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September 28th, 2014

Link Foundation Fellowship Final Report

Research Narrative

Introduction

Energy poverty – the circumstance of depending on expensive, inefficient, and unproductive energy fuels and technologies that are harmful to human health and the environment – is rampant globally and especially so in Haiti. More than 75% of Haitians live without access to electricity, and the average household spends 10% of its income on kerosene and candles for lighting. Globally, 1.3 billion people, mainly in less developed countries, lack access to electricity (International Energy Agency, 2012).

While central grid extension often provides electricity at very low cost, the reliability of the central grid in less developed countries is so low that the priority given by policy makers to central grid extension must be questioned. Rather than maximizing the extent of often unreliable or simply unenergized central grid extensions, we sought to show the imperative to consider a multi-track approach to electricity access that includes microgrids and high quality solar lighting products. Through case studies and modeling efforts based on extensive empirical data, this research provides new insight to this imperative and elucidates on the nature of the challenges and solutions for microgrids to eradicate energy poverty.

Results

My project was comprised of four investigations into energy access and energy poverty, with unique hypotheses and results described below.

1. Alternatives to Unreliable Central Grids for Lighting Can Increase Consumer Surplus

Many developing countries have low levels of central grid reliability, especially in rural areas, which results in dependence on low quality lighting fuels like kerosene as a back-up to the grid, and their continued use while waiting for a grid extension to arrive (Besant-Jones, 2006). This research sought to quantify the extent to which parallel energy systems, such as microgrids and solar lighting systems, may recover forgone consumer surplus due to central grid unreliability and sporadic usage of kerosene/candles in the absence of electricity. Using demand curves for lighting in five African countries derived from the Lighting Africa Market Assessment (International Finance Corporation and The World Bank, 2008), a consumer surplus model for lighting provided by low quality fuels, high quality grid alternatives and the central grid was developed. The analysis demonstrates that electric lighting saves consumers on the order of 1 to 5 USD per month, and increases consumer surplus by 2 to 18 USD per month. It also finds that high quality lighting

alternatives are preferable to central grids that have an average system unavailability index (ASUI) of 13% to 40%, depending on the country.

2. Financial Requirements for Improving Rural Micro-Grid Operations in Haiti

All 36 of Haiti's diesel micro-grids operate for far fewer hours than their nominal operating schedules, which are typically three to four hours a night for four to five nights per week. On one closely studied microgrid it was found that tariffs are set at levels 10% below operating costs, which prevent them from operating at their scheduled output, and that grid operators do not have sufficient working capital to make up for gaps in untimely customer tariff payments. Results indicate that replacing incandescent light bulbs with CFLs and using a smaller diesel generator or a hybrid PV-diesel system halves operating costs relative to the existing system and would allow the grid to double its operating hours while yielding a positive return on investment with the existing tariffs. Other demand-side interventions, such as LED light bulbs, load-limiters, and load-shifting, coupled with an appropriately sized diesel generator do not offer as great a level of operational cost savings or as many additional hours of availability as the CFL-replacement intervention.

3. The Commercial Viability of Remote Microgrids in Developing Countries: A Case Study in Haiti

The potential of microgrids to scale and make a dent in the global energy access probelm is contingent on their commercial viability. Assuming appropriate tariffs, two arguments have emerged against the case for commercial microgrids: 1. User-specific costs on microgrids are high, which make them unsuitable for pay-as-you-go tariffs; and 2. Low-income customers are too poor to make consistent payments for electricity for microgrid operators to earn cost recovery (Economic Consulting Associates Limited , 2013). The operation of a rural microgrid in Haiti shows that neither argument is generally applicable. Using anonymized consumption and payment data from customers' smart meters for ten months of operations, this research demonstrates that pay-as-you-go payments were sufficient for user-specific costs to be recovered within 5 years for 78% of users, and 3 years for 57% of users. It was also shown that the frequency, quantity and magnitude of user payments are sufficient to provide regular cash flow to the utility.

4. Microgrids for rural electrification: A critical review of best practices based on seven case studies

Recent works have used case studies as guides for analyzing successes, failures and lessons learned for programs promoting access to modern energy services and the goals of the United Nations Sustainable Energy for All initiative (Sovacool, 2013; Bazilian, et al., 2012). Fewer works have focused solely on gleaning insights from case studies of microgrids specifically, though a small number of existing guides and reports on rural electrification delineate "best practices" in microgrid planning, operations and maintenance (Alliance for Rural Electrification, 2011; Ashden India Sustainable Energy Collective, 2012; ESMAP, 2000; Martinot et al., 2002; Harper, 2013; Sovacool, 2012). We sought to understand the extent to which these best practices are applicable, and what the factors are that determine a microgrids success or failure. This research is underpinned by extensive travel in Haiti, India and Malaysian Borneo to conduct seventeen site visits and interviews with six microgrid developers, and resulted in a set of highly detailed case studies. We found that

the applicability of best practices is strongly affected by the business model and goals of a microgrid developer, which vary from community empowerment to political mandate to return on investment. Through our case studies, we developed a model for microgrid operations to show how the factors that determine success or failure are inter-related in "vicious" or "virtuous" cycles.

Significance and impact

Unless countries take a parallel path approach to electrification, where high quality lighting alternatives are strategically deployed to areas that will not be connected to the central grid for years or that are connected but experience high outage rates, consumers will forgo substantial economic value. Our research collectively underscores the imperative to rapidly replace low-quality lighting fuels with kerosene and candles, potentially with microgrids. Our report on microgrid best practices, serves as a warning that microgrids are susceptible to many factors that may result in failure – causing households to revert back to low-quality fuels and losing out on economic development opportunities. However, by brining these factors and the specific contexts in which they are relevant to light, we also offer recommendations and lessons learned to increase the likelihood that microgrids will succeed.

Works Cited

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Scholarly Contributions

Published:

Schnitzer, D., Lounsbury, D. S., Carvallo, J. P., Deshmukh, R. Apt. J. and Kammen, D. M., "Microgrids for rural electrification: A critical review of best practices based on seven case studies," United Nations Foundation, 2014. (Report)

Buevich, M., **Schnitzer, D**., Escalada, T., Jacquiau-Chamski, A., & Rowe, A. (2014). A System for Fine-Grained Remote Monitoring, Control and Pre-Paid Electrical Service in Rural Microgrids. The 13th ACM/IEEE Conference on Information Processing in Sensor Networks (IPSN), April. Berlin. (Conference Proceedings)

Expected:

Schnitzer, D., and Harish, S., "Alternatives to Unreliable Central Grids for Lighting Can Increase Consumer Surplus." (Journal Article)

Schnitzer, D., Soto, D. and Rajagopal, N., "Financial Requirements for Improving Rural Micro-Grid Operations in Haiti." (Journal Article)

Schnitzer, D., Lounsbury, D. S., Carvallo, J. P., Deshmukh, R. Apt. J. and Kammen, D. M., "Microgrid Best Practices: Insights from Seven Case Studies." (Journal Article)

Invited Talks and Presentations:

Webinar Presenter, United Nations Energy Access Practitioner Network, "The Role of Microgrids in Promoting Access to Electricity." United Nations Foundation. April 22, 2014.

Panelist, Advancing Universal Access to Sustainable Modern Energy, World Bank Spring Meeting, "Energy Access in Haiti." The World Bank, Washington D.C. April 10, 2014.

Panelist, IFC Investment Climate Workshop, "Microgrid Development in Haiti." International Finance Corporation, Washington, D.C. January 13, 2014.

Webinar Presenter, Pay-As-You-Go Solutions for Rural Electrification Business Models, "SparkMeter: Smart Meters for Low-Income Electricity Customers." The World Bank. November 11, 2013.

Panelist, World Bank Annual Meeting, "The World Bank's Coal to Clean Energy Transition." The World Bank, Washington, D.C. October 12, 2013.

Panelist, Advancing Energy Access in South Asia Conference, "Critical Review of Best Practices for Microgrid Operations: A Case Study Approach." United Nations Foundation, Bihar, India. September 10, 2013.

Panelist, American Renewable Energy Day Conference, "Energy Access for All." Aspen, Colorado. August 18, 2012.

Statement of use of discretionary funds

Discretionary funds from Link Foundation Energy Fellowship were used as follows.

Travel:

- To defray travel costs to India and Malaysian Borneo to conduct interviews and site visits for microgrid case studies, January 2013.
- To defray travel costs to India to present preliminary results of microgrid case study report at United Nations Foundation Advancing Energy Access in South Asia Conference, September 2013.

Equipment:

- Purchase of a new computer capable of running Matlab and HOMER-based models for microgrid load profiles, optimization and financial performance.
- Purchase of the AEMC ML914 Simple Logger II Four-Channel MiniFlex Current Data Logger. Used to record one-minute resolution electricity consumption on Port-a-Piment microgrid in Haiti.

Importance of Fellowship Support

There is a dearth of funding available for research into energy poverty and energy access, and alternative sources of funding for my Ph.D. studies would have restricted my scope of research to domestic energy issues in the United States. Thanks to the Link Foundation Energy Fellowship, I was able to study the issues that I feel genuinely passionate about – energy access in developing countries. Unlike many other research areas in the energy domain, there is a startling paucity of data on energy access at high resolution. As such, a good deal of my research was spent collecting raw data rather than being able to move directly into building a model. The discretionary funds were essential to this data collection process, as the data logger I purchased was used to gather a years' worth of consumption data on a microgrid in rural Haiti. The travel funds were applied towards an unforgettable trip to some of the most remote parts of India and Malaysia to collect data on microgrids through interviews and site visits.