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Rural energy access through solar home systems: Use patterns and opportunities for improvement

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ABSTRACT

Solar photovoltaic (PV) products are touted as a leading solution to long-term electrification and development problems in rural parts of Sub-Saharan Africa. Yet there is little available data on the interactions between solar products and other household energy sources (which solar PVs are often assumed to simply displace) or the extent to which actual use patterns match up with the uses presumed by manufacturers and development agencies. This paper probes those questions through a survey that tracked approximately 500 early adopters of solar home systems in two off-grid markets in Africa. We find that these products were associated with large reductions in the use of kerosene and the charging of mobile phones outside the home. To a lesser extent, the use of small disposable batteries also decreased. However, solar home systems were, for the most part, not used to power radios, TVs, or flashlights. We also did not observe adopter households using these solar products to support income-generating activities.

Background and motivation

Sub-Saharan Africa is home to approximately 600 million people without access to electricity (IEA, 2014). This is a function of both the limited ability of low-income populations to pay for electricity and the institutional barriers in many countries that hinder a build-out of the national electric grid. Over the past decade, solar photovoltaic (PV) products have emerged as a possible solution to Africa's long-term electrification and associated development problems. Adoption rates have been dramatic, with market-based sales of household-sized or smaller solar units in the region soaring to well over 10 million since 2011 (Lighting Global, 2016).[1]

The dominant products sold to date to rural, non-electrified populations have been basic, so-called "picoPV" products that have just one LED light bulb powered by a small solar panel of less than 10 W. Larger "advanced picoPV" products are also common, and feature a 10–20 W solar panel that powers a longer-lasting and brighter light, as well as limited phone charging functionality; these products can charge 1–2 basic mobile phones per day. Beyond that, household-sized solar home systems ("SHSs") are increasingly common, although they are estimated to represent less than 5% of the off-grid solar market by number of products sold as of June 2016 (GOGLA and Lighting Global, 2016). They typically have a larger solar panel installed on a building's roof that charges an external battery which, in turn, powers several electric bulbs and can charge multiple phones each day. Higher rungs on the solar PV "energy ladder" involve the use of still larger SHSs that can power radios, TVs, and even energy-efficient refrigerators for the largest models (see e.g. Lighting Global (2014)).

The solar industry across Africa is led by for-profit social enterprises that are typically beneficiaries of significant market development support provided by many multilateral institutions, development agencies, non-governmental organizations (NGOs), foundations, governments, and impact investors. These stakeholders are thought to be attracted to the sector by the vision of solar PV products as environmentally sustainable solutions that provide brighter, safer, and healthier lighting than traditional sources. Solar products are also perceived by many of these stakeholders as a way to provide basic electrification at scale more reliably, cheaply, and quickly than other modern but unreliable or environmentally unsustainable solutions like national grids or diesel generators.

Despite the extremely encouraging sales trends and broad appeal of the potential for socially-desirable impacts, important questions remain about the nature and role of consumer-facing solar products in Africa. In particular, there have been few systematic investigations into how households that adopt solar products use them or the extent to which actual use patterns match up with the ones presumed by the African solar industry or its supporters. Recognizing that applications valued

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[1] These are very conservative estimates as they only account for verified sales of small solar products and exclude the larger, household-sized ones; in addition, they do not account for the so-called "generics" or "no-name" brands that are estimated to account for a majority of actual off-grid solar PV product sales in the region (Lighting Global, 2016).

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by consumers are not always those prioritized by development agencies or solar enterprises, this paper proceeds by presenting the results of an original survey that tracked the self-reported use patterns of solar home systems. The methodology is described in Section 2 and the result detailed in Sections 3–6.

We find that once adopted, a SHS is associated with a significant reduction in kerosene use and the transition to modern electric lights as a household's dominant lighting source. We also observe dramatically lower rates of charging mobile phones outside the house. The story is not as clear, however, when it comes to the displacement of disposable dry-cell batteries or the ability of SHSs to readily and adequately power flashlights, radios, or televisions. Our results suggest that a number of barriers still need to be overcome in order for SHSs to be effective tools for broader basic electrification. In particular, the widespread use of battery-powered flashlights and radios (as well as ownership of inefficient CRT TVs in a minority of households) *prior* to the purchase of a SHS significantly complicates matters; as a result, it will likely take more time and effort to achieve energy access goals beyond the more immediate impacts on household lighting and basic phone charging patterns. Finally, we observe an overwhelming tendency to use SHS products only as a means to make a home more comfortable rather than for income-generating activities.

In the conclusion (Section 7), we evaluate the extent to which our data appear to support common assumptions with respect to the use of SHS products and, more broadly, the development impacts of the off-grid solar PV industry in Africa. The results are strictly observational and descriptive but they are nevertheless among the first data-driven systematic efforts to offer insights into actual adoption and use patterns in this space. They can also help support the development of more nuanced household energy models, such as the framework proposed by Kowsari and Zerriffi (2011), to better explain the solar-driven energy transitions currently under way in rural Africa.

Our hope is that this research will help solar social enterprises, nonprofit organizations, development agencies, and governments better direct scarce resources towards achieving their energy access and development goals. We also offer potential strategies that may enable future end-users to gain further benefits of SHS ownership beyond the ones we already observe. These insights are a first step in evaluating whether SHSs are realizing their potential to deliver sustainable energy or broader development benefits, for which more research is needed.

Research approach

We partnered with a solar manufacturer to interview and track new purchasers of mid-sized and large solar home systems (SHSs) from two sales points, one shop in western Uganda and one in western Kenya. We chose these locations because East Africa has been at the center of the significant entrepreneurial activity in solar products. Uganda and Kenya have seen the entry of many businesses competing to sell low-power picoPV products. These are also the countries that saw the earliest meaningful deployment of household-sized SHSs, although sales of SHSs continue to be only a fraction of the region's picoPV deployment. The two specific sales locations that our research focused around were newly-opened shops in mid-sized towns that served as centers for the surrounding (overwhelmingly rural and non-electrified) communities. Both shops were among the first to offer SHSs of this size in their respective regions, although the market for picoPVs had been well established for several years prior in both locations.

We focused this research on SHS adoption and use because this scale of solar product appears to be especially poorly understood. Prior studies have tended to focus on picoPVs, as that is where the industry and market supporters have centered their efforts. Yet SHSs are perceived as having much greater energy access and development potential relative to picoPVs and, since 2015, more efforts have been made to support the scale-up of these products and encourage existing adopters of picoPVs to "climb the energy ladder" and buy SHSs (see, e.g. Chattopadhyay et al., 2015; Lighting Global, 2014; RMI, 2015).

The SHS products we studied had solar panels of between 15 and 100 watts (W), with lead acid battery capacities of between 7 and 38 ampere-hours. They were all able to power at least 4 light points (0.5–2.0 W LED bulbs) for 4–6 hours per day, in addition to charging several phones (with the bigger units capable of charging more than 30 phones daily). They could all also power a small radio and the majority of the systems could also be connected to an energy-efficient TV. Such radios and TVs were also sold by the SHS manufacturer from the same shops. Depending on the size of the SHS, a customer would need to balance loads on their battery and perhaps reduce the daily lighting and phone charging amounts in order to power these other electronics.

Our efforts focused on interviewing the customers of the two SHS shops. Baseline interviews were conducted at the time of purchase (in the shop), during SHS installation (at the customer's home), or shortly thereafter by research staff hired for this project and embedded in the two shops.[2] The final data consists of 375 customer interviews in Uganda, undertaken between September 2013 and March 2015, as well as 190 in Kenya, carried out between March 2014 and October 2014. The interviews focused on characterizing the non-cooking energy options to which SHS adopters have access, as well as associated use and expenditure patterns. Face-to-face endline interviews collected the same information for all participants in November 2014. At the time of the endline interviews, most participants had owned their SHS between 3 and 6 months. Although baseline data collection continued in Uganda with about 100 additional customers through March 2015, this group was not invited for an endline interview. Sample screenshots of the survey instrument are included in the Appendix. We also carried out five rounds of brief 10-minute phone interviews (in March, April, June, July, and September 2014) with a randomly selected subset of the participants. These phone interviews were much narrower in scope and were intended to detect whether the users were experiencing any problems or otherwise needed after-sales support for their newly-acquired SHS (see Table 1).

The results that follow should be interpreted within the context that the data was gathered in. First, the population under study is self-selected early adopters of SHSs in areas where the technology was relatively new. We cannot say much about how the broader rural population would use such products if there was a more concerted effort to scale-up their adoption among households who would not otherwise choose to purchase them. Nor can we speak about the longer-term sustainability or use patterns of the SHSs in this early adopter population (although we are planning a round of follow-up data collection with our study participants in 2017). Second, the study tracked the customers of only one SHS manufacturer. Although this company continues to be among the leading companies in the African off-grid solar PV industry, with products of similar size and functionality as other SHS manufacturers, we do not have a way to measure the extent to which the results would have been different had we tracked a broader pool of SHS products or how this manufacturer's other services (warranty support, financing mechanisms, product installation,...) impacted the use patterns we observed. Third, caution should be exercised in generalizing the results beyond the rural areas in Uganda and Kenya, where traditional kerosene use is well entrenched and the solar market quite robust. Finally, the results are descriptive and we make no claims to establishing

[2] Initially, all new customers of the two newly-opened shops were invited to participate in the research, and nearly all accepted the invitation to be interviewed. When the volume of new customers began exceed the interviewing capacities of the enumerators assigned to each shop, they interviewed as many as they could. Although no formal randomized selection was enforced, enumerators were instructed to at all times interview the latest person that had bought a SHS at their shop. We have no reason to believe that there is systematic bias in the SHS adopters that participated in the study and those who were not interviewed, especially since the total sample size represents a significant fraction of all customers at those shops during the relevant time periods.