Welfare Benefits of Decentralized Solar Energy for the Rural Poor in India

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Sector(s): Environment & Energy

Location: Bihar, India

Sample: 48,979 households in 100 villages

Target group: Rural population

Outcome of interest: Energy access

Intervention type: Renewable energy Pricing and fees

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Partner organization(s): Acumen Fund, Husk Power Systems, International Growth Center (IGC), Shakti Sustainable Energy Foundation, United States Agency for International Development (USAID), LGT Venture Philanthropy

Nearly one billion people around the world lack access to electricity. However, recent investments in infrastructure, newer technologies, and subsidized connections mean rural households face a growing number of choices on from where they can source electricity. To evaluate the demand for solar electricity, researchers randomly offered solar microgrid connections at different prices to households in rural areas of Bihar, India. Demand for microgrids was highly variable and low when they were offered at market price, likely because there were several other sources of electricity providing similar services. Researchers suggest that while central energy grids will likely continue to drive rural electrification, microgrids, and other off-grid solar products can be important sources of electricity when the grid is unavailable, unreliable, or unaffordable.

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Nearly one billion people around the world lack access to electricity. Up until recently, the frontier for household electrification was defined by the limits of state-run electric grids, which are provided by state-run energy companies and are often expensive and slow to expand into rural areas in low-income countries. However, recent investments in infrastructure, newer technologies, and subsidized connections mean rural households face a growing number of choices on from where they can source electricity. The falling cost of small-scale solar energy allows households the option to access electricity regardless of whether the grid has reached them, opening a potential faster, greener path to universal energy access. However, the role off-grid solar electricity will have on the road to universal electrification depends on whether there is demand for these types of products. Are rural, low-income households willing to pay for off-grid solar electricity relative to other sources?

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The evaluation took place between 2013 and 2017 in Bihar, India, which is home to around 104 million people and has one of the lowest electrification rates in India. In 2012, only 25 percent of households in Bihar had access to electricity, compared to 79 percent of households across India. At the start of the evaluation, the average Bihari household used 122 kWh of electricity annually, enough to power two lightbulbs for six hours per day, though many households had no electricity at all. Households that participated in the study had lower daily incomes than the average in Bihar, the majority of participating households owned agricultural land, and less than half had a solid roof.

The energy landscape in Bihar went through a number of changes during the period when the study was conducted. In 2015, the Government of India launched a program to extend the national electric grid to unconnected rural villages and provide subsidies for low-income households to connect to the grid at no cost. Grid access for villages participating in the study increased from 29 percent to 72 percent over the study period. The price of household solar panels also fell by 10 percent during the study period, with solar panels and batteries also becoming more efficient and reliable. The proportion of households with access to electricity across the state increased from about 27 to 64 percent between 2013 and 2017.

Households had access to the state-run electric grid only if the grid was available in their village. Households also had access to a variety of off-grid energy sources, including diesel generators which could power groups of 60 to 200 households in a village, solar panels which individual households could buy and install, and solar microgrids. Microgrids were offered by Husk Power Systems (HPS), a private company that installs and maintains solar microgrids for a monthly charge. The microgrids consisted of central 240-watt solar panels that could power a small network of six to nine households. Households on the microgrids received 3.2-volt rechargeable batteries and energy meters, along with high-efficiency lights and an electrical outlet, and access to the battery in exchange for a monthly fee.



Installing a solar microgrid in India. Photo: Anna da Costa | CC BY-NC-ND 2.0

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Researchers conducted a randomized evaluation to measure households' demand for different sources of electricity, namely the state-sponsored grid, solar microgrids, diesel-powered generators, or no electricity. In partnership with HPS, researchers offered solar microgrids to 100 rural villages in Bihar. Researchers randomly assigned villages to receive one of three microgrid offers:

1. *Market price offer* (33 villages): Villages had the option to connect to HPS microgrids at the standard market price. The market price for microgrids was INR 200 (US$11.76) per month at the start of the intervention but fell to INR 160 (US$9.41) per month in eleven villages.
2. *Subsidized price offer* (33 villages): Villages had the option to connect to microgrids for INR 100 (US$5.88) per month.
3. *Comparison* (34 villages): HPS did not offer microgrids to comparison villages.

Researchers conducted an initial survey in November and December 2013, and HPS began selling the microgrids shortly thereafter in January 2014. The evaluation lasted about three and a half years, with researchers conducting an endline survey in May 2016 and a follow-up survey in May 2017. After the endline survey, HPS began offering microgrids to all villages at the current market price of INR 170 (US$10) per month. Researchers collected information on household take-up of solar microgrids and welfare outcomes, such as household income, students' test scores, and respiratory health. They also collected information about households' overall electrification status, grid and microgrid electricity paid for and consumed, and asset ownership to understand how households were using electricity supply.

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Demand for microgrids was highly variable and decreased when offered at market price, likely because there were several other sources of electricity providing similar services.

Demand for solar microgrids: Demand for microgrids was higher when households received the subsidized offer. Among the subsidized group, 19 percent of households connected to a microgrid compared to 6 percent in the market price group. However, demand fell after the endline when the subsidies were discontinued and households were only offered access to the microgrids at the INR 170 (US$10) market price. Four years after the start of the evaluation, only about 8 percent of households in the subsidized price group and 2 percent of households in the market price group were still connected to a microgrid. Researchers suggest that the increasing availability of home solar and the state-run grid at lower prices reduced the demand for microgrids, which may explain why demand fell even among households already paying for microgrids at the market price.

Household electricity consumption and well-being: Despite low take-up, electricity consumption increased. This was particularly pronounced in households that were offered the subsidized price where uptake was higher. Compared to comparison households, households that took up microgrids at the subsidized price increased hours of electricity used by 0.94 hours per day and were 3.4 percentage points more likely to own mobile phones (from 88 percent in the comparison group). They spent less money charging their mobile phone because with electricity they no longer needed to pay a shop to do so. These effects, however, did not lead to increases in well-being in terms of household income, reading and math test scores, or self-reported respiratory problems.

Demand for off-grid solar compared to other sources of electricity: Despite improvements in the quality and reductions in the cost of off-grid solar, households generally preferred the state-run grid when it was available. Demand for the grid was highest among richer households, likely because they had greater access to appliances, like fans and televisions, that could only be supported by this source of electricity. However, using a model of households' value for all sources of electricity, researchers suggest that households value the choice between multiple sources of electricity more than any one source alone. Researchers also suggested that the rapid expansion of the state-run grid in Bihar and state-sponsored subsidies that lowered the cost for households to

connect to the grid may have driven households' demand for the grid. In regions where the grid has yet to expand, or where connecting to the grid is prohibitively expensive, households' demand for off-grid solar may be higher.

The results suggest that microgrids and other off-grid solar products can be important sources of electricity when the grid is unavailable, unreliable, or unaffordable. However, grids will continue to drive electrification as they become more accessible and reliable.

Burgess, Robin, Michael Greenstone, Nicholas Ryan, and Anant Sudarshan. "Demand for Electricity on the Global Electrification Frontier." Working Paper, 2023.