globally, prosumers are typically motivated to install rooftop solar PV systems by two factors. The first is the economic returns and/or savings associated with rooftop solar PV. The second is the opportunity to be an energy supplier and to be more energy independent (Pillai 2014). However, when asked what factor(s) attracted them to install a rooftop solar PV system, most current residential prosumers cited "being green" and the environment as their main motivation, followed by community benefits[29] and financial opportunities (Table 10).

Table 10 | **Main Motivating Factors Cited by Residential Prosumers**

QUESTION	AGGREGATED RESPONSES
What were the main factor(s)—list your top three—that attracted you to installing a PV system? (That is, what moved/might have moved you beyond interest to action?)	■ Being a part of green movement/social pressure (7) ■ Green energy/environment (6) ■ Benefits to community/nation (3) ■ Cost/investment, transmission and distribution losses, and ease of opportunity (2)

These responses suggest that the current net-metering program may appeal to potential prosumers not because of cost benefits or support programs, but rather because they produce "green energy" and allow prosumers to give back to the community.

Lack of Awareness

Project developers noted a general lack of awareness about and understanding of solar PV both among current prosumers and among the general public. Developers confirmed that current and potential prosumers interested in net-metering are more aware than the general public, but insisted that even this group lacks full awareness and understanding of the technology, economics, and net-metering specifications (see section on "Poor Understanding").

One developer cited lack of solar PV awareness as the key barrier to prosumer adoption of rooftop solar PV in Bengaluru. Another developer stated that awareness was poor in Bengaluru due to weak promotional programs. Conversely, no developers mentioned awareness or general outreach strategies of their own.

Prosumer Interest and Initiative

Potential prosumers are, for the most part, left to themselves to find answers to their questions about installing a rooftop solar PV system. In effect, this likely means that only the most motivated participate. This is highlighted by the fact that:

- All 12 residential prosumers interviewed had a general interest in the topic area prior to installing their system
- All 12 showed initiative by researching the available products, vendors, and developers

In deciding whether to install a system, many of the prosumers we interviewed depended on information from friends who had already installed a rooftop solar PV system. Others formed and/or joined Google and Yahoo forums where prosumers share information.

A lack of clear and easily accessible information about available products, vendors, and developers may pose a challenge to those who do not have the time, resources, or motivation to perform this research.

Lack of Financing Options

Financial support and financing options for residential prosumers are not readily accessible. All prosumers interviewed self-financed their systems, meaning that they had enough funds to invest in a system upfront.

CAPITAL SUBSIDY FAILURE

None of the residential prosumers interviewed took advantage of the 15 percent capital subsidy offered by the national government. They cited difficulty in obtaining the subsidy, and a slow and restrictive approval process, to explain why they did not participate in the subsidy offer. Developers have been equally dissatisfied with the capital subsidy program. Developers reported that they sometimes discourage customers from applying for the subsidy, explaining to them that it is too hard to obtain. Furthermore, only developers certified by the Ministry of New and Renewable Energy are eligible to apply for the subsidy, and attaining this certification was described as difficult.

NO LOAN OR POWER PURCHASE AGREEMENT OPTIONS

None of the residential prosumers interviewed took out a loan to finance their rooftop solar PV system. This may be explained by the high interest rates on loans, or by the unwillingness among banks to offer priority sector loans.[30] Similarly, none of the residential prosumers interviewed entered into a power purchase agreement (PPA) with a developer; indeed, there is uncertainty about whether PPAs are permissible under the net-metering program.

However, even if PPAs with developers are allowed under the current net-metering program, project developers are unlikely to take the net-metering benefit into account because BESCOM will pay only the homeowner for excess generation. This condition makes it difficult for project developers to make the PPA deal economically attractive for residential customers.

It will be impossible for consumers who do not have upfront capital to participate in the net-metering program if loans or PPAs are not available. Making financing available to potential prosumers could facilitate the expansion of the net-metering program. The United States, for example, has seen a huge uptick in residential rooftop solar PV since 2008, with over 60 percent of these systems coming online in 2012–2014 thanks to PPAs and similar models (Litvak 2015).

Impact and Recommendations

Understanding the motivations and levels of awareness that drive prosumers to become involved in such programs will help program administrators and project developers better design the program to appeal to a wider customer segment. Understanding which customer segments are being reached, which ones are not, and the limiting factors to adoption within a broader demographic could enable program administrators and project developers to expand the reach of the net-metering program. Specific actions include:

- Program administrators can undertake market research to improve their understanding of why the program appeals more to certain population segments than others, and to identify how the program can be redesigned to reach more people. Those who design residential energy-efficiency programs commonly engage in market research to better target and design those programs (Jairaj et al. 2013).
- Program administrators, city officials, and government agencies can improve communication on the benefits of solar PV, including economic and environmental benefits. This can be done through frequent newspaper and radio advertisements promoting the technology and the program. Prosumers noted that these benefits are not currently highlighted in promotional materials.
- Program administrators can work with media outlets to highlight community champions and stories of successful systems. BESCOM has already started publishing stories about residential prosumers in local newspapers. Publishing these stories helps spread the word about the benefits of rooftop solar PV, and makes the process easier to understand. Additionally, champions can be highlighted during local community events. These champions can be local figures, such as mayors, or longstanding community members. Similar initiatives have been undertaken in Bengaluru to promote household energy-efficiency measures.
- Government agencies and banks can better facilitate and promote current subsidy and loan programs to ensure that potential prosumers take advantage of these programs. Local experts, project developers, and evidence from other countries, including the United States, suggest that the successful scale-up of

rooftop solar PV and the expansion of the net-metering program will depend in large part on whether the upfront cost to potential prosumers can be lowered. Priority sector lending for rooftop solar PV systems is a policy that could help accomplish this goal, but it is currently underutilized. Priority sector lending and the capital subsidy program are administered by the federal government, but local authorities may be able to provide prospective prosumers with information and resources about these programs.

- Government agencies can create stronger and simpler financial incentives for less financially secure consumers. Current prosumers did not take advantage of the available federal capital subsidy mostly because of cumbersome application and lengthy payment distribution processes. Many prosumers are not taking advantage of BESCOM's promotional net-metering rate (see discussion of the limited effect of the promotional net-metering rate, below). Government at the local and national levels can improve the effectiveness of these policies by making the financial benefit clearer and easier to obtain. Furthermore, both levels of government could choose other policy mechanisms that have helped to incentivize residential rooftop solar PV among other customer segments, such as accelerated depreciation. State and national government could also adopt policy mechanisms that are thought to be less costly, such as interest rate subvention.[31]

5. Limited Effect of the Promotional Net-Metering Rate

Interviewees were asked what their main concerns were prior to installing a rooftop solar PV system, as well as what the main motivation was to install one. High upfront costs of rooftop solar PV were the primary concern for the residential prosumers interviewed. However, economic gain did not drive their decisions to install a system. Instead, environmental and other factors were cited as the biggest motivators. This finding has implications for the effectiveness and promotion of the 9.56 INR per kWh net-metering promotional rate.

Rooftop Solar PV Economics are a Concern, but Not a Motivation

High investment cost and rooftop solar PV economics was the most frequently reported concern among the residential prosumers interviewed, cited by six out of 12 respondents (Table 11). Similarly, the project developers interviewed perceived cost as the biggest concern among potential prosumers.

However, when residential prosumers were asked to rate as low, medium, or high the importance of a preset list of factors relating to their decision to install a rooftop solar PV system, "financial savings" was rated third out of four motivating factors (Table 12). Motivations such as "setting the example" and "environmental consideration" were rated highest, with "financial savings" rating closer

Table 11 | **Main Concerns and Reservations Expressed by Residential Prosumers**

QUESTION	AGGREGATED RESPONSES
Did/do you have reservations—list your top three—about installing a PV system?	■ Investment cost/economics (6) ■ Technical feasibility (4) ■ Grid connection/excess power (3) ■ Reliable electricity supply (2) ■ Rooftop space (2) ■ BESCOM paying net-metering rate (1) ■ Wiring and aesthetics (1) ■ Maintenance (1)

Table 12 | **Motivating Factors Selected by Residential Consumers**

FACTORS	AVERAGE RATING[a]
Lower emissions/environmental considerations	3
Setting example/reputation (company brand equity)	2.3
Financial (money) savings	1.73
Improved reliability of electricity supply	1.45

a. Each prosumer's response was given a numerical value: low = 1, medium = 2, high = 3. To obtain the average across the residential prosumers interviewed, the numerical values of each prosumer's response were summed then divided by the number of responses to that question. Not every question was answered fully, clearly, or explicitly by each prosumer because the questionnaire was slightly modified after the first few interviews and the flow of each interview was slightly different.

to "improved reliability."[32] Environmental considerations were, by far, rated the highest motivating factor.

These findings suggest that current prosumers are driven to install a rooftop solar PV system by environmental and other factors as long as, for the most part, the economics of the rooftop solar PV are such that their concerns are addressed. These findings suggest that although financial savings may be a factor in some prosumers' decisions to install rooftop solar PV systems, the role of non-financial considerations is more significant. Understanding the relative importance of financial considerations in prosumer decisions is important in setting the net-metering promotional rate: If the economics of a net-metered rooftop solar PV system are viable without a promotional rate, introducing such a rate may not attract prosumers from this customer segment (see subsection on net-metering economics below).

System Size

Under BESCOM's net-metering tariff, owners of rooftop solar PV systems that did not receive the federal capital subsidy are paid 9.56 INR per kWh for net excess generation to the grid on a monthly basis. The 9.56 INR per kWh rate is a promotional rate not associated with the electricity tariff that customers pay for their electricity consumption (around 6.25 INR per kWh for LT-2a customers.[33] See Appendix A). The project developers interviewed generally agree that this promotional rate is, indeed, financially attractive to residential customers and fair to both BESCOM and customers.

However, only one residential prosumer explicitly factored the 9.56 INR rate into the decision about how to size a rooftop solar PV system. Similarly, only two out of six project developers said that they size their systems to export on a monthly basis because of this rate.

The lack of interest in promotional rates among the residential prosumers interviewed may be related to the fact that financial gain was not their primary motivation. The project developers interviewed suggested other reasons prosumers may not be interested in the promotional rate, including fear that BESCOM will change the policy in 2018, doubts over whether BESCOM will actually pay for excess generation, and the loss of solar generation during power cuts.

These results do not mean that the promotional rate is not a sufficient financial incentive to drive rooftop solar PV adoption among other segments of residential customers or other customer classes. It also does not discredit the promotional rate as a sufficient financial incentive for the segment of residential customers interviewed for this paper. It may be that the financial benefits of the promotional rate were poorly understood by those interviewed (as was the case with many technical and economic factors). Alternatively, the factors reported by project developers may present too big an impediment for the promotional rate to motivate this segment of residential customers.

Net-Metering Economics

Tables D1 and D2 in Appendix D explore basic cash flow[34] models for two net-metered rooftop solar PV systems in Bengaluru using the 9.56 INR per kWh rate.[35] The outputs of this model include the internal rate of return[36] for an investment in a rooftop solar PV system, as well as the number of years it takes to recover this investment (i.e. payback period). Table D1 shows the cash flow model for a 4 kW system that produces roughly the same amount of electricity as is demanded annually. Table D2 shows the cash flow model for an 8 kW system that produces roughly twice the amount of electricity as is demanded annually.

The improved internal rate of return (11 percent over 8 percent) and payback period (8 years instead of 11 years) of the 8 kW system compared to the 4 kW system highlights the incentive provided by the 9.56 INR rate. It should be noted, however, that the 8 percent internal rate of return provided by the 4 kW system is comparable to interest rates available via savings accounts at Indian banks (ICICI Bank 2015). Ultimately, this means that investing in a rooftop solar PV system that provides a household's annual energy demand and does not take advantage of the promotional 9.56 INR rate yields a return comparable to putting money into a savings account.

Impact and Recommendations

The net-metering rate of 9.56 INR for excess generation may not be necessary to drive further adoption among the current demographic of prosumers, as long as sufficient economic returns—potentially in line with interest rates—can be demonstrated and communicated to this customer segment. However, there are still other

Table 13 | **Number of Utility Employees in India per Million kWh (mkWh) of Electricity Sold, 2011–2012**

RANK	STATE	EMPLOYEES/ MKWH
Lowest	Uttarakhand	0.50
Average	All India	1.12
Highest	Arunachal Pradesh	32
	Karnataka	0.97

Source: Planning Commission (2014).

factors that may be impeding the effectiveness of this promotional rate. Further, it is unclear how big a motivating factor the promotional rate can be in attracting other segments of residential customers, other customer classes, and new project developers. Thus, program administrators, and others, can do the following:

- Undertake market research to understand whether the promotional rate appeals to the current segment of residential prosumers, whether it would appeal to a broader segment of residential prosumers, and whether the funds needed to support the promotional rate could be more effectively used in promotional campaigns.
- If the rate is found to be effective, increase the frequency of radio and newspaper advertisements, and provide more and clearer details on the economics of the net-metering program to ensure that interested consumers understand the financial benefits of the promotional rate, and to attract a broader segment of residential customers. Facilitating prosumer interaction and information exchange through formal online platforms or frequent formal prosumer gatherings may also be helpful.
- Highlight and promote examples where current prosumers were paid and/or billed properly to alleviate concerns of potential prosumers about whether the promotional rate will be paid by the program administrator.
- If the rate is found to be ineffective, increase resources for and promotional information about current financial incentives, such as priority sector loans.

6. Limited Institutional Capacity

Bengaluru's net-metering program is relatively new and is experiencing growing pains. As more consumers join the program, BESCOM's institutional capapcity will need to be strengthened in order to overcome challenges such as long wait times for interconnection appointments and confusion with meter-reading processes. Many of these limitations are acknowledged by BESCOM; the utility recognizes that it is learning as it gains more experience with the program.

Utility Capacity

In India generally, employment in utilities is declining. Between 1998 and 2012, the number of utility employees fell from 977,000 to 660,000, despite growth in energy demand (Planning Commission 2014). These statistics are relevant to the state of Karnataka, and to Bengaluru specifically. According to the Planning Commission of India, as of 2012, the number of utility employees in Karnataka was below the national average (Table 13).

The general consensus among consumers and developers in Bengaluru is that BESCOM's institutional capacity needs to be strengthened in order to properly administer the net-metering program.

Lack of Capacity for Synchronization and Interconnection

The reported time for installation and grid connection varied greatly by prosumer. Based on prosumers' and project developers' responses, it appears that bottlenecks occurred not at the application or system-installation stage, but at the interconnection and meter-testing stages.

Most interviewees agree that the initial net-metering application approval process is fairly quick. BESCOM's response typically comes a few days after the online application is completed. Physical installation of the panels took anywhere from a few days to a couple of weeks. However, two project developers stated that the entire BESCOM approval and interconnection process[37] can take up to five months (four developers mentioned that the BESCOM process took 2.5-5 months) with the metering process (buying and testing a meter) taking over 1.5 months in one case (Table 14).

Table 14 | **BESCOM Net-Metering Process Times**

ONLINE APPLICATION APPROVAL	Usually few days to a week
PHYSICAL INSTALLATION	Few days to a few weeks
NET-METER TESTING	Up to 1.5 months
APPLICATION TO INTERCONNECTION APPOINTMENT	Up to 5 months (4 developers stated 2.5–5 months; 2 stated 1–2 months)

Note: Based on responses from prosumers and project developers interviewed.

At the synchronization stage, customers are essentially waiting for a BESCOM-approved engineer to connect the system. The amount of time that the synchronization[38] and entire interconnection[39] process takes, as reported by interviewed prosumers, points to a need for more human capacity within BESCOM to carry out the technical tasks needed to connect a system to the grid, such as inverter and meter-synchronization procedures.

Lack of Capacity among Meter Readers

Some prosumers mentioned that they had not yet received their net-metering payments or that their bills have been inaccurate.

One of the eight prosumers currently enrolled in the net-metering program had received payment from BESCOM at the time of the interview. According to the developers interviewed, potential customers often state that they are not interested in participating in the net-metering program because they are unsure that they will receive payments associated with the net-metering promotional rate if they are electricity net exporters.

Furthermore, a few prosumers complained that meter readers inaccurately read their meters and, as a result, they were overcharged in their monthly electricity bills. According to BESCOM,[40] only BESCOM-approved local engineers should be reading the net-meters installed in these households. However, this has not been the case.

Lack of Capacity at Subdivision Level

Delays in the interconnection process and mistakes in payment are felt more acutely by prosumers and developers at more remote subdivisions than in the central areas served by BESCOM.[41] This point was noted in several conversations with both prosumers and developers, pointing to the need for BESCOM to target capacity building programs at those levels.

Impact and Recommendations

Institutional capacity constraints are hampering the progress of the net-metering program and will continue to do so if they are not addressed. Long wait times, billing errors, and missing payments illustrate how limited capacity is affecting the success of the net-metering program. Ultimately, these problems can threaten prosumers' trust in the program. Several actions could alleviate some of these problems:

- Program administrators can introduce short-term solutions, such as streamlining the meter-approval processes, which current prosumers perceive as a bottleneck. Program administrators could also allow very small systems to bypass some of the interconnection procedures—a solution that some local experts recommend. Most of the local experts, project developers, and prosumers interviewed suggested that the program administrators introduce an online payment process for payment allocation to net exporting prosumers.
- In the longer term, program administrators can create a "one window" net-metering unit that manages the entire process from application to payments; several prosumers and project developers advocated this approach in the interviews. The program administrators and local experts interviewed suggested additional long-term initiatives, including specialized skill training for meter readers, and product certification and training for more local engineers.
- Project developers and other groups can publicize examples of current prosumers who were paid or billed properly, to alleviate concerns of potential prosumers.

CONCLUSION

The paper recognizes that rooftop solar PV systems can help reduce the pressure to meet demand by providing electricity supply at the point of demand. It provides insights into how Bengaluru can encourage an increasing number of "prosumers" to install rooftop solar PV. It does so by exploring the barriers that currently face existing prosumers and by putting forward a set of recommendations for program administrators and others in Bengaluru and possibly beyond.

Bengaluru has made notable progress in promoting and scaling the use of rooftop solar PV systems. However, the city still has far to go if it is to help Karnataka achieve its 400 MW rooftop solar PV goal by 2018.

In theory, the net-metering program has been well thought out: program details are explained in various documents and formats online; application forms are easy to find and fill out online; and, most importantly, the program has full support from its administrator, BESCOM. In practice, however, the barriers identified in this paper may be impeding prosumer adoption of rooftop solar PV.

To fully understand and address the barriers inhibiting the scale-up of BESCOM's net-metering program, additional research will be needed. Although our sample group for this study generated some insights into the challenges limiting the program, the sample size was small and not fully representative of Bengaluru's population. As such, it could not fully capture the preferences and motivations that drive (or inhibit) the participation of residents of Bengaluru in the net-metering program.

A more detailed set of interviews should be conducted over a larger set of respondents. Future interviews should expand beyond household-level prosumers to include residential apartment buildings, and commercial and industrial buildings. Consumers who do not participate in the program should also be interviewed. Targeting non-participants could shed light on the general population's understanding of solar PV and BESCOM's net-metering program, and reveal what is inhibiting a greater number of people from participating in the program.

In addition to the interviews described above, there are other research avenues that could ultimately support the broader adoption of rooftop solar PV in Bengaluru. Questions worthy of research include:

- Is net-metering the most effective program for scaling-up rooftop solar PV in Bengaluru and other cities?
- What is the role of public participation in designing effective programs for scaling rooftop solar PV?
- Are utilities or governments better suited to drive and support rooftop solar PV programs and prosumer growth?
- What is the role of awareness, education, and marketing strategies in promoting rooftop solar PV in Bengaluru?
- What building codes and regulatory requirements are necessary for enabling rooftop solar PV systems?

APPENDIX A: BANGALORE CENSUS DATA (2011) AND LT-2(A) TARIFF (2015)

Table A1 | **Bangalore Census Data (Rural and Urban), 2011**

Total Population	9,621, 551
Number of Households	2,393, 845
HOUSEHOLD ROOFTOP MATERIAL (%)	
Grass/thatch/bamboo/wood/mud	1.30
Plastic	0.70
Hand-made tiles	1.40
Brick	0.50
Stone	4.10
GI/Metal/Asbestos	22.30
Concrete	67.80
HOUSEHOLD OWNERSHIP STATUS (%)	
Owned	38.40
Rented	58.70
HOUSEHOLD MAIN SOURCE OF LIGHTING (%)	
Electricity	98.00
Kerosene	1.50
Solar	0.10
No lighting	0.20

Source: India Ministry of Home Affairs (2011).

Table A2 | **LT-2(a)(i): Applicable to Areas under Jurisdiction of Bruhat Bengaluru Mahanagara Palike Municipal Corporation and all Urban Local Bodies**

DEMAND CHARGES	For the first KW	25 INR/kW
	For every additional KW	35 INR/kW
ENERGY CHARGES	For 0 - 30 units	2.70 INR/kWh
	31 to 100 units	4.00 INR/kWh
	101 to 200 units	5.25 INR/kWh
	Above 200 units	6.25 INR/kWh

Source: KERC (2014).

APPENDIX B: METHODOLOGY

We conducted interviews in Bengaluru in July 2015 with local industry experts, project developers,[42] and residential customers. The purpose of the interviews was to improve understanding of what motivated the prosumers to participate in the net-metering program, what their experiences had been, and what these experiences suggest about potential barriers to program scale-up. A few of the customers we interviewed were prospective prosumers, but most had already installed a rooftop solar PV system and were, therefore, already prosumers.

We created two questionnaires: one for project developers and one for prosumers (see Appendix E). The questionnaire for project developers included 27 questions, 25 of which were open-ended. The remaining two questions asked respondents to rank their answers based on importance or level of concern. The questionnaire for customers included 23 questions, 18 of which were open-ended. The remaining five questions asked respondents to rank their answers based on importance or level of concern.

We used the questionnaire to interview seven project developers currently operating and providing services related to rooftop solar PV installations in the city of Bengaluru and a total of 16 different types of prosumers. Of the prosumers interviewed, 12 were residential prosumers, two were commercial or industrial, and two were institutional. Project developers and prosumers interviewed were mainly identified through a publicly available list of customers participating in Bengaluru's net-metering program. This list is published by BESCOM, the main electric utility in Bengaluru. It can be found on the utility's website and is updated periodically with information such as the name and contact information of the prosumers, their current electricity tariff, the capacity of their installed rooftop solar PV system, the in-service date of their system, the name of their installer, and the brand of module and inverter used (BESCOM 2016). Other customers interviewed were referred to us by project developers.

We started by interviewing project developers. This allowed us to gain an understanding of the rooftop solar PV market in Bengaluru, and of the number and customer class of the rooftop solar PV installations with which the developers had been involved. In total, the seven project developers interviewed had installed over 150 solar PV systems in Karnataka at the time of their interview. Three of the project developers focus on residential installations, two on commercial or industrial installations, and two work at both levels. The project developer questionnaire included questions about the types of systems they install, the types of customers they interact with, their perceptions about the level of awareness among customers, and their experience with BESCOM's net-metering program (at both the application stage and interconnection stage).

We then interviewed prosumers who have installed rooftop solar PV systems on their rooftops to better understand their perspective and experience with the net-metering program. The questionnaires included questions about the installed system (size, connection, battery, costs, and payback period); prosumer awareness of solar PV technology and rooftop solar PV programs; prosumer experience with project developers, the application, installation, and interconnection processes; and their overall satisfaction with the program. Of the 16 prosumers interviewed, 13 have installed a rooftop system, 11 are connected and exporting to the grid, and 10 are participating in BESCOM's net-metering program (see Table B1 for details and breakdown of customer interviews).

Table B1 | **Prosumers' Interview Information**

NUMBER OF PROSUMERS INTERVIEWED			NUMBER WHO HAVE INSTALLED SYSTEM			ANNUAL ENERGY CONSUMPTION			NUMBER EXPORTING ENERGY TO THE GRID			NUMBER PARTICIPATING IN NET-METERING		
RESIDENTIAL	INDUSTRIAL/ COMMERCIAL	PUBLIC	RESIDENTIAL	INDUSTRIAL/ COMMERCIAL	PUBLIC	RESIDENTIAL	INDUSTRIAL/ COMMERCIAL	PUBLIC	RESIDENTIAL	INDUSTRIAL/ COMMERCIAL	PUBLIC	RESIDENTIAL	INDUSTRIAL/ COMMERCIAL	PUBLIC
12	3	2	11	0	2	100–450kWh/ month	Broad range	Broad range	9	N/A	2	9	N/A	1

APPENDIX C: INDIA'S ANNUAL TARGETS FOR ROOFTOP AND GROUND-MOUNTED SOLAR

On June 17, 2015, the Government of India announced ambitious national targets for solar power. The government set a goal of 100 GW for grid-connected solar power capacity by 2022, with 40 GW coming from rooftop solar PV systems (Government of India 2015). Annual targets for both rooftop and ground-mounted solar power capacity were subsequently released (Table C1) (Kapoor 2015).

Table C1 | **India's Annual Targets for Rooftop and Ground-Mounted Solar**

CATEGORY	ANNUAL TARGETS (MW)						
	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Rooftop Solar	200	4,800	5,000	6,000	7,000	8,000	9,000
Ground-Mounted Solar	1,800	7,200	10,000	10,000	10,000	9,500	8,500
Total	2,000	12,000	15,000	16,000	17,000	17,500	17,500

Source: Kapoor (2015).

APPENDIX D: BASIC CASH FLOW MODELS FOR TWO NET-METERED ROOFTOP SOLAR PV SYSTEMS IN BENGALURU

Table D1 | **Basic Cash Flow Model for 4 kW System Meeting Annual Demand**

SYSTEM ASSUMPTIONS (ANNUAL SOLAR PV GENERATION ROUGHLY EQUIVALENT TO ANNUAL CONSUMPTION)	
Installed system capacity	4 kWp
Installed price per watt	85 INR/W
Annual generation	6,192 kWh
Sunny hours per year	1,548 Hours
Weighted Average Tariff (LT-2a)	5.52 INR / kWh
Monthly Average Consumption	500 kWh
PAYBACK PERIOD	11 years
INTERNAL RATE OF RETURN (IRR)	7.84%
OTHER ASSUMPTIONS (ALL WITHIN RANGE OF ANSWERS FROM QUESTIONNAIRES)	
O&M Escalation	1%
O&M Charges	1% of installed price
Solar Panel Lifetime	25
Tariff Escalation Rate	5% every 5 years
Percent Panel Degradation per Year	0.75%
Increased Capacity Cost	0 INR

Table D2 | **Basic Cash Flow Model for 8 kW System Generating Twice Annual Demand**

SYSTEM ASSUMPTIONS (ANNUAL SOLAR PV GENERATION ROUGHLY EQUIVALENT TO ANNUAL CONSUMPTION)	
Installed system capacity	8 kWp
Installed price per watt	85 INR/W
Annual generation	12,384 kWh
Sunny hours per year	1,548 Hours
Weighted Average Tariff (LT-2a)	5.52 INR / kWh
Monthly Average Consumption	500 kWh
PAYBACK PERIOD	8 years
INTERNAL RATE OF RETURN (IRR)	11.42%
OTHER ASSUMPTIONS (ALL WITHIN RANGE OF ANSWERS FROM QUESTIONNAIRES)	
O&M Escalation	1%
O&M Charges	1% of installed price
Solar Panel Lifetime	25
Tariff Escalation Rate	5% every 5 years
Percent Panel Degradation per Year	0.75%
Increased Capacity Cost	1,260 INR / year (3 kW * 35 INR / month)

APPENDIX E: QUESTIONNAIRES

Prosumer Questionnaire

Context Questions:

1. Have you completed an on-site solar PV project? (If no, skip to question #6)
   a. When?
   b. Who installed the system?
   c. What size is the system in watts?
   d. Does your system have back-up battery storage? Why or why not?

2. Do you know how much energy the system should produce annually (in kWh)?
   a. What is your annual (or average monthly) energy consumption in kWh?

3. Does your system export energy to the grid?
   a. In an average month, is it more than you consume?
   b. If so, how much in an average month?

4. Did you sign a PPA with a developer or invest in the system yourself?
   a. If a PPA, what was the PPA price and contract length?
   b. If an investment, what was the total cost of the system in INR per watt (Rs./W)?
      i. Did you take a loan for the project?
         1. Can you provide details of the loan (payments, interest rate, etc.)?
      ii. Do you know how long it will take for you to recover your investment?
         1. If yes, how long?

5. Are you using any government or other incentive programs as financial support?
   a. Why or why not?
   b. If so, which one(s) and why?
   c. How long did it take to receive approval for each?
   d. How long did it take to receive payment for each?

6. Do you know which electricity tariff you pay (e.g. HT1, LT1, etc.)?
   a. If not, could you provide a bill to show your rate per kWh and other fees (please forward, by June 2015)?

Barrier Questions:

Awareness/Perception

7. Were you previously aware that rooftop solar PV projects are available in your area (before being contacted or installing a system)?
   a. What made you aware of these systems and when?

8. Are you aware of any incentive programs for rooftop solar PV systems?
   a. Which ones?
   b. How and when did you find out about them?
   c. If not already using, would you be interested in any of these? Why?
   d. If not, why not (e.g. long anticipated wait time)?

9. Did/do you have reservations about installing a PV system (i.e., hesitations about installing a system)? If so, please list your top three (max) reservations:
   1) _____
   2) _____
   3) _____

   a. How concerned were you about the following (low, medium, or high):
      - High upfront cost _____
      - System financing _____
      - Cost of solar vs. grid electricity _____
      - Building lease _____
      - Picking/finding a developer and/or installer _____
      - PPA contract length (BESCOM or other) _____
      - Understanding the process _____
      - Long anticipated process/project time _____
      - Anticipated future cost reductions in solar _____
      - Other uses for rooftop space _____
      - Building/infrastructure requirements _____

10. What were the **main** factor(s) that attracted you to installing a PV system (i.e. what moved/might have moved you beyond interest to action)? Please list your top three (max) motivations:
    1) _____
    2) _____
    3) _____

    a. How important were the following in considering a system (low, medium, or high):
       - Financial savings _____
       - Improved reliability of electricity supply _____
       - Lower emissions/environmental consideration _____
       - Setting example/reputation (company brand equity) _____

Evaluation

11. How did you evaluate whether or not to move forward with a rooftop solar PV system?
    a. What information did you use?
    b. How did you find this information?
    c. Who/what organizations did you contact?
    (If you have installed a solar PV system, skip to question #12)

    d. When was the last time you evaluated installing a PV system?
    e. What were the results of the evaluation?
        i. Was your site physically suitable?
        ii. If applicable, what system size and/or costs were quoted?
        iii. Which financial models were you considering?
        iv. Would your system need battery storage? Why or why not?
    f. Ultimately, why didn't you decide to move forward? Please list the (max three) reasons.
        1) _____
        2) _____
        3) _____

Contacting Provider/Developer

12. What was/would have been the first step you took to start the process of installing a rooftop system, and why?
    a. What person or organization did/would you contact first?
    b. What information did/would you use to take these steps?
    c. How did/would you find this information?

13. What were/would have been the deciding factors in choosing a vendor and/or project developers? Why?
    a. From what sources did/would you find this information?
    (If you have not installed a solar PV system, skip to question #23)

System, application, and financing

14. How did you decide what size system to install?
    a. Was an incentive program a part of the decision?

15. How difficult was procuring financing (low, medium, or high)? _____
    a. What type of financing did you receive (e.g. loan, lease, etc.)?

16. How difficult were the following parts of the interconnection process (low, medium, or high):
    - Understanding the interconnection application process _____
    - Completing and submitting the interconnection application _____
    - Waiting for interconnection approval (how long did it take?) _____

17. How difficult, if applicable, was applying for a capital subsidy and/or net-metering (low, medium, or high): _____
    a. Rate the difficulty of each part of the incentive program(s) (low, medium, or high):
        - Understanding the process _____
        - Completing and submitting the application _____
        - Waiting for approval _____
        - Receiving payment _____

Installation and connection

18. Were there any obstacles with the building infrastructure during installation (e.g. electrical systems, infrastructure stability, permitting, etc.)? If so, what?

19. Was there any difficulty in connecting your system to the grid (electricity utility)? If so, what?
    a. When was the problem discovered and how long a delay was it?

20. How long did it take to install the system after you decided to move forward (from initial call to developer/EPC to system operation)?

21. How difficult was the entire installation process (low, medium, or high)? _____

Results

22. Who is responsible for your system's operation and maintenance?
    a. If a third party, was that part of the original contract?

23. If possible, what would you have changed about the process to make it easier?
    a. Would you change anything about your decisions throughout?

Project Developer Questionnaire

Context Questions:

1. How many solar PV systems have you installed? Total installed capacity?

2. What type of buildings/customers do you typically provide services to (i.e. residential, commercial, industrial, public)?
   a. Which tariff schedules are the most common (e.g. HT1, LT1, etc.)?
   b. Demographic of residential customers?

3. How much information do you give customers on their system (size, output, etc.)?
   a. How do you explain your evaluations to customers?

4. How aware of their consumption are they? What do they typically have on hand?

5. By customer class, what is the typical size of installation?

6. What is the typical price range per watt ("landed cost") that you quote customers, by class?

7. What is the typical range of payback period and ROI for customers, by market segment?

8. If a project developer, what range of IRRs do you typically consider?

9. How do your customers typically pay for projects (i.e. which model, OPEX/CAPEX, do you operate under)?
   a. If using the CAPEX model, do you work with the customer to find financing?

10. Do your customers typically sign up for incentive programs (net-metering, capital subsidy, accelerated depreciation)?
    a. Which are the most common?
    b. Any trends by customer class?

11. Is there still a limit to the size of systems that can be signed up for net-metering in Bengaluru? Are there any provisions against exporting to the grid?
    a. If not, do you size the systems differently because of the net-metering program (specifically with residential or commercial customers)?
    b. What percent of annual output above demand is typically fed into the grid?

12. From which customer class have you received the most interest in net-metering: residential, industrial, or commercial?

Awareness/Barrier Questions:

13. How aware do you think the general public is of the availability of rooftop solar PV?
    a. What information are you basing this on?

14. How aware are customers of incentive programs? Do you notice a difference by customer class?

15. Typically, do customers come to you or do you reach out to customers?
    a. If customers come to you, how do they know to contact you?
    b. If you reach out to customers, what are your outreach strategies?
    c. What is the general level of interest/knowledge of these customers?

16. What are your customers' typical interest in rooftop solar PV (i.e. what benefits do they cite, such as savings, etc.)?

17. What are the main concerns of the customers that you work with, by customer class? List the top 5 or 6:

Process

18. When a customer drops out before deciding to move forward with installing a system, what are the reasons they cite?

19. When a customer decides to move forward with a system, typically what are the reasons they cite?

20. Have you had instances of customers dropping out after deciding to move forward with a system?
    a. Typically at what point does this occur? What reasons are cited?

21. Do you manage the application process for the customer? For both interconnection and any incentive programs?
    a. How difficult, from 1–5 (5 being hardest), is the interconnection process?
    b. How difficult, from 1–5 (5 being hardest), are each of the incentive program processes?
    c. How long does each application process usually take?

22. Are there cases where projects weren't able to interconnect? At what point was this discovered?

23. Has building or electricity infrastructure, and permitting for this, been an obstacle? If so, which and how often?

24. How long does a typical system installation take (from initial interaction to system connection)?

25. Are you responsible for O&M of the system? Is it included in the costing?

Concluding Thoughts

26. Do you think the net-metering policy is fair? How do customers, the utility, and the government make out?

27. What changes to the process do you think would have the most impact in making it easier for customers?

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ENDNOTES

1. There is some ambiguity concerning the rooftop solar PV goal. In one place the policy states, "It is proposed to achieve a minimum 400 MW of grid-connected rooftop solar generation projects in the state by 2018," but it then includes "grid-connected and off-grid" projects in the annual goals.
2. In the context of this paper, project developers include solar PV vendors; system installers; and engineering, procurement, and construction companies.
3. There is some ambiguity concerning the rooftop solar PV goal. In one place the policy states, "It is proposed to achieve a minimum 400 MW of grid-connected rooftop solar generation projects in the state by 2018," but it then includes "grid-connected and off-grid" projects in the annual goals.
4. A number of reports discuss prosumers from technical and economic perspectives. Bridge To India (2015) analyses the financial competitiveness and technical potential of RTSPV in India; Pillai et al. (2014) look at the near-term economic benefits of grid-connected residential PV systems; Rickerson (2014) focuses on the financial benefits, as well as costs and risks to utilities, electricity rates and taxing authorities associated with prosumers; Sundaray et al. (2014) assess India's market potential for RTSPV, concentrating on strategies for commoditizing RTSPV; Magal et al. (2014) review international best practices and Indian RTSPV interconnection policies and provide recommendations.
5. In the context of this paper, project developers include solar PV vendors, system installers, and engineering, procurement and construction (EPC) companies.
6. The electricity system, specifically the centralized electricity system for a given country or region, will be called "the grid" hereafter.
7. Distributed solar PV capacity includes systems up to 20 MW in China (IHS Technology Solar Team 2015).
8. IHS defines distributed solar PV systems as 100 kilowatts (kW) and smaller (IHS Technology Solar Team 2015). Distributed solar PV can also be defined as "electricity that is produced at or near the point where it is used" (SEIA 2015), typically on residential, commercial, or industrial buildings or land, with a capacity under 1 megawatt (MW) (SolarPower Europe 2015).
9. According to Navigant Research (2015), 346 GW of distributed solar PV and 289 GW in utility-scale solar PV systems are expected to come online between 2015 and 2024.
10. Distributed solar PV numbers from BNEF are derived from the combined installed residential and commercial solar PV capacity.
11. Market potential takes economic and consumer uptake into account, whereas technical potential does not.
12. A renewable energy system is at "grid parity" when the cost of the system over its lifetime is equal to, or lower than, the price of electricity from the grid.
13. These conditions include accelerated depreciation and the proposed interest rate subvention. The 12 states that have reached grid parity under these conditions for commercial customers are Andhra Pradesh, Delhi, Karnataka, Kerala, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, and West Bengal.
14. Commercial and industrial electricity tariffs are higher in India than residential tariffs, making "grid parity" easier to attain in these sectors than in the residential sector.
15. The 25 states and union-territories include: Andhra Pradesh, Bihar (draft), Chhattisgarh, Delhi, Goa and Union Territories, Haryana, Himachal Pradesh (draft), Karnataka, Kerala, Madhya Pradesh, Maharashtra (draft), Meghalaya, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal.
16. This rate has changed since May 2016 (KERC 2016). The new rate of 7.08 INR/kWh for systems smaller than 10kWh, effective for systems commissioned after May 2, 2016, changes the economics of rooftop solar PV in Bengaluru significantly.
17. Karnataka's solar policy claims a "market potential" of 10 GW for solar power in Karnataka.
18. Guidelines on the net-metering program for customers and BESCOM officials are available at http://bescom.org/en/forms-and-guidelines-2/
19. The rate of 9.56 INR/kWh changed since May 2016 (KERC 2016). The new rate of 7.08 INR/kWh now applies for systems smaller than 10kWh commissioned after May 2, 2016.
20. Source does not specify whether these installations are grid-connected or stand-alone; they are probably a mixture of the two. Karnataka's state targets include both types of systems.
21. Grid-connected systems were not allowed before.
22. The most recent data are available at http://bescom.org/wp-content/uploads/2016/04/COMMISSIONED-INSTALLATIONS-as-on-feb.pdf.
23. Several project developers interviewed provided their financial models, and most others confirmed similar inputs and assumptions.
24. One developer said that it makes clear to potential consumers that there is no payback.
25. During a meeting with BESCOM officials on July 24, 2015, we were informed that batteries and hybrid inverters were recently approved by the technical committee for inclusion as part of the net-metering program, and that at least one such system has already come online.
26. The device that converts the DC output of the solar PV panel to the AC grid connection.
27. As part of the net-metering tariff set by both the Karnataka State Regulatory Commission and BESCOM, participating rooftop solar PV prosumers enter into a 25-year contract with their electric utility for the rate paid for net excess generation from the rooftop solar PV system to the grid (KERC 2013; BESCOM 2014). Prosumers are only eligible to sign this contract until December 31, 2018; after this time, new terms will be determined for anyone wanting to participate. However, the terms for prosumers who have already signed contracts with their utilities will not change. One developer thought the terms of the PPA that current prosumers have already signed would be changed after December 31, 2018.
28. "Upper class" population is defined as population whose income is greater than $50 per day.
29. Interviewees explained that community benefits include contributing excess electricity to the community and helping to alleviate current pressures faced by the city as it tries to meet electricity demand.

30. Traditionally, the objectives of priority sector lending in India have been to ensure that vulnerable sections of society get access to credit. The emphasis today, over and above lending to vulnerable sections, is to increase employability, create basic infrastructure, and improve competitiveness of the economy, thus creating more jobs. This was approved by the national government early in 2015 (Rajan 2015).
31. The national government already offers accelerated depreciation to commercial customers—an incentive roughly equivalent to 25 percent of the capital cost—and has previously considered offering it to residential customers (Khurana 2014). The national government is also in the process of designing an interest rate subvention program (Bridge To India 2015b), which will help overcome the barrier of poor financing options (Rustagi 2015) at a lower cost to the national government than accelerated depreciation (Shrimali et al. 2015). The interest rate subvention program currently under discussion with the national government would "…reduce effective interest rate for rooftop solar projects to around 8.5% p.a. helping to reduce the levelized cost by around 10%" (Bridge To India 2015d).
32. A majority of the prosumers interviewed do not have rooftop solar PV systems that provide this function.
33. LT-2a refers to a domestic customer under BESCOM's retail tariff categories (BESCOM 2014).
34. A cash flow model attempts to catalogue all the relevant costs and revenue generated during the lifetime of a rooftop solar PV system. The cash flow model used here was provided by one of the project developers interviewed, with most of the "other assumptions" listed in cash flow model tables (e.g. O&M escalation) provided. All other assumptions (e.g. monthly consumption, increased capacity cost, etc.) were chosen from the answers provided by the residential prosumers interviewed.
35. Excess generation is settled on a monthly basis, as noted in the section above on BESCOM's net-metering program.
36. This metric can broadly be compared to the annual return on another investment or the rate of interest earned by a bank account.
37. Here the process refers to the steps taken by project developers with their customers, BESCOM, and other local officials to install a rooftop solar PV system from the moment the customer agrees to work with the project developer, and the net-metering application is submitted, to the interconnection of the system.
38. Under BESCOM's consumer guidelines, the synchronization process involves inspection, calibration, and sealing of the purchased bi-directional meter by a BESCOM engineer.
39. The interconnection process involves four steps: (1) application process, (2) utility review, (3) installation and commissioning, and (4) billing (BESCOM 2015b).
40. Information provided by BESCOM at a meeting on July 24, 2015.
41. BESCOM operates in eight districts of Karnataka, 28 divisions, and 116 subdivisions across three zones: Bangalore Metropolitan Area Zone, Bangalore Rural Area Zone, and Chitradurga Zone (BESCOM 2014). Interviewees remarked that BESCOM's human capacity is weaker in more remote subdivisions than in more centrally located subdivisions.
42. In the context of this paper, project developers include solar PV vendors; system installers; and engineering, procurement, and construction companies.

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