Renewable and Sustainable Energy Reviews xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso☆

Gunther Bensch[c], Michael Grimm[a], Maximilian Huppertz[b], Jörg Langbein[c], Jörg Peters[c,*]

[a] University of Passau, Erasmus University of Rotterdam, IZA, The Netherlands
[b] University of Michigan, United States
[c] RWI, University of Passau, Germany

ARTICLE INFO

JEL classification:
D12
D40
O13
O33
Q41

Keywords:
Energy access
Energy poverty
Technology adoption
Branded products
Cost-effectiveness
Rural Africa

ABSTRACT

Off-grid solar electric power is a promising technology for remote regions in rural Africa where expansion of the electricity grids is prohibitively expensive. Using household data from a target region of an off-grid solar promotion program in the Kénédougou province in Burkina Faso, this paper explores the role of quality-verified branded solar home systems (SHS) versus non-branded ones. We find that the adoption rate of non-branded SHS is considerably higher at 36% compared to 8% for branded SHS. We compare potential quality differences as well as the cost-effectiveness of branded and non-branded solar products. We show that non-branded SHSs offer a similar service level as branded solar, that they do not fall behind in terms of consumer satisfaction and durability, and that non-branded products are more cost-effective. These findings suggest that promotion programs and branded solar products do not seem to be necessary in Burkina Faso and might also not be needed to establish sustainable off-grid solar markets elsewhere provided that non-branded products are available. The challenge however is to reach the very poor who are unable to bring up investment costs for any electricity.

1. Introduction

For a number of years, the international community has been striving to provide electricity to non-electrified households around the world. This endeavor is now spearheaded by the United Nations' Sustainable Energy for All (SE4All) initiative whose goal is to provide electricity to all by 2030 [1]. For sub-Saharan Africa, this would imply full electricity coverage 50 years earlier than on current trends [2]. Achieving this by extending national electricity grids to unserved rural areas would require enormous investments [3].

Off-grid solar technologies such as solar home systems (SHSs) and smaller-sized plug-and-play pico-solar Photovoltaic (PV) systems are an obvious pre-cursor to grid extension. Although they provide less power, their modularity allows electricity access at lower costs, especially when distance to the central grid is large. In particular in rural Africa, where demand for electricity is often modest, off-grid solar products seem suitable. The potential of off-grid solar is estimated to be particularly high in Sub-Saharan Africa [4,5]. Lenz et al. [6] and Peters and Sievert [7] argue that off-grid solar are cost-effective alternatives to grid electrification. A more specific analysis by Okoye et al. [8] suggests using off-grid solar as a complement to already existing but unreliable grid connections in urban Nigeria and, outside of Africa, Ghafoor & Munir [9] evaluate economic potentials of solar for households in Pakistan. The emerging evidence on the impacts of off-grid solar tends to agree that off-grid solar improves living conditions and thus welfare, although transformative effects on socio-economic development are less likely [10–18]. Across Africa, many governments, donor agencies, NGOs, and companies promote the dissemination of off-grid solar technologies, in most cases through market-based approaches where households are expected to pay cost-covering prices [3].

For the case of Burkina Faso, the present paper examines rural off-grid solar markets that feature both quality-verified so-called *branded solar products* and *non-branded solar products*. As in most other African countries, non-branded products are widely available, even in remote rural areas, while branded products reach those areas only when some sort of promotion program makes an effort to facilitate their market entry [3]. Specifically, we analyze whether market forces are sufficient to sustain the market for small-scale solar products without further

☆ Financial support by the Policy and Operations Evaluation Department (IOB) of the Netherlands' Ministry of Foreign Affairs is gratefully acknowledged. Peters and Langbein gratefully acknowledge the support of a special grant (Sondertatbestand) from the German Federal Ministry for Economic Affairs and Energy and the Ministry of Innovation, Science, and Research of the State of North Rhine-Westphalia.

* Correspondence to: RWI, Hohenzollernstraße 1-3, 45128 Essen, Germany.
E-mail address: peters@rwi-essen.de (J. Peters).

https://doi.org/10.1016/j.rser.2017.11.003
Received 31 October 2016; Received in revised form 31 March 2017; Accepted 27 November 2017

regulatory interventions and end-user subsidies. To this end, we examine the characteristics and usage patterns of adopters, the quality and technical performance of the solar products, and the effective costs that current non-adopters would incur if adopting a solar product of either type. We use survey data from 880 households from 33 villages that are representative for a province in western Burkina Faso. The study was conducted in 2010 and 2012, a time when pico-PV was not yet widely available and the off-grid solar market was still dominated by SHSs.[1] Between these two surveys, a donor-backed enterprise started to establish a market for branded SHS using a fee-for-service system.

We find that already in 2010 almost 25% of the surveyed households in this poor and remote region had acquired a non-branded solar device from local businesses; this share increased to 36% in 2012. Thus a market for solar products has already existed before any promotion activity or regulatory intervention. We show that these households belong to the better-off strata. In addition, these non-branded products also appear to be of sufficient quality. Subjective satisfaction ratings by users of non-branded SHSs are only slightly worse than those of users of branded SHSs. In terms of cost-effectiveness, non-branded products even perform considerably better than branded products due to considerably lower prices.

Moreover, we examine the investment decision from the perspective of a typical Burkinabè household by comparing the prices of both branded and non-branded products to its current substitutable energy expenditures. We thereby show that – even if credit schemes were available – the additional costs to be borne by the household are considerable and for the poorer strata of the population probably prohibitive. Complementing the analysis of SHS adopter characteristics, our paper thereby also contributes to the broader literature on household technology adoption in resource-poor settings. Energy technology adoption has been studied most extensively for improved cookstoves [21–23], including studies on Burkina Faso [24–26]. For off-grid solar products, empirical evidence is sparse. Aklin et al. [27], Khandker et al. [28] and Harish et al. [29] study SHS adoption among households in India, Grimm et al. [11,30] examine usage and impacts of pico-PV devices and SHS in Rwanda.

The rest of the paper proceeds as follows: Section 2 describes the broader electricity access context in Burkina Faso and in the study region more specifically. Section 3 describes SHS uptake over time, and explores the socio-economic characteristics of users of non-branded and branded SHSs, respectively. Section 4 discusses the quality and comparative costs of non-branded SHSs using branded SHSs as a benchmark. Section 5 concludes.

2. Energy policy and solar market context in Burkina Faso

Electric power in Burkina Faso is predominantly supplied by the national electricity company SONABEL and based on diesel-thermal power plants and hydro power. Burkina Faso's solar feed-in potential is mostly untapped so far. Electricity prices are among the highest in sub-Saharan Africa, with an average of 26 US cents per kWh [31]. The electrification rate is stalling at 14% nationally (40% in urban areas and a mere 5% in rural areas). Electricity consumption per capita was about 50 kWh in 2013 [31], which is way lower than in other West-African countries such as Côte d'Ivoire (252 kWh) or Cameroon (278 kWh) [32].

The focal region of this study is Kénédougou province in the Hauts-Bassins region (see Fig. 1). Roughly 92% of its 350,000 inhabitants live in rural areas [33]. The case of Kénédougou is interesting due to the coexistence of branded SHSs marketed with donor support and non-branded SHSs that have made inroads to the region without any governmental or non-governmental support. Households have relatively easy access to non-branded SHSs of varying sizes that enter local markets via nearby Bobo-Dioulasso, Burkina Faso's second largest city, and bordering Mali. In addition, in 2008 a single donor-backed company started to offer branded SHSs to households and small enterprises on a fee-for-service basis. In the following, this electricity service provider will be used as a benchmark for the non-branded solar products.

The company was set up by a Dutch non-profit foundation that received co-financing from the European Union and the Netherlands, among others, and already had over five years of commercial experience in rural electrification with solar home systems in Mali and South Africa. The company obtained the national regulation authority's exclusive concession to supply ten out of the 13 départements of Kénédougou with SHSs that use quality-verified components not readily available on local markets. It chose a fee-for-service model to ensure sound maintenance of the solar panels and to make them affordable for poorer households that may struggle to raise high up-front costs. Under the fee-for-service approach, customers rent the SHS from the service provider. They typically go to a sales shop in their area to subscribe to the service, for which they have to pay a connection price plus a monthly fee. Unlike integrated pico-PV kits or solar lamps, standard SHSs are made up of different components including a solar panel, a rechargeable battery, a charge regulator, compact fluorescent lamps (energy savers), and sockets.

3. Diffusion of solar home systems

3.1. Local solar market development

In 2012, when we conducted our second survey, 36.3% of the 880 surveyed households possessed a non-branded SHS. In comparison, 7.9% of all households used branded SHSs from the service provider. This aggregate SHS penetration rate of 44% is a clear increase compared to the 28% in the first survey in 2010, when the service provider had reached a share of 3% [20]; it is also substantially higher than the official average estimate across sub-Saharan Africa of 5% and also higher than what we have found in other studies on solar power access in sub-Saharan Africa [2,34]. Fig. 2 shows the cumulated uptake over time for both types of SHSs. Very few SHSs were acquired prior to 1999. There is a clear increase in purchases starting in 2000 and continuing exponentially until the end of our observation period in 2012. Notably, households owning non-branded SHSs have been using their SHSs for much longer than their counterparts with branded systems, simply because the program effectively started having customers only in 2009. Most non-branded SHSs have been in use for between 1 and 6 years with an average of 3.9 years. Branded SHS have been in use for about 1 year.

Between 2009 and 2012, the service provider also managed to increase its customer base. While we do not have more recent data on market shares of non-branded SHSs at hand, the number of subscribers to the fee-for-service provider is known to have stagnated after 2012. In light of little demand for their fee-for-service concept, the company eventually had to file bankruptcy in 2015.

One reason for the general take-up expansion of non-branded SHSs after 2000 are certainly falling prices. This is underpinned by Fig. 3, which shows inflation-corrected prices of non-branded SHS in our sample over time. Clearly, prices have decreased significantly since 1998: the estimated trend over the whole period, which is statistically significant at the one-percent level, suggests that prices fell by 57 $ per year. Components of the fee-for-service package of the service provider as well experienced price decreases. It reduced both its connection cost and monthly fees in 2010 and 2012 by an aggregate of around 40%.

Both figures only plot the purchase date and price of SHSs currently in operation. The lack of information on purchase prices and purchase

[1] Structured questionnaires were administered to the head of the household, which were complemented by semi-structured interviews with community leaders and focus group discussions. For more information on the data, context, and an evaluation of the impact of the intervention by the electricity service provider, see Bensch et al. [20].