Off-Grid Rural Electrification in Africa

Bahman Kashi, Limestone Analytics

Background & Motivation

"Off-grid rural electrification" reminds most of us about bringing solar lanterns to rural communities who otherwise use kerosene for lighting. The menu of technological options is, however, much broader than solar lanterns. 2019 Jaglin categorizes off-grid, or "autonomous," generation technologies as mini-grids, energy kiosks, and individual systems. Each of these systems can come with a range of technological options.

Similarly, the use of electricity is also not limited to household lighting and can include other appliances and productive use. For instance, in a recent study in Kenya (2017 Rom), 48% of rural households reported using cell phone light as their secondary source of lighting, after Kerosene (99%). The same population's use of solar lights and electricity-powered lights is at 6% and 2%, respectively. Mobile phones, in such a population, clearly dominate the electricity use.

More than ever before, donors and governments are concerned about rural electrification. In the pursuit of economic development and equitable access to electricity, significant amounts of funding have been driven towards rural electrification in recent years. Since 2000, the share of people with access to electricity in the least developed countries has more than doubled (sustainabledevelopment.un.org/sdg7). The experience with the impact of energy access on welfare, however, is mixed. As shown in the benefits section of this brief, many studies find no attributable impact in the short to medium term.

The nature demand for off-grid electricity solutions is also complex. For instance, off-grid solutions such as solar home system are popular in Haiti for on-grid applications as opposed to off-grid. The solar home system can perform a coping function and address the reliability issues of the grid. The rural population is also often reported to have negligible demand and low willingness to pay for electricity. 2015 Peters reports an average of 4.6 to 11 kWh of electricity consumption for off-grid households that are provided solar home systems or connected to a village grid per month in Rwanda, Senegal, and Burkina Faso, compared with 867 kWh in the US (www.eia.gov/tools/faqs/faq.php?id=97&t=3).

2019 Grimm suggests that off-grid solar is the most cost-effective technology for most of rural Africa. Other studies (2018 Leo, 2016 Baurzhan, and 2017 Robert) suggest mini-grids and grid extension are the solution and highlight the importance of understanding the use of electricity beyond lighting (industrial, air conditioning, etc.) when thinking about increasing access to electricity.

This brief uses principles of cost-benefit analysis to bring the readers' attention to the nuances and contextual parameters that can help in scaling up access to electricity. Furthermore, the paper provides a crude estimate of the benefit-cost ratio based on preliminary calculations.

Scale

According to the International Energy Agency (https://www.iea.org/sdg/electricity/), 600 million people lack access to electricity in Sub-Saharan Africa. Considering an average household size of 5 people, the energy access gap is **120 million households** in Sub-Saharan Africa alone. Based on a recent study (2017 Rom), 68% of all households and 83% of rural households in sub-Saharan Africa remain without access to electricity.

Benefits

Past studies have listed a range of benefits associated with electrification, these benefits include education, health, safety, income, economic development, and time-savings. Recent studies, however, provide conflicting evidence on the realized impacts. Studies in Kenya (2018 Lee and 2017 Rom) report no impact, while other studies report significant impact (2011 Dinkelman and 2018 GOGLA) in South Africa, Kenya, Mozambique, Rwanda, Tanzania, and Uganda. The internalized

portion of the benefits can be captured by Willingness to Pay (WTP) studies.

2019 Grimm and 2018 Lee estimate the WTP for electricity for off-grid and under-grid households respectively. 2019 Grimm considered 3 different solar home systems while 2018 Lee considered grid extension for serving households with electricity. Both studies found the costs of service is greater than the WTP. Furthermore, they both argued that the investment gap will not be closed even after the inclusion of external impacts. 2019 Grimm reports that the WTP for the three solar kits is between 38 and 55 percent of their respective market prices. The costs are 13, 37, and 180 USD for the three technologies. With an average life of 3, 6, and 4 years, and a discount rate of 10% the monthly **WTP comes to 0.72 to 1.05 USD per household per month**[93].

2015 Peters provides a summary of education outcomes reported by recent literature. Studies in Rwanda, Burkina Faso, and Indonesia show report that access to electricity has no impact on the total number of hours studied. A recent evaluation report in El Salvador (2017 MCC), however, reports the health impacts of electrification due to improved home air quality. This study uses the relative risk published by 2017 MCC for cardiovascular disease and lung cancer, along with the Disability-Adjusted Life Years estimated reported by 2018 Lancet and the value of statistical life reported by 2017 Viscuzi to calculate the value of health benefits. The value of DALYs averted per household per month in Sub-Saharan Africa is **2.05 USD**.

Costs

The investment costs for solar home systems included in the study by Grimm (2019 Grimm) range from 13 to 182 USD for 0.5 Watt, a 3.3 Watt, and a 20 Watt device. The study, however, finds the willingness to pay to be significantly lower and concludes that there is no economic justification for subsidizing electrification using solar home systems. 2019 Lee, arrives at a similar conclusion when looking at grid extension to areas that are close to the grid but not connected, "under-grid."

Micro-grids are a middle step between individual systems and grid connection. These systems are considered as the most cost-effective off-grid solution by a recent study (2018 Reber). The same study reports a Levelized Cost of Energy (LCOE) for micro-grids in Africa that ranges from 0.75 to 0.85 per kWh. To make this estimate comparable with the WTP reported earlier, monthly consumption of 4.6 to 11.1 kWh is borrowed from 2015 Peters. As a result, the **monthly cost of generation per household is 3.45 to 9.44 USD**.

Benefit-Cost Ratio

As explained under the Benefits and Costs sections. A crude estimate of the revealed benefits, based on willingness to pay reported by 2019 Grimm ranges from 0.72 to 1.05 USD per household per month. The cost of serving this demand using micro-grids is 3.45 to 9.44 USD per month. The resulting **Benefit-cost ratios by household per month, therefore, range from 0.08 to 0.30**. Adding the health benefits increases the range of benefit-cost ratio to **0.29 to 0.90**.

A Policy View & Recommendations

The calculations provided in this study are based on crude assumptions and must not inform decisions. Some of the key parameters in this study come from Rwandan data. Rwanda's electrification rate and income is considered average among Sub-Saharan African countries. The main goal of this brief is to bring attention to the complexities involved with the analysis and decision-making when it comes to off-grid rural electrification. There are many technologies to consider, and the demand must not be overestimated. Alternatively, one can consider a policy lens and focus on the least-cost approach to achieve universal access. 2019 Grimm finds the individual systems (such as solar home systems and solar lanterns) as a more cost-

[93] Note that all three systems run on solar panels.

effective approach to achieve such a policy goal.

The parameters used to estimate the cost of generation relate to the technology selected, its useful life, and the consumption level of subscribers. Depending on the value of these parameters in each location, the right choice of technology can be different.

Another important policy concern raised in the literature is that market-based solutions, naturally, do not target the poor. The lack of incentive to serve the poor justifies direct subsidies or cross-subsidies to fund rural electrification programs.

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