



# Solar home systems for rural India: Survey evidence on awareness and willingness to pay from Uttar Pradesh<sup>☆</sup>



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## ARTICLE INFO

### Article history:

Received 1 April 2014

Revised 30 October 2014

Accepted 30 October 2014

Available online 24 December 2014

### Keywords:

Solar home systems

Rural electrification

Off-grid electricity

Energy access

Energy poverty

India

## ABSTRACT

While solar home systems hold considerable promise for improving access to electricity in developing countries in tropical regions, scholars and practitioners argue that the lack of awareness, interest, and ability to pay for the technology undermines the growth of the market. We describe and explain patterns of awareness and interest in solar home systems (SHS) in a survey of 760 respondents in rural Uttar Pradesh, India. We conducted the surveys in collaboration with a local solar enterprise, Boond, and chose villages that are prime locations for the installation of solar home systems. We found that high household income and education levels, as well as young age, predict awareness of SHS products. In addition to wealthy and educated households, willingness to pay is higher in households that have electricity. The findings can help policymakers identify and target households with low levels of awareness and solar entrepreneurs identify suitable customers for their products.

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## Introduction

More than a billion people in the world remain without access to even basic household electricity (IEA, 2013), and energy access has become an important topic for both academics and practitioners (Cook, 2011; Javadi et al., 2013). The year 2012 was declared as the year of Sustainable Energy for All by the United Nations and the years 2014–2024 the decade for the same. New technologies, such as solar power, play an increasingly prominent role in rural electrification efforts. Indeed, thanks to the rapid decrease in the cost of solar panels, the possibility of electrifying rural communities in a decentralized fashion with solar home systems (SHS) has become a promising alternative to conventional rural electrification through grid extension (Wamukonya, 2007; Chaurey and Kandpal, 2010; Kamalapur and Udaykumar, 2011). Both government programs and private companies can install SHS in rural communities previously without access to electricity grid or limited electricity supply.

In technology adoption, informational barriers play a critical role (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Mainali and Silveira, 2011). In the case of solar power, one impediment to the development of a healthy SHS market is the lack of awareness among rural

populations (Rebane and Barham, 2011). Indeed, the survey data we have collected shows that segments of the rural population in the Indian state of Uttar Pradesh remain unaware of SHS. According to Wong (2012), solar projects in India and Bangladesh have failed in the past because the local population has not participated in them. Since SHS are a relatively new technology and remain relatively rare in most developing countries, including India, many rural households are not aware of this option. Even if they know about SHS, they may not know where to purchase solar products or whom to ask for adequate maintenance services (Friebe et al., 2013). The demand for SHS may not be sufficient to encourage supply by private entrepreneurs. Low awareness reduces demand for SHS, and the low demand discourages entrepreneurs from entering the market.

This article offers a new contribution to the study of SHS markets by investigating patterns of awareness, access, and public perceptions of SHS in the Unnao district of Uttar Pradesh, located in the northern part of India. To describe and identify variation in awareness and access to solar products, we conducted a survey in January–February 2014 in the 76 largest villages of the central subdistrict around the district capital, Unnao. This area is of great interest for understanding SHS because it has low levels of electrification and, even where electricity is available, households typically have access for only 4–8 hours a day. Unnao is also close to the capital of Uttar Pradesh, Lucknow, making it a potentially attractive market for solar technology entrepreneurs. We fielded a 20-minute survey with detailed questions on household characteristics, awareness and access to SHS, willingness to pay, and policy preferences.

Overall awareness levels are relatively high, as 64% of the respondents report knowing what a SHS is. Moreover, after we explain the

<sup>☆</sup> We thank MORSEL India for excellent data collection. We are grateful to Seth Ariel Green and Eugenie Dugoua for insightful comments on an earlier draft. The survey was funded by the Earth Institute at Columbia University under an Earth Clinic grant.

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concept of SHS to the respondents, 89% say that they have seen such a system before. Wealthy and highly educated households with young household heads are more aware of SHS than their counterparts. Of particular importance is the strong association between education and awareness. In their study on SHS awareness, for example, [Rebane and Barham \(2011\)](#) did not consider the role of education. Our study identifies education as an important factor in predicting willingness to pay for an SHS, highlighting the added value of our study. Our results on age and income, on the other hand, are fully consistent with those reported by [Rebane and Barham \(2011\)](#).

Regarding willingness to pay, education, household income, and kerosene expenditures have positive effects, exactly as one would expect based on earlier studies ([McEachern and Hanson, 2008](#); [Rebane and Barham, 2011](#); [Lay et al., 2013](#)). Perhaps most interestingly, we find that electrified households are, even controlling for the aforementioned factors, more willing to pay for SHS. This could reflect their earlier decisions to purchase electric appliances that are difficult to use on grid electricity due to the low quality of the supply in Uttar Pradesh. While perhaps surprising, the finding is consistent with the fact that early adopters of solar panels in Tanzania tend to have grid electricity ([Smith and Urpelainen, 2014](#)). One possible explanation is that grid electricity in the state of Uttar Pradesh provides only intermittent and unreliable supply, with high transmission and distribution losses and frequent load shedding ([Urpelainen \(2014\)](#)). Future research could further scrutinize this hypothesis using data that yield more variation in the quality of household electricity supply.

These findings have notable implications for the academic study of SHS and distributed energy generation more generally. Our findings complement a growing body of literature on solar technology adoption ([McEachern and Hanson, 2008](#); [Rebane and Barham, 2011](#); [Lay et al., 2013](#)). Most interesting is the fact that, while grid electricity does not enhance awareness of SHS products, it does increase willingness to pay. The strong effect of education is notable as well. For policymakers, the findings are also significant. There is still a great scope for improving awareness through education and information campaigns, and progress in rural electrification seems to contribute to, as opposed to subtract from, the development of a robust SHS market in rural Uttar Pradesh – at least as long as the quality of the power supply remains a problem.

### **Solar home systems for rural electrification: challenges and opportunities**

A SHS consists of a solar panel and the ancillary equipment – typically batteries, charge controllers, wiring, and electric appliances – needed to generate electricity for household uses, such as lighting and mobile charging. The SHS charges a battery during the day, and households typically use the electricity at night. System size may vary from 10 to 500 W, depending on the household's willingness and ability to pay. Even a 40-watt system is enough to significantly improve the quality of household lighting, while also offering a convenient solution to the problem of mobile phone charging. As [Chaurey and Kandpal \(2010\)](#) note, the SHS is a preferred alternative to a village microgrid in small habitations, sparsely populated areas, and geographies that prevent wiring. More generally, [Harish and Raghavan \(2011\)](#) argue that countries such as India should put more emphasis on decentralized energy generation and direct their national policies toward improving affordability, finances, and product standardization.

Even though the SHS does not replace grid electricity, there is reason to believe that they have notable benefits for rural households. Although economists have yet to conduct randomized controlled trials of the benefits of SHS to rural households, several observational studies find suggestive evidence for positive benefits ([Samad et al., 2013](#)). According to these studies, SHS can increase children's study time, reduce kerosene consumption, and provide health benefits. Observational

studies of rural electrification from sub-Saharan Africa and South Asia report broadly similar findings ([Dinkelman, 2011](#); [Khandker et al., 2013](#)). In India, [Van de Walle et al. \(2013\)](#) report long-term benefits from rural electrification through improved earnings and female education. However, it is important to remember that electrification is but one aspect of the broader energy access problem. As [Bhattacharyya \(2012\)](#) notes, electrification is not an adequate solution to the pervasive problem of sustainable cooking and heating energy in developing countries.

The world market for SHS has grown rapidly in the past years. While the total number of SHS in the world is difficult to estimate, they are now available in virtually every country, though there is significant variation between different areas within any given country. In Bangladesh, there are now more than two million SHS in rural areas, largely thanks to a collaboration between the World Bank, the national government, and the local non-government organizations ([Samad et al., 2013: 3](#)). In the country, the nonprofit company Grameen Shakti has promoted energy access through off-grid solutions since 1996 with excellent results and useful implications for common lessons to other energy development aid projects ([Sovacool and Drupady, 2011](#)). Kenya is another example of a robust and vibrant SHS market, and the neighboring country of Tanzania is also catching up with increasing mature markets ([Ondraczek, 2013](#)).

In India, where we fielded our survey, the SHS market has also begun to grow. According to the 2011 Census of India ([Government of India, 2011](#)), there are now more than one million households in India that use solar power as their main source of lighting. With an average household size of almost five, this means that about five million people in India rely on solar for their lighting needs. According to the literature, the potential for expansion is also large ([Kamalapur and Udaykumar, 2011](#)). The solar market has grown fast in the past years and the government has made off-grid electrification a core component of the National Solar Mission. [Kapoor et al. \(2014\)](#) review the solar policy of India, noting that the interest in solar markets is growing as both the central government and various state governments are increasingly investing in solar energy, both on-grid and off-grid.

Despite encouraging growth, many obstacles remain to further the growth of solar markets. One key problem is finance ([Palit and Chaurey, 2011](#); [Wong, 2012](#); [Friebe et al., 2013](#); [Palit, 2013](#); [Kapoor et al., 2014](#)). Rural households rarely have the disposable income to purchase the systems as an alternative source of electricity. Instead, they have to rely on leasing arrangements or bank loans. This means that the reach and effectiveness of the local banking system can be a serious impediment to SHS market growth. Unless banks are able to develop financial instruments that allow them to profit from small loans to rural households in difficult conditions, the lack of disposable income may prevent otherwise willing households from adopting SHS. According to [Palit and Chaurey \(2011: 266\)](#), the development of an “innovative micro-lending model” is essential for improving the sales of SHS in India, due to the problem of end user finance. In a more recent article, [Palit \(2013\)](#) also emphasizes process standardization, infrastructure development, and local technical capacity as keys to successful SHS projects for governments, business, and communities.

Our emphasis here is on behavioral issues, such as the lack of awareness and access to products among potential customers. In a survey in Nicaragua conducted by [Rebane and Barham \(2011\)](#), only half of the respondents, who did not possess SHS, considered themselves familiar with the technology, and only 37% lived in a neighborhood where some SHS had been already installed. [Lay et al. \(2013\)](#) also found that in Kenya, education levels are an important predictor of SHS use among potential customers. According to [Mainali and Silveira \(2011\)](#), awareness about the benefits of SHS and related products has increased significantly in Nepal with greater demand in rural areas, but finance remains an issue. [Wong \(2012\)](#) notes that low levels of customer participation in solar projects and

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