# Solar Microgrids and Remote Energy Access: How Weak Incentives Can Undermine Smart Technology

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## Executive summary

1. Motivations underlying the research

Over 1 billion people currently live without electricity in their homes, and nearly one third of these people live in India. In recent years, expanding access to a modern energy supply has become an important goal for policymakers, non-governmental organizations, and international donors. The United Nations includes "access to affordable, reliable, sustainable and modern energy for all" among its Sustainable Development Goals. In India, the government has a set goal of achieving 24x7 power for all by providing electricity services to each household across the country. Experts disagree, however, about how to best meet these objectives. The costs of extending and maintaining large-scale grid infrastructure to remote areas can be very high. Moreover, once connections to the grid have been established, utilities and distribution companies often face weak incentives to provide reliable service to poor and remote communities. Microgrids are viewed by many as a transformative solution for the future. Our recent experience with a solar microgrid provider in India, however, has fallen short of these expectations. We think there are important lessons in our project's trajectory.

2. A short account of the research performed

We set out to evaluate the real-world performance of a promising solar microgrid technology in remote areas of India where conventional grid power is very expensive to supply. We partnered with a startup, Gram Power, founded by one of us (Yashraj Khaitan). Gram Power's original goal was to allow unelectrified, rural communities to transition from no power to a smart grid system that integrates off-the-shelf solar panels, modular battery storage, inverters, and a pre-payment model. The company has been widely recognized for its innovative solutions to rural electrification challenges. We received grant funding to deploy about 40 Gram Power microgrids in rural Rajasthan, India. At the time, the government was subsidizing private sector microgrid providers. Gram Power planned to charge its customers just enough to cover its after-subsidy costs: A one-time 1,000 INR (~$20) connection fee, a per kWh charge of 20 INR per kWh ($0.40/kWh), and 150 INR per month fixed charge ($3). If all households paid for the power they consumed, and if the solar PV systems operated reasonably efficiently (~13% capacity factor given the local operating conditions), the company projected cost recovery in about 6 years.

In terms of reliability, households were promised 24/7 power as long as they limited their consumption to basic services, such as cell phone charging and lighting. Customers could add

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higher wattage appliances, like refrigerators and fans, but continuous supply for higher wattage appliances wasn't guaranteed. Gram Power followed many of the industry best practices. When recruiting customers, they convened community meetings to gauge demand. They hired and trained local villagers to help run the systems. They offered connection packages for commercial loads. They designed smart meters capable of detecting theft. Nevertheless, they ran into problems.

The first challenge arose when Gram Power tried to identify potential customers. The company located villages that were unlikely to gain conventional grid access in the foreseeable future. They visited 176 of these unelectrified villages to actively market their microgrids. Many villagers were holding out for "real" electricity. In some cases, local politicians had made election promises that a connection to the centralized grid was imminent. Legitimately, the Government of India has made truly impressive strides towards its promise to provide electricity access for all. Although the fine print of this pledge leaves many households in the dark, the promise of relatively cheap conventional grid power was enough to dissuade many potential microgrid customers. Households also balked at the price of the Gram Power system. To put Gram Power's $20 conneciton fee into perspective, the average income among households in the villages that adopted microgrids was around $110 per month. Also, the subsidized per kWh charge for grid power for poor rural customers is less than $0.08 per kWh. Gram Power's average-cost-based per kWh charge was four times as high.

Power theft is a problem in India, and Gram Power correctly anticipated this challenge. Yash and his colleagues developed smart metering technology to detect theft using a sophisticated, but impressively cheap, mesh network technology. What we learned the hard way, however, is that smart theft detection is not enough. Gram Power's technology can detect when a meter is being tampered with and identify where on the microgrid the problem is occurring. Power supply to this area is automatically shut off in response. But, if you're in the business of selling power, you don't want to punish a thief forever. Negotiating this interaction requires a local agent who can exercise discretion and turn the power back on when the theft problem has been addressed.

Gram Power hired and trained local entrepreneurs to not only maintain the system, but also crackdown on theft. However, when it came time to report theft or enforce penalties, these individuals were very reluctant. Delegating this unsavory task to community members is complicated by the fact that local entrepreneurs typically have strong personal relationships with the very people they are being asked to monitor and penalize. During our field visits, entrepreneurs acknowledged that theft was happening, but refused to provide names or document the behavior formally. The upshot is that this principal-agent problem proved to be an important vulnerability for these smart microgrid systems.

## 3. Main conclusions and policy implications of the work

Some of the problems we faced could be addressed with better policy. For example, to manage households' expectations about receiving conventional grid access, some countries have explicitly announced plans to connect certain areas with microgrids. Recently, the Indian government seems to be rethinking its rural electrification strategy, moving away from microgrids and towards providing rural customers with electricity access via solar home systems. Future success will depend on getting both the technology – and the incentives – right.