



Harnessing Sunlight for Green Power

The potential for behaviour change and rooftop solar panels

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Executive Summary

Rooftop solar panels dramatically reduce greenhouse gas emissions and help mitigate climate change. Electricity and heat generation have the largest share of carbon dioxide (CO₂) emissions in India, with the residential sector being a significant contributor (IEA, 2022b). With every unit of solar energy preventing 0.7 kg of CO₂ emission, and a 1 kW system generating around 120 units of electricity a month in India (Jain, 2018), use of solar rooftop cuts carbon emissions by approximately 1 tonne of CO₂ equivalent in a year. Widespread household adoption of rooftop solar panels has great potential to minimise the country's carbon footprint, improve air quality, and combat climate change.

This diagnostic brief focuses on behavioural aspects in its investigation of the barriers and facilitators in the adoption of rooftop solar by Indian households, using the cities of Ahmedabad and Surat in the state of Gujarat for fieldwork. Barriers range from limited awareness of solar benefits, high upfront costs, and complexities in the buying process for rooftop solar to unorganised vendor bases and mismatches between government and vendor prices. Facilitators for rooftop solar adoption include social influence, trusted brand presence, and government mandates or subsidies. Providing a comprehensive view of the country's rooftop solar landscape, the brief suggests various behavioural interventions and policy enhancements to promote households' transition to rooftop solar, and thereby lower the carbon footprint of electricity consumption in India.

Section 01: The Project

Installation of solar panels on rooftops to generate clean and sustainable energy from sunlight is a game-changing option for a country like India with its huge, growing population and energy needs. More and more countries around the world are transitioning to renewable energy sources as they seek to reduce reliance on fossil fuels. In the global Net Zero Emissions by 2050 Scenario, the number of households relying on solar photovoltaics (PV) is projected to exceed 100 million in 2030, the goal being an annual addition of 630 gigawatt (GW) of solar PV by 2030 (IEA, 2022a; IEA, 2021). Considering the country's abundant sunlight and surging energy demand, rooftop solar has the potential to transform India's energy landscape and contribute immensely to global efforts to mitigate climate change.

Rooftop solar panels provide a renewable energy solution by harnessing and converting sunlight into electricity utilising PV technology, with benefits ranging from reduced reliance on grid electricity, cost savings on energy bills to the opportunity to contribute to a greener future. Adoption of equitable and low carbon energy systems like rooftop solar requires a comprehensive approach, encompassing structural and policy alterations by governments as well as behavioural and normative shifts at the individual and household levels.

The Low Carbon Lifestyles Project at CSBC seeks to initiate behaviour change towards sustainable lifestyle choices, including low carbon energy consumption, in Indian cities. It aims to design interventions to redirect household choices towards sustainable behaviours and technologies. The primary goal is to ensure that policy incorporates an understanding of the context of consumer choices and of local barriers to the uptake of low carbon consumption, essential to devise levers for higher adoption.

In the domain of energy consumption, the project promotes the adoption of low carbon options such as rooftop solar and energy-efficient air conditioning. This brief examining the barriers and facilitators in the adoption of rooftop solar panels in Indian cities is based on fieldwork conducted in Surat and Ahmedabad, Gujarat. Exploring best practices, challenges, and enablers in households' transition to rooftop solar systems in depth, it contributes valuable insights for widespread implementation of this sustainable energy solution nationwide.

Project Objective:

A key objective of the Low Carbon Lifestyles Project is to advocate the adoption of rooftop solar panels. To promote low carbon energy consumption in Indian cities, this project aims to encourage middle- and high-income households to install rooftop solar panels which also offer significant cost savings in the long run.

- Target Behaviour: Purchase and installation of rooftop solar panels
- Target Population: Urban Indian households belonging to middle- to high-income groups

Rooftop Solar Panels – The Indian Context

The global shift towards renewable energy has led to growing attention on sustainable technologies, including rooftop solar, in developing countries like India. As electricity bills rise, households and businesses in the country are increasingly looking for alternative sources of energy, and rooftop solar offers a clean, reliable, and cost-effective solution.

The Government of India has been actively promoting rooftop solar installations for residential and commercial purposes through its policies and initiatives such as subsidies and net metering. In 2015, the government set a target of 175 GW of renewable energy by 2022, including 100 GW of solar energy, with grid-connected solar rooftop installations (residential and commercial) accounting for 40 GW (PIB, 2018). By November 2022, India's installed solar power capacity had reached around 62 GW out of the targeted 100 GW, with total rooftop solar capacity at 8.8 GW by December 2022 – a significant jump from 3.2 GW in 2020 (Mercom India, 2023), but far short of the 2015 target of 40 GW. Programmes launched by the Ministry of New and Renewable Energy (MNRE) targeting improved uptake of residential rooftop solar include the Grid Connected Rooftop and Small Solar Plants Programme, Phase II (2019) of which aimed to install 4 GW of rooftop solar plants in the residential sector by 2022 (MNRE, 2022). However, only 2 GW of residential rooftop capacity was achieved as of 2021–2022 (IEEFA, 2022). The government has extended the Phase II programme to March 2026 (MNRE, 2022).

MNRE provides capital incentives to residential consumers, including individual households and housing societies, for rooftop solar installation (MNRE, 2023a). Further, net metering policies allow consumers to feed surplus electricity generated from their solar panels back into the grid, earning them credits for the excess power. Additionally, several states in India have introduced their own policies and incentives to encourage the installation of rooftop solar panels. For example, the Surya Urja Rooftop Yojana-Gujarat (SURYA-Gujarat), launched in August 2019, offers incentives and subsidies for rooftop solar adoption to promote the installation of large-scale solar rooftop systems on private residential roof terraces.

The country's residential rooftop solar market is projected to continue growing, with total installed capacity expected to reach 16.2 GW by 2030 (Bridge to India, 2021). The uptake of residential rooftop solar in India has been fuelled by factors such as falling costs of solar panels and rising electricity tariffs (*Business Standard*, 2021). The private sector also plays a significant role in this growth, with solar companies, system integrators, and energy service companies providing easier access to services such as system design, installation, and maintenance. Financial institutions such as banks and non-banking financial companies are also increasingly offering financing options for rooftop solar installations with varying interest rates and repayment periods (Bridge to India, 2021).

With the country eyeing a renewable energy future, the government's continued commitment, financial incentives, and supportive policies hold out good prospects. Despite commendable progress, challenges persist in India's rooftop solar adoption, marked by deviations from targeted capacities and extension of programmes. Acknowledging and identifying the challenges, along with the enablers, is pivotal in shaping effective strategies, fostering collaboration between stakeholders, and unlocking the full potential of rooftop solar.

Choice and Rooftop Solar Panels

Based on an extensive literature review, several barriers impeding the widespread adoption of rooftop solar panels – globally and in India – have been identified. On the demand side, there is the formidable financial challenge, rooted in high upfront costs and protracted payback periods (Elmustapha et al., 2018; Mah et al., 2018; Nasirov et al., 2023; Parsad et al., 2020). The perceived value of rooftop space is another barrier in countries like Nepal and India, where consumers resist dedicating precious rooftop space to solar panels as these areas are used for various purposes like clothes drying and social activities (Mah et al., 2018; Shrestha & Raut, 2020). Lack of access to technical, financial, and operational information poses a strong barrier, impeding the decision-making process and sometimes leading to the abandonment of solar panel projects, as studies in Delhi and Kerala show (Dutt, 2020; Parsad et al., 2020). On the supply side, limited financing options emerge as a substantial barrier to rooftop solar adoption, making it difficult for households to bear the high initial capital costs.

Several factors buoy the adoption of rooftop solar. Increasing environmental awareness and concerns about climate change attract households towards a clean, sustainable energy source like rooftop solar (Horne et al., 2021). Social norms and beliefs facilitate adoption, with the actions and choices of peers and community influencing individuals (Aggarwal et al., 2019). The fear of high conventional electricity costs also motivates adoption (Hsu, 2018; Sommerfeld et al., 2017). Access to transparent information from trusted sources – online resources or government agencies – has been identified as a critical facilitator in multiple studies (Sommerfeld et al., 2017). Government incentives and financial aid are also

significant facilitators, reducing upfront costs and shortening payback periods (Bekti et al., 2022; Mah et al., 2018). In India, states like Haryana and West Bengal have implemented mandates and subsidies for suppliers, which have resulted in greater adoption. Changing development processes, so installation of solar panels may be a precondition to obtain a completion certificate for new house construction, can also boost uptake.

Project Methodology

While there are some behavioural studies on the adoption of rooftop solar panels at the household level in India, much more needs to be done. This study seeks a deeper understanding of behavioural and policy barriers that limit the uptake of rooftop solar panels, along with the facilitators for adoption. A robust methodology was accordingly designed to identify the main factors and map out interventions based on the findings.

- First, a detailed literature review was conducted to identify national- and state-level policies and incentives for building a sustainable rooftop solar ecosystem in Indian cities.
- This was supplemented by a stakeholder mapping to understand the diverse actors involved in implementation.
- Next, the team designed and conducted fieldwork with 35 participants, covering middle- and high-income households and suppliers from the cities of Surat and Ahmedabad, which were chosen given the current uptake and adoption of rooftop solar installations. The study surveyed both households which already have a rooftop solar panel installed and those that could be considered potential customers for rooftop solar panels, and suppliers. The team ensured gender and age diversity within the sample.
- Finally, we consolidated and analysed the insights from fieldwork to identify behavioural and structural barriers to and facilitators for adoption of rooftop solar panels in households.
- This was followed by ideation workshops to identify interventions to improve adoption.

Section 02: Insights from Fieldwork

Whether or not an individual consumer adopts a given sustainable behaviour depends on two sets of factors: (1) Demand side factors -- The preferences, needs, and beliefs of the individual can make her/him more likely to adopt that behaviour (such factors are demand-side facilitators of sustainable behaviour), or less likely to adopt the behaviour (demand-side barriers) and (2). Supply-side factors: The availability and accessibility of infrastructure and/or services at the systemic level make an individual more likely (supply-side facilitators) or less likely (supply-side barriers) to adopt the behaviour.

Our diagnostic fieldwork revealed 18 distinct barriers and facilitators that impede the adoption of rooftop solar panels among households in Surat and Ahmedabad in Gujarat.

Demand-Side Barriers

1. *Limited understanding of the benefits and functioning of solar panels:* The research revealed a pervasive lack of understanding about how solar panels work and their benefits. There were concerns about whether they work in winter or monsoon, solar panels causing a blackout at home, etc. Some people shared that they feel embarrassed to ask basic questions, and seeking information online is at times overwhelming or ineffective. Some lacked understanding of the environmental and economic benefits of solar energy: cost savings in the long run, reduced dependence on non-renewable energy sources, and positive environmental impacts. For instance, some people had unrealistic expectations of solar panels completely eliminating their electricity bill.
2. *High upfront cost:* The high upfront cost of installation is a major deterrent for many households which may not have sufficient funds. This barrier is compounded for non-salaried people who may find it difficult to get a loan to invest in solar panels, due to their inability to provide proof of income or collateral required by most financial institutions. Additionally, there is lack of clarity on the expected costs of solar panel installation (see supply side barrier #3), therefore customers with a benchmark cost in mind may find their budgets surpassed, causing them to reconsider or refrain from purchase.
3. *Fears and uncertainty about repair, maintenance, and performance:* The study found that people are hesitant to invest in solar panels as they are unaware of the maintenance that is required and are worried about needing frequent repairs. Given that solar panel maintenance is required for optimal performance, and that maintenance is challenging given rooftop access and

the cost of professional assistance are high, the worry that maintenance is needed too often is a deterrent to purchase. There is also a lack of clarity about performance, in case a taller building blocks sunlight to the roof or what happens to panels in case a customer was to move to a new house. People are often unaware of warranties and how to avail of them, if they need.

4. *Diffusion of responsibility:* We found that many people believe solar panels are only for the rich or intellectuals who have enough money to do good for the environment. This mindset makes it difficult for individuals to change and invest in solar energy systems
5. *Over-Reliance on Grapevine Communication:* Hearing about negative experiences from friends or family who have installed solar panels can also be a significant barrier to adoption. Till a few years ago, when the solar industry was not as regularised, prices for solar panels were very high, there were procedural delays, and net metering had not started, resulting in fewer benefits. Given that human beings place disproportionate trust in information received from their social networks, negative information received via informal interpersonal channels of communication were observed in our study to predict lack of purchase. This is particularly unfortunate since this informally received information is likely to be not just inaccurate and non-representative, but also outdated.

Supply-Side Barriers

6. *Vendors' lack of technical expertise and formal training:* The research found that solar panel vendors often lack technical expertise or training in selling solar energy systems, installation, and maintenance. Usually, their updates on solar panels come from YouTube and WhatsApp, which cannot be considered reliable sources. Often unable to properly explain to potential buyers the cost-benefit analysis, vendors are unable to counter a prime obstacle to solar panel sales: the high perceived cost of solar panels. More generally, vendors' poor understanding of technical aspects renders them unable to answer customer questions and provide accurate information, leading to customers feeling misled or cheated.
7. *Long and complex process of buying and installation:* Our research uncovered the difficulties people face in understanding the process of buying solar panels, including brand and vendor selection, determining the correct kW capacity, navigating the purchase processes with multiple stakeholders, and providing the required documentation. Installing solar panels requires professional expertise, and it can be time-consuming, with the entire system sometimes taking several weeks to install, depending on the size of the system.

8. *Unorganised vendor base, lack of accountability, and price discrepancies:* The study revealed that the solar panel market is not well regulated with a question mark hanging over the reliability and authenticity of many vendors.
 - a. The number of illegal sellers – who are not government registered – has increased in the market; they offer lower prices. Once the solar panels are installed, since customer retention is not a priority, the vendor may not provide adequate support or follow-up services. Some vendors may try to cut costs by using poor-quality products or by not providing complete installation services. This can include skipping steps such as proper earthing, which is essential for safety and performance.
 - b. Additionally, [even legitimate] vendors seldom have a marketing strategy in place and rely solely on walk-in customers or word-of-mouth referrals, which prevents them from reaching a wider market.
 - c. Finally, our findings revealed a significant disparity between government-listed prices and those provided by vendors in the solar panel market. Consumers wish to opt for well-known brands; however, these larger brands often have prices that don't align with the figures quoted by the government. The mismatch arises because government-listed prices exclude taxes and fail to consider factors like quality variations or individual house dynamics. This information gap represents a supply-side barrier that contributes to customer uncertainty regarding accurate pricing details in the solar panel market.

9. *Complications and delays in subsidy and rebate processes:* The research found that the process of applying for and availing subsidy is confusing for both customers and suppliers. Issues include:
 - a. Potential customers are unaware of the different types of subsidies available.
 - b. The process of obtaining subsidies is complicated and time-consuming.
 - c. There is lack of clarity on who can avail subsidy (supplier or consumer), if there is a direct transfer or not, documents required, and which vendors are approved for subsidy.
 - d. The subsidy framing indicates an upfront discount, while in actuality, it is a rebate, implementable post purchase.

Furthermore, the process of rebate implementation is contingent on local authorities and distribution companies (DISCOMs). Vendors and homeowners reported making multiple trips to government offices to ensure credit of the rebate, which is supposed to be straightforward and automatically issued in 30 days. Insufficient resource persons within government offices and DISCOMs and their lack of training to handle queries and questions make the process even more difficult to navigate.

Demand-Side Facilitators

1. *Word-of-mouth recommendations and referrals:* Our study found that the influence of friends, family, and neighbours is a powerful motivator for households to adopt rooftop solar panels. The positive experiences of those they know and trust make individuals see solar panels as a viable and worthwhile investment, and reassure them of the ease of adoption. We also found that word-of-mouth recommendations and referrals play a significant role in vendor selection. Customers often prefer to work with vendors recommended by people they trust.
2. *Emergence as a social symbol:* Our fieldwork revealed a growing perception of solar as a status symbol in India. Having solar panels installed on one's rooftop shows intellectualism and forward-thinking. Households that adopt this technology are often viewed as leaders and trendsetters in their communities. When individuals see solar panels installed on the rooftops of people they know and respect, it creates a positive impression and serves as a powerful endorsement of the technology's benefits.
3. *Trusted because of the presence of known brands:* The fieldwork suggests that customers consider the presence of trusted brands in solar panel manufacturing a crucial factor in their decision to opt for solar panels. With the solar industry still at a nascent stage in India, potential customers lack awareness about the technology, installation process, and benefits, which creates a trust deficit; solar also involves a significant financial investment. This is where well-known brands with a proven track record of success play a crucial role by building customer trust and confidence in the solar panel industry. Moreover, solar panels come with a warranty of up to 25 years, and customers want to ensure they invest in a brand with a proven track record of reliability.
4. *Savings in electricity bills:* The research found that the main driver for purchase is considerable savings in electricity bills, with cost recovery occurring in about three to five years. Households may also produce an excess of electricity compared to their consumption, triggering net metering and additional savings on their electricity bills. Importantly, these savings on bills could grow gradually, especially as the cost of traditional electricity continues to rise. Consequently, the worth of the solar panel system could also escalate over time, presenting a long-lasting investment for homeowners in terms of energy savings.
5. *Long-term reliability:* One of the primary benefits of rooftop solar panels is that they usually come with a warranty period of 25 years. This provides peace

of mind to the customers, knowing they have a reliable source of renewable energy for a long time.

6. *Purchase triggers*: The fieldwork shows several purchase triggers for people to install rooftop solar panels. One of the main triggers is when individuals buy or renovate their houses. This presents an opportunity to incorporate solar panels into the design and construction, reducing dependence on traditional energy sources. Installing solar panels is sometimes prompted by a new source of income, such as starting a home-based business or renting out a part of the house.

The government subsidy is also a significant purchase trigger, as it helps to make solar panel installation more affordable. Word-of-mouth recommendations, such as neighbours installing solar panels, also play a role in influencing individuals' decisions to install solar panels. Higher electricity bills also strongly motivate individuals to switch to solar energy. Planning for an electric vehicle is also a trigger – also highlighted in a study (Kaufmann et al., 2021) – as individuals consider the benefits of producing electricity to power their vehicles.

Supply-Side Facilitators

7. *Influence of role models*: A study finding is that role models influence the adoption of solar energy. For instance, the emphasis by political leaders like Prime Minister Modi on the use of solar energy has created awareness and increasing public interest in solar energy, especially in his home state of Gujarat. He has promoted the SURYA-Gujarat scheme to create a favourable environment for solar panel adoption, has led to a rise in the number of people adopting solar panels. This has created a ripple effect, with other states also following suit and implementing similar policies to promote the adoption of solar energy.

Section 03: Recommendations and Interventions

This study has uncovered key behavioural and structural barriers that limit adoption of rooftop solar in India. Utilisation of these insights is critical for policy, enabling the government to employ a powerful set of levers to spur the uptake of rooftop solar panels in Indian households.

To activate the behavioural bridge to policy, this study employs the 4Es Model of the UK government's Department for Environment, Food and Rural Affairs (DEFRA), which aspires to enable, encourage, exemplify, and engage in moving individuals towards sustainable practices (Institute for Government, 2015). This model offers an approach to addressing behavioural and structural gaps in policy:

1. Enable focuses on providing the necessary infrastructure to make sustainable choices accessible and attractive.
2. Encourage delves into the realm of information dissemination and public awareness to motivate individuals.
3. Exemplify emphasises the importance of leading by example.
4. Engage encourages active participation and collaboration amongst stakeholders to influence policy.

Through a series of ideation workshops, this project identified nine interventions that address the behavioural barriers to adoption of rooftop solar panels, organised below in the 4Es framework.

Enable

Policymakers and stakeholders should recognise that the residential environment influences decisions related to rooftop solar adoption. The project suggests the following intervention to overcome contextual and structural barriers and enable households to opt for rooftop solar:

1. *Streamline the process of solar panel installation*: Solar panel adoption can be boosted by simplifying the processes of applying for subsidy, of approvals and verifications, of net metering, etc. (by improving the state-level portals and helplines with DISCOMs) and providing easy access to new or updated rules or guidelines. Each stage and element of the process needs to be clear and transparent: subsidy details, application steps, eligibility criteria, approved vendors, peer and government ratings, installation procedures, maintenance guidelines, and direct transfer procedures.

Encourage

Augmenting conventional tools such as information provision, regulations, incentives, and communication campaigns with insights from behavioural research

can heighten their persuasive power. This is particularly effective in addressing the concerns of those hesitant to adopt solar technology. The project proposes the following innovative strategies of targeted behaviour change communication campaigns to encourage rooftop solar uptake:

2. *Reframe subsidy as a rebate*: Position the financial support for installing solar panels as a rebate rather than a subsidy, emphasising the benefits of receiving a direct refund or reduction in cost to incentivise households to adopt solar energy.
3. *Reframe price of solar as percentage of total house expenditure*: Present the cost of installing solar panels as a percentage of total house expenses, helping households understand the financial benefits and making the investment more attractive.
4. *Develop a solar support app, including RoI calculator*: Design an integrated mobile application that serves as a user-friendly hub for solar panel adoption. This all-in-one app can offer a range of features, including an RoI savings calculator, easy-to-follow installation guidance, subsidy details, peer and government ratings for approved vendors, maintenance instructions, and direct support for frequently asked questions.
5. *Frame benefits of solar beyond environment friendliness*: Motivate households to embrace solar panels by showcasing how their integration reflects a cutting-edge, hi-tech lifestyle. Highlight the resilience against power cuts, positioning solar energy as a reliable and uninterrupted source of power.
6. *Deliberately compare on-grid and off-grid systems*: Emphasise the advantages of on-grid systems, such as reduced reliance on traditional power sources, uninterrupted power supply, and the ability to sell excess energy back to the grid. This comparison will make on-grid systems more appealing to households considering solar panel installation.

Exemplify

The project suggests using respected or high-profile figures in society to set an example for others to follow by embracing rooftop solar energy.

7. *Seed with a 'changemaker' house for social proof/status*: Install solar panels on a notable house within the community to serve as a visible example of solar energy adoption. This act can inspire other households to follow suit, as they witness the benefits and positive impact first-hand.
8. *Leverage influential role models*: Feature well-known personalities or influential individuals in campaigns to endorse and promote the benefits of

solar panels. Their endorsement can inspire others to adopt solar energy, leveraging their credibility and influence for increased adoption rates.

Engage

Extending the spread of rooftop solar requires the engagement of diverse stakeholders. The project suggests the following multi-stakeholder interventions:

9. *Introduce a pay-after-use model for solar panels:* Introduce a pay-after-use model in collaboration with vendors where households can try solar panels for six months before making any payment. By alleviating the burden of high upfront costs, this approach allows households to experience the benefits first-hand, fostering greater adoption.
10. *Elevate vendor credibility through tailored sales scripts:* Collaborate intensively with solar panel vendors to develop compelling and customised sales scripts. These scripts will focus on highlighting the vendors' expertise, product quality, and commitment to customer satisfaction. The infusion of trust and credibility into vendor interactions will reassure households about the reliability of vendors, fostering higher rates of solar panel adoption.
11. *Target electric vehicle (EV) buyers or owners:* Focus on households that already own or have expressed interest in purchasing EVs. Position solar energy as a sustainable and cost-effective solution for powering their EVs, creating synergy between the two environmentally friendly technologies. EV companies can actively promote clean solar energy for EV charging, broadcasting the concept of a 'green' household.
12. *Partner with Resident Welfare Associations (RWAs) to create peer pressure:* Collaborate with RWAs to drive solar panel adoption in the community. RWAs can collaborate with solar panel companies to facilitate workshops, seminars, and awareness programmes to educate residents about the benefits of solar panels and address any concerns or misconceptions they may have.

Towards Greener Energy Through Widespread Rooftop Solar Adoption

This study on rooftop solar panels emphasises the critical role of behavioural insights in addressing challenges and promoting widespread adoption. As the world increasingly seeks sustainable energy solutions, understanding and addressing the behavioural factors associated with the adoption of rooftop solar technology becomes paramount. The findings and recommendations presented here provide a foundation for informed decision-making and policy development, contributing to a more resilient energy landscape in India, and paving the way to a sustainable and environmentally conscious future.

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